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Analysis on the fluctuation of China's imported iron ore freight rate in recent

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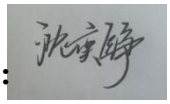
DECLARATION

I certify that all the material in this dissertation that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this dissertation reflect my own personal views, and are not necessarily endorsed by the University.

Signature: 

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Abstract

The international shipping market is an important part of the shipping market. It is a service market formed between the international shipping owners and the international traders with the international waterborne (mainly maritime) cargo transportation services as the object. Its shipping volume accounts for about 1 / 3 of the world's total shipping volume. The demand of international dry bulk shipping market is composed of iron ore, coal, grain and some other small bulk goods, among which iron ore shipping is the largest part. International dry bulk transport, like other modes of transport, is a derivative demand of international trade. Its development is closely related to the development and changes of world economy and trade. However, due to its drastic fluctuations, it is difficult to predict the price changes of international iron ore shipping.

This paper uses wavelet analysis and neural network prediction model to make qualitative analysis and quantitative modeling of international iron ore shipping freight rate in recent 20 years, trying to find the potential change law and make detailed and efficient prediction. And I hope to provide some reference and help for the international shipping industry, in order to avoid risks and seize opportunities.This paper first introduces the current situation and components of the international dry bulk market, and analyzes and discusses the relevant concepts and elements, so as to have a deep understanding of the international dry bulk market and the international iron ore shipping market, and points out the substantive significance of this study. After that, this paper introduces the wavelet analysis and neural network prediction model, including the theoretical basis and development process of these two analysis methods, and carries on the applicability analysis, in order to reflect the advantages of these two analysis methods. After that, wavelet analysis and neural network model are used to process and model the data, and the international iron ore freight rate in the next 50 months is predicted, and the combined prediction is carried out. Then, the results are compared with the actual data without processing, and the rules are summarized. Finally, it summarizes the whole paper and looks forward to the future of iron ore shipping.

Key words: iron ore, wavelet analysis, neural network

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Chapter 1：Introduction

1.1 Research background and significance

1.1.1 Research background

China's rapid development for more than 30 years in a row has given a strong impetus to the world economy and played an important role in leading and promoting the economic development of all countries in the world. With the rapid development of economy, there is a huge demand for world resources. In recent years, the government has been committed to promoting the country's urbanization construction, promoting China's transformation from agriculture to industrialization; the resulting expansionary demand for means of production and living leads to a strong desire for steel and other basic resources. China's self-produced iron ore is far from self-sufficient. It is an inevitable choice to purchase from Australia, Brazil, India, South Africa and other countries with rich overseas resources. Sea transportation provides the most economical and convenient transportation mode for overseas procurement of such resources.

The long-term large-scale demand for iron ore and other bulk cargo in the world has finally triggered a huge increase in the international bulk cargo transportation market in recent years. It is true that the prosperity of shipping is not the result of a single factor, but the development of international trade is still the main driving force. This paper tries to comprehensively analyze the factors that affect the iron ore sea

transportation market from many aspects.

1. The explosive growth of iron ore trade. Trade is the leading factor and decisive force of shipping. The huge growth of iron ore trade leads to a strong demand for transport capacity, which is the main contradiction to promote the upsurge of iron ore shipping market.

2. The growth of market capacity. The trade volume is growing, and the transport capacity is growing explosively, so as to get a share in this shipping tide. From 2017 to 2019, the number of bulk cargo ships ordered has increased by a large amount. Although the impact of COVID-19 has subsided, the excessive increase in capacity will eventually lead to a decline in freight rates.

3. Port efficiency and construction. Due to the relative concentration of iron ore trading ports in the world, a large number of ships gather, which leads to the frequent occurrence of pressure on ports. Especially for some large iron ore trading ports, pressure on ports has become a compulsory course for shipping companies. Port pressing is a phenomenon of delaying the operation of ships, which may only show as expensive demurrage between a single shipowner and a charterer. But from the macro level of the world, port pressing means reducing the efficiency of ship transportation and the quantity of iron ore transported per unit time. The reduction of unit transportation efficiency will cause the tension of transportation capacity. Although pressure on port is a kind of negative efficiency, in a sense, it is one of the factors to stabilize and boost the freight rate.

4. The distance of the voyage. The lengthening of the sea voyage also has the same effect as the pressure on the port, which reduces the transportation efficiency of the ship in unit time. The reluctance of Australia and India to sell iron ore has pushed China's demand for iron ore to Brazil and Africa to a certain extent, making the voyage longer and the freight rate stronger for a long time.

5. The change of ship form. The change of ship type also fundamentally changes the

transportation efficiency of ships. The farther the voyage is, the more economical the transportation will be. The increase of ship type improves the transportation efficiency of ships, which is a negative factor for the freight rate.

6. Other factors. Including the fluctuation of currency exchange rate, the country's macro policy, the development speed of the country's overall economy, and the concentration of negotiation strength will have a considerable impact on the demand for iron ore, thus the transfer will have a considerable impact on the sea freight rate of iron ore.

1.1.2 Research Purpose

Iron ore price changes and transportation costs are closely related to the world economic globalization. The main purpose of this paper is to establish a model to analyze the factors that affect the freight rate of imported iron ore in recent 20 years, and to find some rules, so as to provide decision-making reference for relevant shipping companies, and also provide suggestions for iron ore trading companies to rent ships. The research of this paper will provide a useful reference value for the relevant transportation companies to improve the competitiveness of the company, so the strategic planning has direct applicability.

1. To improve transportation efficiency and energy conservation.
2. To provide suggestions of chartering decision making.
3. To guide proper daily operation and identify risk.

1.2 Overview of research status

1.2.1 Research on the current situation of iron ore transportation market

Scholars and experts have done a lot of research on the current situation of iron ore shipping. The world's iron ore resources are mainly concentrated in Australia, Brazil, China, Russia and other countries. The world's major iron ore importing countries and regions. Jiren Zhen and Zhou Fang (2013)’s analysis in the book China's iron ore transportation demand analysis, and concluded the following conclusions. There are two main ways of international iron ore trading: long term contract (agreement ore) and spot trading (trade ore). The former requires annual negotiations, which are held once a year. This kind of iron ore price negotiation mechanism has a history of more than 20 years since its formation. The tradition of iron ore negotiation is that the first negotiated price is usually accepted by other iron and steel enterprises and mining enterprises, while those who refuse to accept the initial price can only sell or buy iron ore in the spot market.

Professor Yanni Jiang (2011) in the global dry bulk transport market said that because the iron ore trade has the characteristics of stable production and consumption place, the iron ore transportation route is generally fixed. According to the supply and demand characteristics of iron ore industry, the routes from Brazil and Australia to Europe, Japan and China are taken as the main routes for freight analysis.

Professor Wei Wang (2017) studies the relevant issues in her paper Analysis of the

factors influencing the price of imported iron ore in China. China price. Due to the scale effect of iron ore transportation, the fleet engaged in international iron ore transportation is generally very large. In terms of ship types, the mainstream ship types for iron ore transportation are super large bulk carriers, Cape ships and Panamax ships, and some handy ships or even smaller tonnage ships appear on some regional routes. In addition, professor Yinghao Zhu (2015) also mentioned related problems in his book Research on the relationship between the cost of new shipbuilding materials and the change of international iron ore price.On the whole, Cape ships are the main force of 自 iron ore transportation, accounting for nearly 70% of the total market volume.

1.2.2 Influence factor

Professor Binwei Zhu.(2009)'s paper prediction of iron ore shipping price based on wavelet analysis draw a conclusions are as follows. Through a lot of data analysis, it can be found that the factors affecting the iron ore spot freight can be roughly classified into three categories: first, seasonal factors; second, mutation factors, such as war, breakthrough in iron ore negotiations, changes in iron ore import policy; third, market indicators (transport capacity, traders' desire to hoard goods, loading port) The results show that there is a positive correlation between the pressure on the port, the spot rent level at the unloading port, the oil price, the market atmosphere, the FFA index, etc.

On the other hand, professor Jieli Shang & Wenping Luo.(2012)'s paper The neural network model is used to predict the spot freight rate of iron ore. water transport management gave me another useful suggestions. By referring to the

existing research literature, combined with the current background of green shipping development in the Yangtze River economic belt, the main factors affecting shipping freight are as follows: first, the level of economic development. The level of economic development affects the development of the entire shipping industry. The faster the speed of economic development, the larger the scale, and the more products provided to the society, will inevitably produce more transportation demand and bring more development opportunities to shipping enterprises. Second, transportation cost. Transportation cost is one of the main factors that affect the shipping price of the Yangtze River. The transportation cost of shipping enterprises is mainly composed of capital cost, operation cost and management cost. Among them, the cost of capital refers to the cost of ship purchase, which can be expressed by loans, interest and taxes; the operating cost is mainly reflected by the cost of fuel; and the management cost is the expenses incurred by the shipping industry management department for the organization and management of transportation production activities. Third, shipping market factors. The rapid development of the Yangtze River economic belt has brought the increase of shipping demand. At the same time, the competition among shipping enterprises is also more intense. Under the background of green shipping, some shipping enterprises without qualification are listed in the green shipping blacklist, which reduces the number of shipping enterprises to a certain extent. The fierce competition in the shipping market, the demand and supply level of the shipping industry will be different It affects the shipping price to a certain extent. Fourth, the route and port conditions. Route and port conditions are also one of the factors that affect shipping rates. Different route distance, different berth conditions and port handling equipment will inevitably affect the traffic efficiency of inland shipping, and the proposal of green route and green port further improves the shipping infrastructure and equipment, thus affecting the cost of shipping enterprises, which is finally reflected through the freight price.

In the later specific analysis, we should analyze the interaction of different factors and the impact on the freight rate according to different situations.

1.3 Selection of modeling and analysis methods

After data collection, relevant experts used the following methods for data analysis: 1. CARCH model; 2. Grey correlation analysis; 3. Lagrangian formula; 4. Wavelet analysis (ARMA model); 5. Fourier transform; 6. Combination forecasting model; 7. Neural network model; 8. GM (1.1) model; 9. Holt winters non seasonal model.

For example, professor Jieli Shang & Wenping Luo.(2012) in their study The neural network model is used to predict the spot freight rate of iron ore. water transport management used the way of neural network model. Because the spot shipping price of iron ore is the result of many factors, and its formation mechanism is a nonlinear system with a high degree of complexity, the neural network, which has strong learning ability and can better fit the nonlinear system, is selected to test the spot shipping price of iron ore. Based on the existing data, this paper takes the spot shipping price of iron ore and its influencing factors as learning samples, and forecasts the future spot shipping price of iron ore through neural network. The error between the final value calculated by this method and the actual value is three decimal places. However, in determining the priority areas of port development, this study only considers the coordination between the port itself and the economic hinterland, but does not consider the coordination between the ports, which needs further study.

On the other hand, Shanhua Wu,Xiaolin Liu and Zhongzhen Yang.(2011) in their study A multi-step forecasting method of iron ore shipping price based on

combination model used the way of combinatorial model. In order to improve the accuracy of the prediction model, combined with ARMA model, a combined prediction model is developed according to the higher accuracy of short-term time series prediction and the fact that GM (1,1) model is suitable for the time series with less samples, Finally, the combined model is verified by the actual data of the prediction group. The results show that the combined model is superior to the common single prediction model and has better prediction effect.

There are some connections and similarities between different methods, but they are independent and professional. After the collection and learning of relevant professional knowledge, referencing the papers of Binwei Zhu.(2009).Prediction of iron ore shipping price based on wavelet analysis and Fujie Zhao & Xinlian Xie.(2013).Prediction of iron ore freight rate based on wavelet analysis, I finally decided to use wavelet analysis and Neural network predictionto model and analyze the topic.

Due to the influence of various environmental and social factors, the prediction of iron ore shipping price is complex and non-stationary. The wavelet analysis is a very suitable mathematical tool for the non-stationary signal processing, so the wavelet analysis is finally introduced to model and process it.

Using wavelet analysis for modeling analysis follows the following steps. Through MATLAB software programming, wavelet analysis is used to denoise the data series of iron ore freight rate. Haar wavelet is used to decompose the data series into six levels, and the iron ore shipping price is decomposed into different scales. Neural network model are used to forecast the scale transformation series.

Chapter 2: Analysis of international shipping of iron ore

2.1 International dry bulk shipping market

Dry bulk is the goods and products circulating in the international dry bulk shipping network. These goods are usually transported on a large scale and are easy to be handled and transported in bulk. These dry goods are mainly some primary products, such as iron ore, grain, coal, bauxite, apatite and some agricultural products, cement, wood, chemical fertilizer, scrap iron and steel, etc. their characteristics are that they do not need to be packaged and can be directly loaded into the cabin for transportation. As the main source of dry bulk cargo shipping, it is also the raw material of industrial production. The five major dry bulk cargo, including iron ore, grain, coal, apatite and bauxite, are the foundation of world economic development. The five dry bulk goods have played the role of development cornerstone and industrial raw materials in different fields. Therefore, the importance of dry bulk can reflect the irreplaceable role of international dry bulk shipping for the development of the world economy. Among them, iron ore, coal and grain are the largest dry bulk goods, and they play an important role in the international dry bulk transportation market.

2.1.1 Iron ore transportation

Iron ore is a mineral aggregate containing iron monomers or iron compounds which

can be used economically, and is an important raw material in metal production industry. The world's iron ore resources are concentrated in Australia, Brazil, Russia, Ukraine, Kazakhstan, India, the United States, Canada, South Africa and other countries. The global steel production is basically highly correlated with the transportation volume and distribution of iron ore, which is positively related and the trend is basically the same. The iron and steel production is related to the trend of the world economy, and it is basically rising. In this context, the demand for iron ore is increasing year by year, and the sea transportation of iron ore is booming. Even in the face of the impact of the new crown disease, the amount of iron ore transportation has risen steadily in the current situation under control. However, the sea transportation of iron ore between developing countries and newly industrialized countries led by China is increasing day by day. With the increasing of iron ore transportation, the demand for iron ore quantity and quality is also rising. At present, the iron ore exporting countries are mainly Australia, Brazil, India, South Africa and other countries, while the import of iron ore into Japan, China, South Korea, EU and other countries and regions is an important object of iron ore import. China is undoubtedly the main importer of iron ore with the highest demand. With the rapid development of economy in China for more than 30 years, China has become the world's largest importer of iron ore. The world resource demand, including iron ore, has surpassed Japan, and the dependence on imported iron ore will be higher and higher. Although China is a big country in iron ore production in the world, the quality of self-produced ore is relatively low compared with imported iron ore. It can not meet the demand of steel quality in China's economic development. Therefore, the price of imported iron ore every year is still an important reference factor for international iron ore price for a period of time. With the rising price of imported iron ore, the price of iron ore in domestic market is also rising. In recent years, even if domestic iron ore prices are under pressure from weak demand and oversupply, they

are still wanton. In mid-2015, the iron ore price in Tangshan area of Hebei Province was about 980 yuan / ton, which rose to 1325 yuan / ton by the beginning of may2018. As of May 23, 2021, the price of domestic Tangshan Iron Ore rose to 1545 yuan / ton. However, due to the recent entry of China Australia relations into the freezing point, and the disorderly rising prices of imported iron ore from abroad are common, the China Steel Association issued a self-discipline initiative for the steel industry at 11:00 on May 26, 2021. The state will control the price personally. In a period of time, the price of iron ore will be relatively stable in theory, which will have a certain impact on the volume and freight rate of iron ore shipping. This also reflects that iron ore is one of the lifeblood of China's economic development.

The development of iron and steel industry in the world promotes the development and change of international iron ore shipping division. With the development of heavy industry and large-scale machinery industry in national construction, the main demand for iron ore is mostly reflected in the use of certain quality iron raw materials, which also reflects the steady growth of iron and steel materials and even metal materials manufacturing industry to a certain extent. However, with the development of science and technology in various countries, the focus of economic and production development in most countries has shifted and changed. For developed countries, their economic growth point has changed from heavy industry to emerging information technology and national strategic emerging industry. High tech industry and manufacturing industry have attracted more capital flow, which has led to a decline in the demand for steel and raw materials in these developed countries to a certain extent. In contrast, the developing countries are gradually emerging on the international economic stage, and the process of industrialization is in full swing among the developing countries. The most important part is the massive construction of infrastructure and the completion of social supporting facilities,

which greatly increases the demand for iron and steel in these developing countries, which also directly promotes the production and import demand of iron ore. In this context, the shipping circulation of iron ore has changed from the production and export to Europe, America, Japan and other developed countries to China and other developing countries. Moreover, compared with developed countries, developing countries have a very favorable advantage, that is, lower steel-making cost brought by low labor cost. Therefore, developed countries are more willing to import steel raw materials and finished products from developing countries, which promotes the international trade of iron ore and steel products, and also promotes the development of iron ore shipping.

According to relevant data, China's demand for imported iron ore has led to an increase of 50% of the growth of Global trade in the past 20 years. China, known as "global iron ore", is currently the largest buyer of the world's iron ore market. China, as the largest iron ore demandering country and importer in the world, has not only a small reserve of iron ore, but its grade is unfortunately low. In order to consider the economic nature of industry, the vast majority of iron ore demand depends on the imported iron ore from Australia, Brazil and other countries rich in iron ore. As the main raw material of iron and steel industry, iron ore combines China's abundant labor resources with China's rapidly rising industrialization level, which has resulted in the trend of gathering processing bases of various industries, especially metal industry, to China, and China has more and more influence on the international iron ore market and transportation context. Although China's domestic macro policies can affect China's steel production capacity to a certain extent, and then China's demand for iron ore, China's demand for iron ore will increase in general.

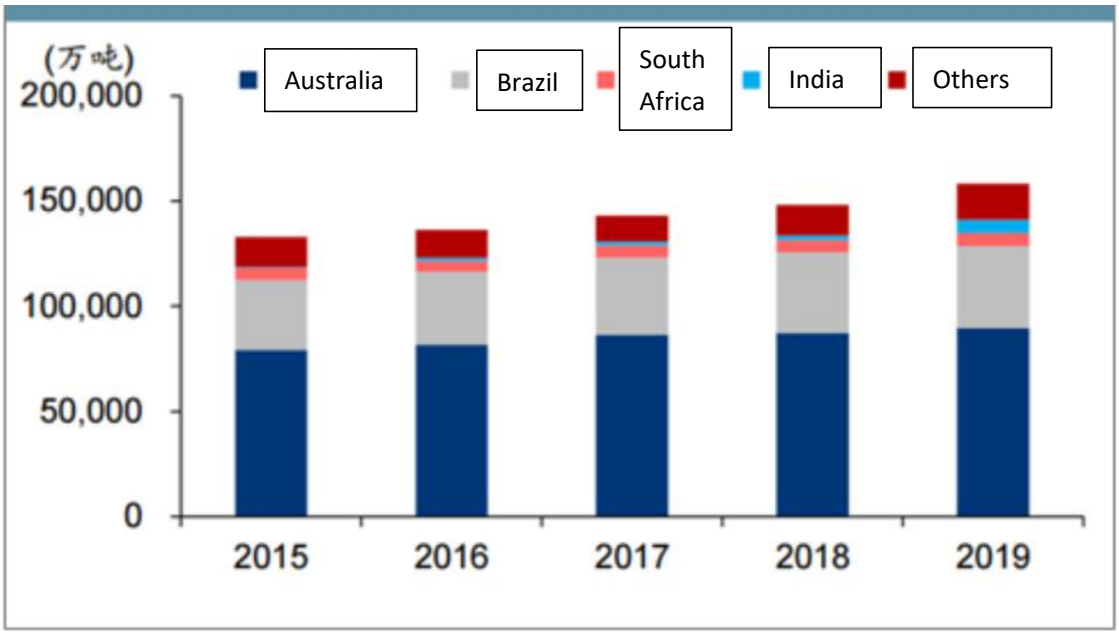

Table 2.1 Iron ore trade volume of major iron ore exporting countries in the world

Data source: hellosea.net

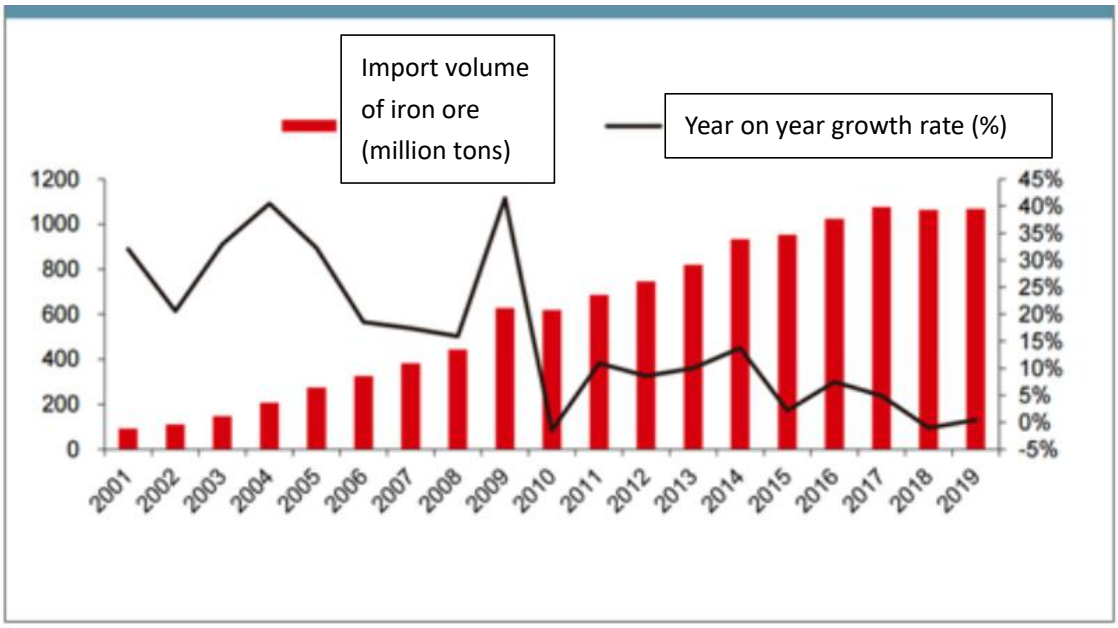

Table 2.2 China's iron ore import volume over the years and year-on-year growth rate

Data source: www.nmdis.org.cn

2.1.2 Coal transportation

Coal is a kind of solid combustible mineral formed by ancient plants buried underground through complex biochemical and physicochemical changes. Coal is the most abundant and widely distributed fossil fuel on the earth. It is one of the main energy sources used by human beings since the 18th century. It has the reputation of black gold and industrial food. There are mainly two kinds of coal, steam coal and coking coal. The former is mainly used for combustion capacity heat generation and power generation, while the latter is mainly used for steel refining and metal production. The main coal export areas are Australia, Canada, the United States, South Africa and Poland, and the import areas are Japan and Western Europe. The import demand of Southeast Asia, South Korea and South America around the Pacific region is also increasing year by year. If divided by region, the Pacific market, Atlantic market and Indian Ocean market constitute the international coal shipping market. Although the important position of coal has been gradually replaced by oil with the development of science and technology, due to the gradual depletion of oil resources, it will gradually decline in the future. Due to the huge reserves of coal, coupled with the development of emerging technologies, coal gasification and other new technologies are becoming more and more mature, which are widely used and have a very promising prospect. For the future coal shipping demand, it can be considered that this kind of demand will exist for a long time, but it is difficult to increase significantly in a short time without relevant scientific and technological innovation, and it will be in a partial bumpy dynamic equilibrium state.

2.1.3 Grain transportation

In the international trade, grain goods are mainly divided into wheat, coarse grain and soybean. The United States is the largest winter wheat producer in the world. The world wheat yield is closely related to the American winter wheat harvest. Brazil and Argentina, as the main export places of South American grains, are the shipping time of new grains and soybeans from April to June every year. The market is called South American grain season. The amount of their exports is generally closely related to the output, price and exchange rate. On the one hand, the main grain exporting countries are Brazil, Canada, Australia, Argentina, the United States and France; On the other hand, the main grain importing countries and regions are scattered, including Japan, other regions in Asia, the Middle East, Eastern and Western Europe, central and South America, Russia and other CIS countries. According to relevant data, the increase of international soybean consumption in recent years mainly comes from China. Weather condition is the decisive factor of international grain trade. When the output of producers or the demand of consumers changes due to the sudden abnormal weather, the grain shipping volume will also change. In recent years, with the different attitudes towards the grain produced by genetic technology, the grain trade is also changing. The development of new energy and a series of new industrial revolution have also brought many impacts, including the use of plants to develop fuel (such as corn as raw material to produce industrial alcohol), which also caused changes in grain shipping volume.

2.2 Analysis of the world dry bulk carrier fleet

2.2.1 Transportation supply and demand

Transportation demand refers to the demand of national economy and social development for transportation capacity and service in a certain period of time and at a certain level of freight rate. Transportation demand is people's willingness to pay for transportation services, and it also reflects the change of this willingness with the level of transportation price or cost. Total transportation expenditure provides some important information about transportation demand, but not all, because it can't tell us the change of transportation volume with price. On this basis, the supply of dry bulk shipping market refers to the tonnage that all ship owners, namely carriers, can and are willing to provide under various freight rates in a certain period of time. Therefore, the desire to rent and the actual capacity are the two conditions for the supply of 1000 bulk cargo. Freight demand is usually expressed as the product of tonnage and haul distance, which is traditionally called demand tonnage. In recent years, the international shipping market has developed rapidly. Even though the impact of COVID-19 has been controlled to a certain extent, the international dry bulk shipping demand has also recovered rapidly. In this context, shipowners accelerate the ordering of bulk carriers and postpone the dismantling date of old ships one after another, which leads to a higher growth rate of international dry bulk carrier capacity and a higher net growth of dry bulk shipping market capacity. Although the demand for freight in the global dry bulk shipping market continues to rise, the rapid decline in the volume of Global trade caused the rapid collapse of

COVID-19's capacity due to the outbreak of early 2020. At the same time, the price of old ships fell and the number of ship breaking increased. The impact of the world economy directly reduced the Baltic dry bulk index from 2518, the highest on September 4, 2019, to 398, the lowest on May 13, 2020. This gives shipping practitioners a wake-up call, but also tells us that to a certain extent, a reasonable forecast of freight rates can avoid certain risks, and use accurate decision-making and rigorous attitude to enable shipping enterprises to maintain strong competitiveness in the economic downturn. This is obviously a very constructive work.

Combined with the analysis of the supply conditions of international dry bulk shipping market, it can be concluded that there are the following five main factors affecting the supply of dry bulk shipping market：

（1）The size of the dry bulk fleet. The new ship building and the ship dismantling quantity decide its growth or decrease. There are two characteristics in the growth process of international dry bulk fleet: first, due to the demand of scale economy, a large number of iron ore and coal offshore trade demand make large dry bulk carriers enter operation continuously and become the main driving force for the growth of the whole fleet capacity. At the same time, the ship large-scale was continuously promoted, and large dry bulk ships were put into the market. Second, the realization of the scale economy of dry bulk shipping makes a large part of the bulk cargo originally carried by the general cargo ship or liner ship be carried by the dry bulk carrier.

（2）The ship is sealed up. The supply of international dry bulk shipping is provided by the operating capacity of dry bulk, not by the total capacity of dry bulk. On this basis, when the total transport capacity is fixed, the change of ship storage capacity

will cause the reverse change of fleet size. The level of freight rate plays a key role in the ship owner's decision on whether to seal up the ship, including the level of freight rate, operating cost, sealing cost and so on.

（3）International shipping regulations. In general, international norms will restrict the old ships from entering the shipping market. Therefore, every international standard introduction and update represents a large number of old ships are about to exit the shipping market, which reduces the global fleet size and stimulates the development of shipbuilding market. According to the old and new degree of purchasing ships, the ship market can be divided into new shipbuilding market and second-hand ship market. The owner can choose to buy new ships or lease new ships according to their own business needs and market conditions, and also can purchase or lease ships with low price and moderate ship age in the second-hand ship market. At the same time, with the change of market situation, the ship dismantling situation is different. In general, in the period of market boom, shipowners prefer to take the risk of low safety coefficient of old ships than miss the rare market situation, so the ship dismantling speed generally slows down. On the contrary, if the international shipping market is not optimistic, the shipowners will dismantle the ship when it reaches its service life, even in advance in the case of forecast of the bad shipping market.

（4）Political factors. Political events generally refer to the deterioration of relations between countries, regional conflicts, a country's internal revolution or coup and the nationalization of foreign capital. Political events often bring sudden and unpredictable disasters to the demand of dry bulk shipping, and its negative impact on the dry bulk shipping market is obvious. Political factors have a direct impact on the economic situation, and also directly reflect the changes in shipping demand. For

example, the impact of war on Oil Trade and transportation, the restrictions of trade protectionism on world import and export trade, and the adjustment of industrial policies of certain goods producing or consuming countries.

（5）Operational productivity. Operational productivity refers to the number of DWT nautical miles per unit DWT. It is an important variable to determine the supply of dry bulk shipping. It is determined by three main factors. One is the average shipping speed. Rational and excellent ship owners usually determine the best speed according to the principle of profit maximization and different rates, fuel prices, operating costs and other parameters. Second, the utilization of deadweight tonnage. The higher the utilization rate of DWT, the higher the production rate of ship operation, and vice versa. Third, the number of days of ship production in the whole year. The higher the annual productivity of ships, the higher the shipping supply.

The main index of capacity supply is the tonnage provided by shipowners to the market. In the international shipping market, the supply of ship tonnage is affected by many factors, such as freight rate, ship trading market, transportation cost, the number of new ships completed, crew labor market and the operating environment of shipping companies. These factors jointly determine the total supply of ships at a certain level of freight rate in a certain period of time. Because shipping supply basically depends on shipping demand, some factors that affect shipping demand will affect shipping supply.

2.2.2 Freight index

Freight index refers to the ratio of the shipping market price in a certain period of time to the shipping market price in the benchmark period. This ratio is used to reflect the dynamic relative number of the changing trend and degree of shipping freight level in different periods, often expressed as a percentage. Based on the average freight rate of a fixed base period, by comparing the average freight rate of each comparison period with that of the base period, the percentage of the comparison between the average freight rate of each period and that of the base period is obtained. According to the different base period used in the calculation, the freight index can be divided into fixed base freight index and ring comparison freight index. In terms of international dry bulk shipping, the Baltic dry bulk composite index (BDI) is the most authoritative dry bulk freight index. It is issued by the Baltic shipping exchange of the United Kingdom. It is known as the "barometer" of the international dry bulk shipping market. It is weighted by BCI index representing Capesize, BPI index representing Panamax and BHI index representing handy, It is used to reflect the change of freight rate level in the whole dry bulk shipping market.

The Baltic Capesize Index rose to a year high. Headland dry bulk carriers carry goods including iron ore and coal. In March 2020, the dry bulk transport market will be impacted, and the freight index of headland bulk carriers will be negative for a time. In April 2021, the BCI freight rate index rose to 2883 points, reaching the highest level in the year, recording the largest monthly increase since June 2020, partly due to the growth of China's iron ore shipping demand.

Table 2.3 BCI Trend Chart

Data source: eastmoney.com

2.2.3 Type of shipping

The dry bulk transport market can be divided into the following six basic forms according to different chartering modes: voyage charter, time charter, charter party, bareboat charter, bareboat charter and voyage time charter. The main differences between them are reflected in the extent of shipowners' participation in the operation, cost sharing and the extent of goods specified in the lease.

Voyage charter, is a basic form of charter based on voyage. Its biggest characteristic is that there is no fixed route, fixed port of loading and unloading and fixed sailing schedule, but it is stipulated in voyage charter party according to the needs of Charterers and the possibility of shipowners. The shipowner shall carry the specified cargo for the charterer on one or more voyages between the designated ports by the designated ship and bear all expenses except cargo handling charges; The charterer shall pay the freight according to the actual quantity of the goods and the Charter rate agreed by both parties.

Time charter is a form of charter based on ship and charter period. The shipowner shall charter the appointed ship to the charterer within the agreed time limit, and shall be responsible for the ship's manning, insurance, maintenance, material supply, crew supply and other corresponding expenses, i.e. the operating expenses of the ship. The charterer shall dispatch and arrange the chartered ship by himself, and bear the expenses incurred in each voyage during the charter period, i.e. voyage expenses, Including fuel charges, port and canal charges, cargo handling charges and so on, and pay the ship owner the rent according to the tonnage of the ship, the charter period and the rental rate agreed by both parties. The term of time charter varies from a few months to one or two years or even more than ten years. During the charter period, the carrier can use the chartered ship to arrange the irregular ship or liner transportation, and can also sublet it to a third party.

The contract of carriage is that the shipowner transports a batch of designated goods with a fixed amount for the shipper by several voyages between designated ports within the agreed period. The shipowner has the right to arrange any suitable ship freely, and the number of voyages (or the period of voyages) is generally not agreed. As in voyage charter party, the owner shall bear all expenses except loading and unloading. The shipper shall pay the freight according to the quantity of the goods actually shipped and the rate agreed by both parties, and the loading and unloading charges shall be borne by the loading and unloading clause in the contract.

Bareboat charter is also a form of charter based on ship and charter period, but it is different from time charter. In bareboat chartering, the owner charters an empty ship to the carrier within the agreed period; The charterer shall dispatch and arrange the ship by himself, bear the corresponding voyage expenses, be responsible for the

Manning, insurance, maintenance and material supply of the ship, the supply of crew's provisions, bear the corresponding operating expenses of the ship, and pay the rent to the owner according to the tonnage of the ship, the charter period and the rental rate agreed by both parties. In many cases, the owners of bareboat charter are banks and other financial institutions. The term of light charter is generally longer than that of time charter. Similar to the same period chartering, bareboat Charterers can use the chartered ship to arrange irregular ship or liner transportation, and can also re charter. It is because of the diversity of business methods that the international dry bulk market presents a complete competitive situation. In this case, shipping companies should be cautious.

Bareboat charter party is a special form of bareboat charter party, which means that the shipowner provides the charterer with a ship without crew. During the lease term, the charterer shall possess and use the ship and transfer the ownership of the ship to the charterer at the expiration of the agreed period, so that the charterer can pay the hire purchase fee.

Voyage charter is a kind of time charter for the purpose of completing a voyage, but the charter is based on the time required for the voyage, and the general time unit is days. This kind of Charter does not include demurrage and dispatch expenses, and the shipping party is not responsible for the operation and management of cargo transportation.

2. 3 Characteristics of international dry bulk shipping market

The international dry bulk shipping market is a market with fierce competition and changeable environment. Generally speaking, it has the following characteristics of a completely competitive market：

（1）The concentration is low. Unlike liner companies, international dry bulk shipping companies must have corresponding fleet size in order to maintain regular transportation and certain ship departure density. For international dry bulk shipping companies, only one ship can be put into operation, which makes it easier to enter the market. Therefore, there are many ship owners or ship transport operators in the market. However, in recent years, the concentration of cargo owners in the international dry bulk shipping market has greatly improved. According to the survey conducted by the United Nations Conference on Trade Development in 2019, about 3 / 4 of the iron ore transportation is related to multinational companies, which are mainly steel giants. Some of them directly own the mining rights of mines, and some control iron ore through long-term contracts; As one of the raw materials for iron and steel smelting, the transportation of coal is also related to iron and steel giants; The horizontal integration degree of aluminum smelting is higher than that of iron and steel industry, so the transportation of aluminum is closely related to multinational companies; Apatite production is mainly controlled by state-owned companies in developing countries, but sales and transportation are also controlled by several major fertilizer manufacturers. Grain trade is also manipulated by a few multinational companies, which have global sales network, specialized wharf and storage facilities; Some of these multinational companies invest in shipbuilding and buy their own ships to engage in ship business. Some of them sign medium-term and long-term chartering contracts with ship owners to obtain the right to use the ships for a long time. By controlling some of the ships, they enhance their ability to influence the market.

（2）Product identity is very high. In the international dry bulk shipping market, the demand and supply places of bulk dry bulk cargo are generally concentrated, and several large and stable routes have been formed in the world, such as China Australia and China Pakistan routes in iron ore transportation, Taiwan Japan and Taiwan northwest Europe routes in bulk grain transportation, etc, The changes of routes basically reflect the development and changes of the whole international dry bulk shipping market. Every shipowner in the market transports the goods from the place of departure to the designated destination within the specified time according to the requirements of the shipowner. Therefore, the products they provide are the spatial displacement of the goods they carry. There is basically no difference in the transportation process, that is, the products they provide have high similarity, and the subtle difference is mainly reflected in the service quality, That is, the timeliness, safety, integrity and integrity of the goods transported.

（3）There are no entry and exit barriers in dry bulk transportation market. The dry bulk shipping market belongs to the tramp market. In the international dry bulk shipping market, the dry bulk cargo is generally carried by tramps. When it is in operation, there is no fixed route and port, and there is no scheduled shipping schedule and rate. Instead, it changes the route, cargo type and rate constantly according to the time, place and cargo carried in the charter party, which is an irregular transportation. For the international dry bulk shipping company, as long as there is a ship, it can be put into operation. The requirement for investment is relatively small, and there is no market entry barrier for new suppliers. New suppliers can enter the market as long as they raise relatively low funds to purchase ships or rent ships in the chartering market. Therefore, the international dry bulk shipping market basically has no market barriers for shipowners and shipowners. For

shipowners, no matter how much capacity and volume they carry, they can freely enter or exit the market. Many shipowners can also freely enter the market, and both sides can reach a deal through competition.

（4）Complete information. Under the condition of modern communication technology, the information exchange between the shipowner and the shipowner, that is, the demand and supply sides of the market, is very fast and convenient, and the scope of contact covers the whole world, and the transparency of the transaction is quite high. The transparency of information enables both sides of the transaction to fully compare, select the best and eliminate, and enhance competitiveness. At the same time, complete information also enables both sides of the transaction to make the best decision.

Therefore, from the above analysis, the international dry bulk shipping market is basically a completely competitive market, in the market, the supply side and the demand side are very sensitive to the price fluctuation, so it is very important to understand the market supply and demand situation and grasp the price trend.

2.4 Analysis of global iron ore transportation market

The international trade of iron ore is mainly concentrated in sea trade, which accounts for more than 90% of the total trade volume of iron ore; Iron ore transportation mainly depends on dry bulk cargo fleet, and the demand of iron ore shipping accounts for about 30% of the demand of dry bulk cargo shipping. From 2015 to 2020, the global iron ore seaborne trade volume and dry bulk carrier capacity

growth show an upward trend. Since 2017, the dry bulk shipping industry has recovered from the bottom of the 2016 cycle, and the main driving force is the improved supply and demand relationship of the industry. Driven by the growth of China's iron ore shipping demand, in April 2021, the freight index of headland ships carrying goods including iron ore and coal rose to 2883, reaching the highest level in the year. From 2014 to 2019, the global iron ore trade volume shows an upward trend, with a compound annual growth rate of 4.12%. The four major international iron ore production giants Rio Tinto, Vale, BHP Billiton and FMG account for more than 70% of the world trade volume. Driven by the crude steel output of China, India and Japan, the global iron ore trade volume has further increased. In 2019, the total global iron ore trade volume will reach 1.652 billion tons.

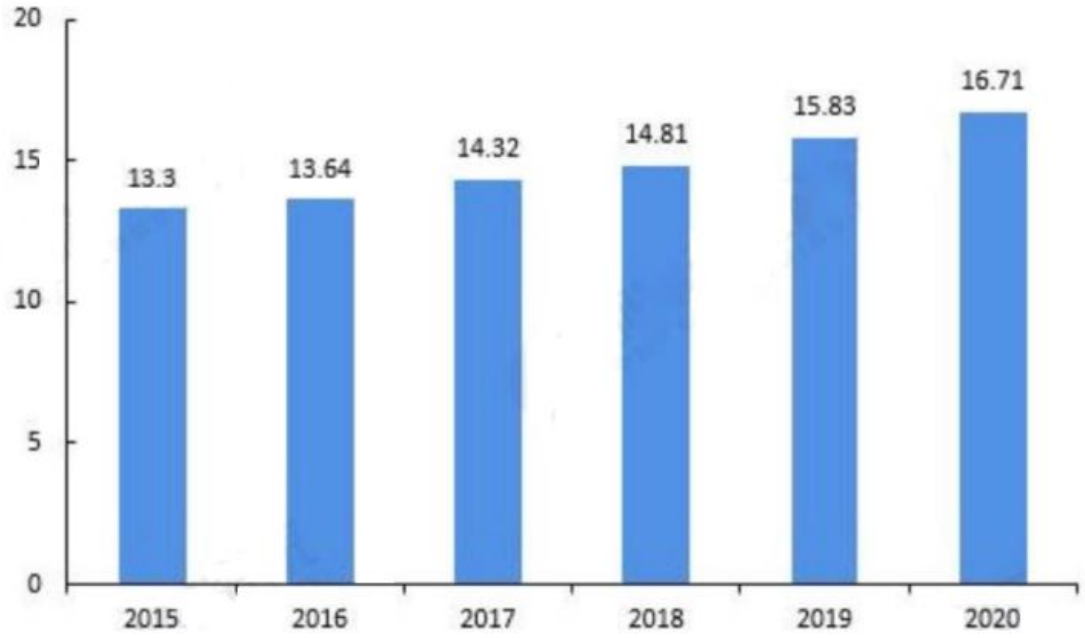

Table 2.4 Changes in global iron ore seaborne trade volume (unit: 100 million tons)

Data source: my steel network

The international trade of iron ore is mainly concentrated in the sea trade, with less

than 10% of the total iron ore transported by rail and other means. In 2012, the total global iron ore trade volume was 1.13 billion tons, and the sea trade volume exceeded 1 billion tons, more than 90% of the total iron ore trade volume. By 2013, the global iron ore sea trade volume was about 1.1 billion tons, and sea trade has become the main mode of international iron ore trade. In 2019, the global iron ore trade volume will reach 1.652 billion tons, and the seaborne trade volume will reach 1.583 billion tons, accounting for 95.8% of the total iron ore trade volume.

At the same time, the global dry bulk carrier capacity is also on the rise. The transportation of iron ore mainly depends on the dry bulk cargo fleet. According to Clarksons and other institutions, in 2020, the global demand for dry bulk cargo shipping will reach 5.098 billion tons, and the demand for iron ore shipping will reach 1.492 billion tons, accounting for 29.27%. Among them, the seaborne volume of iron ore and grain increased, while the seaborne volume of coal decreased. It is estimated that the demand for iron ore shipping will reach 1.53 billion tons in 2021, up 2.5% year on year. In terms of capacity, Clarksons data shows that the growth rate of global dry bulk carrier capacity is on the rise from 2016 to 2020. In 2020, the global dry bulk shipping capacity will reach 912 million dwt.

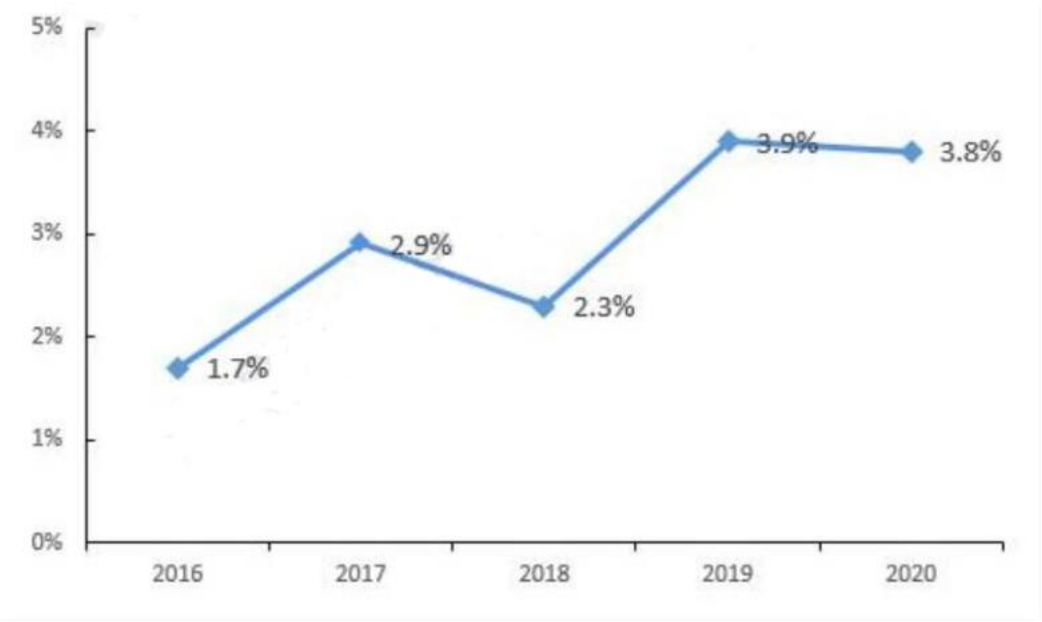

Table 2.5 Growth rate of global dry bulk carrier capacity (unit:%)

Data source: Clarkson Research Service Limited

In recent years, the international shipping volume has been increasing, which makes the trend of ship large-scale development becoming increasingly fierce. The world bulk carrier can be divided into four levels according to the load tonnage: Super Pana Li bulk carrier with a tonnage of 180000 tons or above, a cap type ship of 100000-180000 tons, a Panama ship of 50000-80000 tons and a flexible bulk carrier of 30000-50000 tons. At present, the main international shipping is Cape and Panama bulk carriers, which account for more than 75% of the world's iron ore transportation; The main transport of ore in the ocean is Panama type ships. The driving force of large-scale ships is the scale benefit of large ships.

China's iron ore imports are mainly super large bulk carriers and Cape ships on the routes of Brazil and South Africa, and Cape ships on the routes of Australia; On the Indian route, restricted by the terminals of the loading port in India, the main types of bulk carriers are Panamax and handy.

China's iron ore imports are mainly transported through coastal ports, with less than 1% of railway and aviation imports. At present, China's iron ore loading and unloading ports are mainly concentrated in the eastern and northern coasts, while the capacity of southern ports is not enough. At present, iron and steel enterprises in Central South and southwest China need to import ore through the Yangtze River. The rapid growth of China's iron ore import has brought unprecedented pressure to port, railway and road transportation. Except for Shanghai Baosteel, other iron and steel enterprises in China rely on railway or inland river transportation for raw materials and products export, especially the iron and steel enterprises that mainly rely on imported iron ore for ironmaking are in a disadvantageous competitive position in terms of the cost of raw materials.

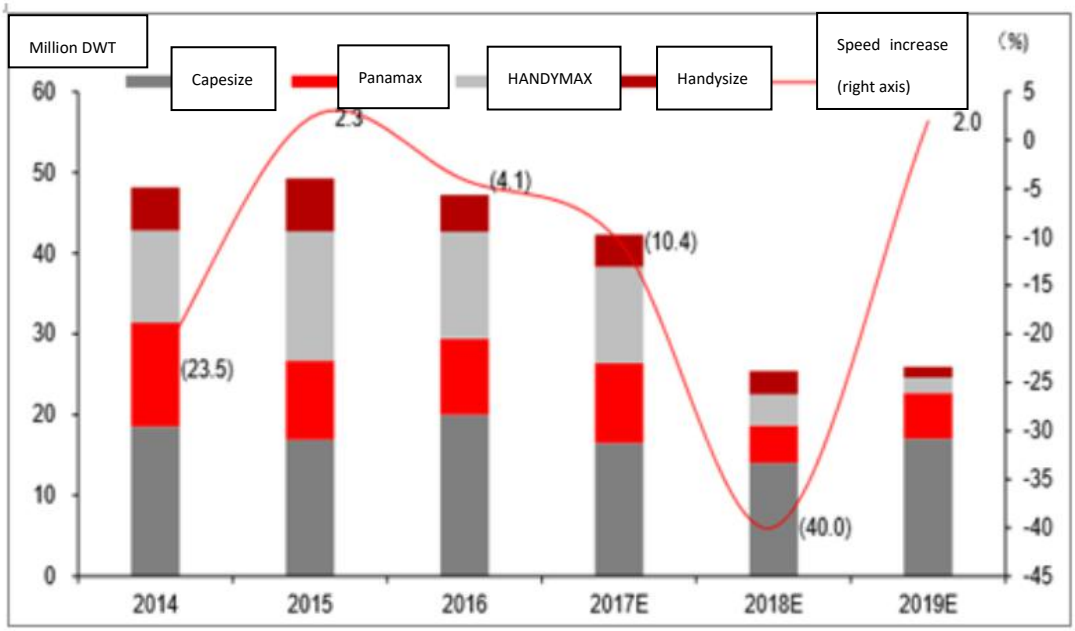

Table 2.6 New ship delivery capacity and growth rate of the industry

Data source: www.Chinaisa.org.cn

Chapter 3：Introduction to basic theory of Technology

3.1 Wavelet Analysis

3.1.1 The concept and historical development of wavelet analysis

Wavelet is a term, as its name implies, "wavelet" is a small waveform. The so-called "small" means that it has attenuation; And called "wave" refers to its volatility, its amplitude is positive and negative vibration form. Compared with Fourier transform, wavelet transform is the localization analysis of time (space) frequency. It can refine the signal (function) step by step by means of expansion translation operation, and finally achieve the time subdivision at high frequency and frequency subdivision at low frequency, which can automatically adapt to the requirements of time-frequency signal analysis, thus focusing on any detail of the signal, and solving the difficulty of Fourier transform, It has become a major breakthrough in scientific methods since Fourier transformation. Some people call wavelet transform "mathematical microscope".

The concept of wavelet transform was first proposed by J. Morlet, an engineer engaged in petroleum signal processing in France, in 1974. The inversion formula was established through the needs of physical intuition and practical experience of signal processing, which was not recognized by mathematicians at that time. Just as the French Thermal Engineer j.b.j.fourier proposed in 1807 that any function can be expanded into an infinite series of trigonometric functions, the innovative concept

was not recognized by the famous mathematicians j.l.lagrange, p.s.laplace and A.M.Legendre. Fortunately, as early as the 1970s, the discovery of A. Calderon's representation theorem, the atomic decomposition of Hardy space and the in-depth study of unconditional basis made a theoretical preparation for the birth of wavelet transform, and J. o. Stromberg also constructed the wavelet basis which is very similar to the current wavelet basis in history; In 1986, the famous mathematician y. Meyer accidentally constructed a real wavelet basis, and cooperated with S. Mallat to establish a unified method for constructing wavelet basis. After adding multi-scale analysis, wavelet analysis began to flourish. Among them, "ten lectures on wavelet", written by Belgian female mathematician I. Daubechies, played an important role in promoting the popularization of wavelet. Compared with Fourier transform and window Fourier transform（Gabor transform）, it is a local transform of time and frequency, so it can effectively extract information from the signal, and carry out Multiscale Analysis of the function or signal through the operation functions such as stretching and translation, which solves many difficult problems that can not be solved by Fourier transform, It is a milestone in the history of harmonic analysis.

3.1.2 Basic principle of wavelet analysis

Wavelet function is derived from multi-resolution analysis. Its basic idea is to express the function f(t) in the expansion as a series of successive approximation expressions, each of which is the smoothed form of f(t), and they correspond to different resolutions. Multi resolution analysis, also known as multi-scale analysis, is a theory based on the concept of function space. Its idea comes from engineering.

Mallat s, the founder of this theory, established it when he studied image processing. At that time, a very common method to study the image is to decompose the image in different scales and compare the results to obtain useful information. The proposal of Meyer orthogonal wavelet basis makes Mallat think whether to use the multi-scale characteristics of orthogonal wavelet basis to expand the image to get the "information increment" between different scales of the image. This idea leads to the establishment of multiresolution analysis theory. MRA not only provides a simple method for the construction of orthogonal wavelet bases, but also provides a theoretical basis for the fast algorithm of orthogonal wavelet transform. The idea coincides with that of multi rate filter banks, so that we can combine wavelet transform with the theory of mathematical filter. Therefore, multiresolution analysis plays an important role in the theory of orthogonal wavelet transform.

Wavelet analysis is a time-frequency localized signal analysis method with fixed window size and variable shape, that is, it has higher frequency resolution and lower time resolution in the low frequency part, and higher time resolution and lower frequency resolution in the high frequency part. Set up $\psi(t) \in L^2(R)$ ($L^2(R)$ is square integrable real space, that is, space signal with limited energy), it's Fourieta transform is $\hat{\psi}(\omega)$， when $\hat{\psi}(\omega)$ satisfies the admissible condition：

$$C_\psi = \int_R \frac{|\hat{\psi}(\omega)|^2}{|\omega|} d\omega < \infty$$

In this case，$\psi(t)$ is called Base Wavelet or Mother Wavelet。It can be inferred from the admissible condition that the fundamental wavelet must at least satisfy $\hat{\psi}(\omega = 0) = 0$. In other words, it must have band-pass property. A wavelet sequence is

obtained by stretching and translating the mother wavelet:

$$\psi_{a,b}(t)=\frac{1}{\sqrt{|a|}}\psi(\frac{t-a}{a}) \qquad a,b\in R;a\neq 0$$

Where α is the scaling factor or scaling factor, and the basic wavelet is scaled; b is the translation factor, and the basic wavelet is used as the displacement. The wavelet transform of signal $f(t)$ is defined as:

$$W_\psi f(a,b)=\frac{1}{\sqrt{a}}\int_{-\infty}^{+\infty} f(t)\overline{\psi}(\frac{t-b}{a})dt$$

If

$$a=a_0^{\ }, \quad b=nb_0a_0^m, \quad a_0\succ 1,b_0\succ 1,b_0\in R$$

Then the discrete wavelet transform of $f(t)$ is:

$$W_\psi f(m,n)=a_0^{-\frac{m}{2}}\int_{-\infty}^{+\infty} f(t)\overline{\psi}(a_0^{-m}-nb_0)dt$$

3.1.3 Analysis method and adaptability to iron ore freight rate analysis

The application of wavelet analysis is closely combined with the theoretical research of wavelet analysis. It has made remarkable achievements in the field of science and technology information industry. Electronic information technology is an important field of the six high-tech, its important aspect is image and signal processing.

Nowadays, signal processing has become an important part of contemporary science and technology. The purpose of signal processing is: accurate analysis, diagnosis, coding compression and quantization, fast transmission or storage, accurate reconstruction or recovery. From a mathematical point of view, signal and image processing can be regarded as signal processing, and image can be regarded as two-dimensional signal. In many applications of wavelet analysis, it can be attributed to signal processing. For signals whose properties are stable with time, Fourier analysis is still an ideal tool. However, most of the signals in practical applications are unstable, and the tool especially suitable for unstable signals is wavelet analysis.

In nature and engineering practice, many phenomena or processes have multi-scale characteristics or multi-scale effects. At the same time, people often observe and analyze phenomena or processes on different scales (resolution). Therefore, it is very natural to use multi-scale theory to describe and analyze these phenomena or processes. It can well show the essential characteristics of phenomena or processes. In addition, when solving many practical problems, the multi-scale method has the advantages of clear thinking, simplicity and low computational complexity. The multi-scale system theory provides a theoretical basis for the signal processing of iron ore shipping price. This is because there are a lot of unstable factors in the complex market environment, which have an impact on the transport price of iron ore at different levels and scales. This paper collects the price data of iron ore transportation in the past 20 years, which covers many shipping cycles. There are not only the time when the shipping law plays a role, but also the period when the shipping market oscillates in high frequency under different influencing factors. It has the basis of multi-scale analysis in form.

The selection of wavelet function for analysis should consider various factors. The

fluctuation characteristics of the international dry bulk shipping market itself are included in the low frequency part of the sequence, while the impact of various emergencies in the shipping market is included in the high frequency part of the sequence signal. Based on the needs of practical application, we usually need to consider the orthogonality, symmetry, tight support and vanishing moment of wavelet function.

Since wavelet decomposition needs to decompose the data sequence of iron ore shipping price at multiple levels, it is obvious that orthogonality must be considered first; symmetry is conducive to the recovery and reconstruction of decomposed signal; the smaller the support width is, the better the local resolution of wavelet is, and the more precise the decomposition is; the vanishing moment characteristic makes the high-order smooth part of the signal be eliminated during wavelet expansion, so as to reflect the singularity of signal better.

3.2 Neural network model

3.2.1 Concept and application basis of neural network model

Artificial neural networks (ANNs) is also referred to as neural networks (NNs) or Connection Model. It is not only a kind of nonlinear dynamic system which imitates the behavior characteristics of animal neural network, but also a kind of nonlinear

dynamic system which includes many simple nonlinear computing units or connection points. It is a complex network composed of a large number of simple processing units. It is an algorithmic mathematical model for distributed parallel information processing, which imitates the behavior characteristics of animal neural network. This kind of network achieves the purpose of processing information by adjusting the relationship between a large number of internal nodes. Artificial neural network has the ability of self-learning and self-adapting. It can analyze and master the rules between them through a batch of corresponding input-output data provided in advance, and calculate the output results with new input data according to these rules. This process of learning analysis is called "training". The structure of neural network can be divided into input layer, hidden layer and output layer. The nodes in the input layer correspond to the prediction variables, and the nodes in the output layer correspond to the target variables. There is a hidden layer between the input layer and the output layer (invisible to the users of the neural network). The number of hidden layers and the number of nodes in each layer determine the complexity of the neural network.

No matter what type of artificial neural network, their common characteristics are large-scale parallel processing, distributed storage, elastic topology, highly redundant and nonlinear operation. Therefore, it has high computing speed, strong association ability, strong adaptability, strong fault tolerance and self-organization ability. These characteristics and capabilities constitute the technical basis of artificial neural network simulation of intelligent activities, and have been important applications in a wide range of fields.

Chapter 4：MATLAB data prediction and processing

4.1 Wavelet threshold denoising

The data of iron ore shipping freight constitute a group of one-dimensional discrete signals. The basic principle of denoising by wavelet analysis is as follows.

A one-dimensional data signal with noise can be expressed as follows:

$$s(i) = f(i) + \sigma e(i) \qquad i = 0,1,\cdots n-1$$

In this formula，$f(i)$is the real signal，$e(i)$is noise，$s(i)$is the signal containing noise.

The denoising process of one-dimensional signal can be divided into three steps:

（1）Wavelet decomposition of one-dimensional signal. Select a wavelet, and determine a wavelet decomposition level N, and then decompose the signal S by N-level wavelet decomposition.

（2）Wavelet decomposition is used to quantize the threshold of high frequency coefficients. For the high frequency coefficients of each layer from the first layer to the N layer, a threshold is selected for soft threshold quantization.

（3）One dimensional wavelet reconstruction. According to the low frequency coefficients of the Nth layer of wavelet decomposition and the high frequency coefficients from the first layer to the nth layer after quantization, the wavelet reconstruction of one-dimensional signal is carried out.

Before the wavelet threshold denoising, the following steps should be performed on the table data:

（1）Clear variable space and command line.

（2）Read in the raw data.

（3）Data analysis. In this step, the function fliplr is introduced to operate the matrix. The function of fliplr makes the matrix X flip left and right along the vertical axis.

（4）Remove the value of Nan.

The steps of wavelet threshold denoising are as follows:

（1）Wavelet decomposition. In this step, we need to use the wavedec function：[C,L]=wavedec(E,5,'haar'). Where C represents the approximate and detail coefficients, L represents the length of the coefficients of each layer, and the number of decomposition layers is 5. The type of wavelet is Haar wave, which is the simplest and most widely used wavelet. Its analytical expression and schematic diagram are as follows：

$$\psi_H = \begin{cases} 1, & 0 \le x \le \frac{1}{2} \\ -1, & \frac{1}{2} \le x \le 1 \\ 0, & else \end{cases}$$

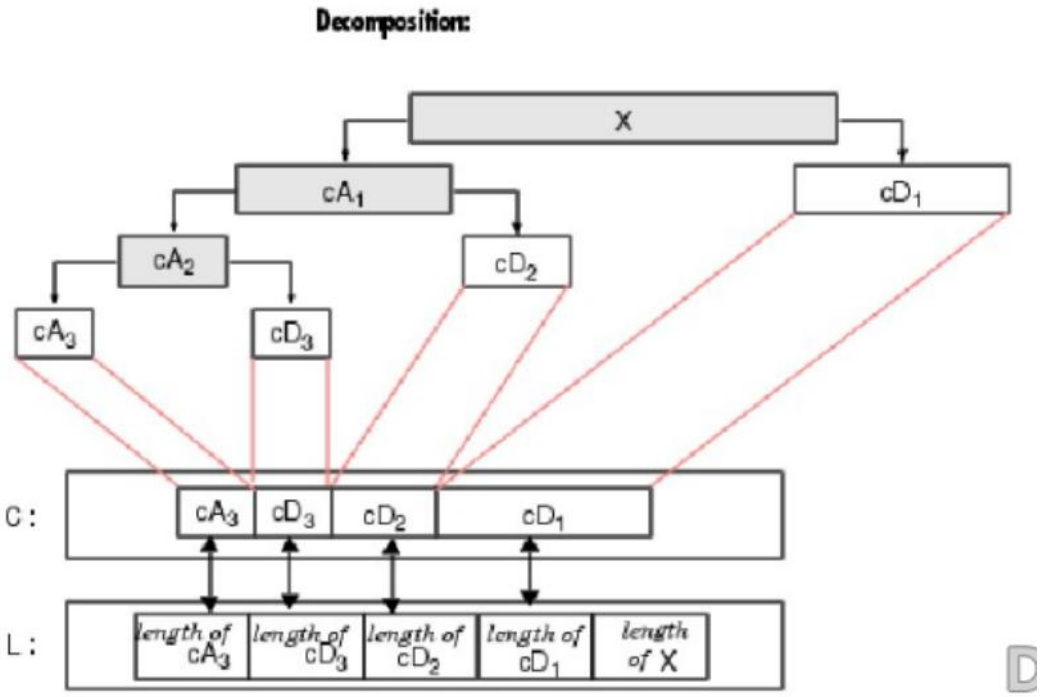

Table 4.1 The principle of wavelet denoising

（2）The n-th approximation coefficient (CA) and detail coefficient (CD) are extracted from decomposition coefficients [C, l] by using wavelet 'Haar'. In this step, appcoef and detcoef functions are used to process the data. In wavelet analysis, the differences of wrcoef, appcoef and detcoef functions are as follows:

Wrcoef: single branch reconstruction of wavelet coefficients. This is the most commonly used reconstruction function. Taking a three-layer DWT as an example, it can get its own reconstruction signal through the wavelet coefficients of A1 D1 A2 D2 A3 D3 in the decomposed [C, l] fabric. When the parameter type is a, n = 0, it can even get the reconstructed original signal S. So this function can replace the sum of the functions of upcoef, upwlev and waverec. For a large number of applications of DWT, it is necessary to reconstruct the wavelet details and approximation coefficients of each layer into their corresponding signals. In the application of DWT,

the wavelet coefficients have no dimensions, so it is difficult to explain the significance of the results of processing various signals with physical significance. Only by reconstructing the wavelet coefficients of infinite steel can they be "restored" to signals with actual dimensions and approximation coefficients, To make it physically meaningful.

Appcoef: extract the approximation coefficients of DWT wavelet.

Detcoef: extract the detail coefficients of DWT wavelet.

（3）Using Stein's unbiased likelihood estimation principle to select the threshold of each layer, the "rigrsure" is the type of unbiased likelihood estimation threshold. In this step, the purpose of using Thselect function is to select the threshold for wavelet denoising. According to the principle of threshold de-noising, threshold is the watershed to distinguish signal from noise. Obviously, it has a crucial impact on the de-noising performance. If the threshold is too high, the signal will be distorted, and if it is too low, the de-noising is incomplete. Generally speaking, the determination of threshold is mainly based on the following criteria：

1. Unbiased risk estimation criterion(rigrsure): an adaptive threshold selection method based on Stein's unbiased likelihood estimation principle. For each threshold, the corresponding risk value is calculated, and the one with the least risk is selected.
2. Fixed threshold criterion (sgtwolog)。
3. Mixed criteria (heursure)：It is a mixture of rigure and sqtwolog. When the SNR is very low, there is a lot of noise in the estimation of rigure criterion, and a fixed threshold is used.
4. Minimax criterion (minimaxi)： This is also a form of fixed threshold selection. This principle is used in statistics to design estimators. Since the de-noising signal can be assumed to be the estimator of unknown regression function, the minimax

estimator is the one to realize the minimum mean square error under the worst condition.

In this paper, the 'rigrsure' criterion is used to determine the threshold.

（4）Determine the threshold of each layer, including hard threshold and soft threshold. Thresholding is to make the gray value become a small value when it is lower than the set threshold; When the gray value is greater than the set threshold, let it become a large value. Hard threshold is a threshold that can not be exceeded by the detected data. Soft threshold is to specify the range of the detected data.

The final wavelet analysis results are as follows:

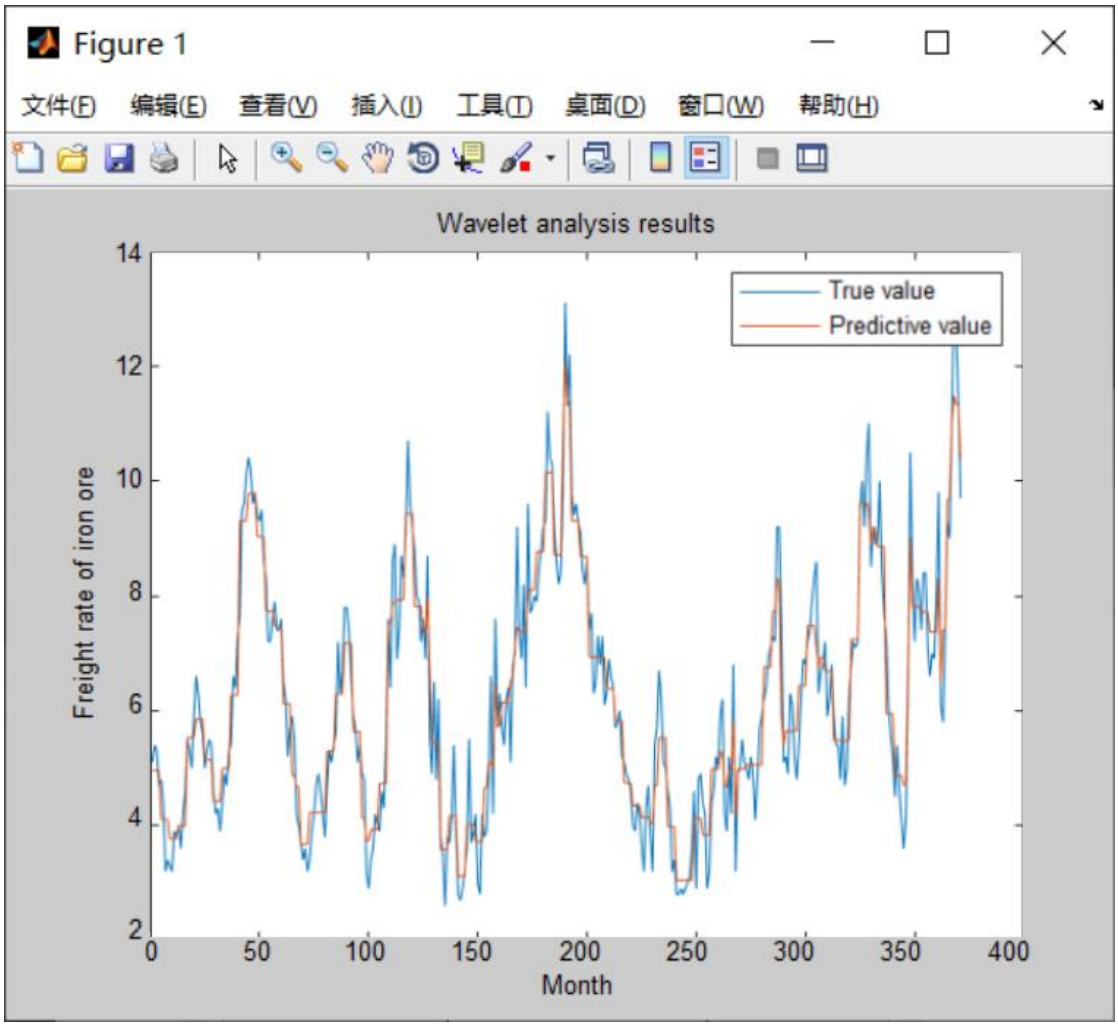

Table 4.2 Wavelet analysis results

The low frequency signal profile obtained from the analysis of the data signal of iron ore shipping price by wavelet transform with Haar wavelet as the wavelet function is compared with the original data graph of iron ore shipping price. It can be found that the signal reconstructed by wavelet transform is sawtooth (ladder) shape. That is because the analytic expression of Haar wavelet is similar to a piecewise function, and the original signal appears step phenomenon after wavelet transform, Therefore, it is very different from the original data signal of iron ore shipping price and loses the characteristics of the original signal.

4.2 Gray prediction

Gray prediction is the first gray system theory put forward by Professor Deng Julong in the world. Grey system theory is the extension of cybernetics in economic and social systems. It is also the result of the combination of automatic control science and mathematical methods of operational research.

According to the theory of grey system, the objective world is the world of matter and information. There are not only a lot of known information (called white), but also many unknown or unascertained information (called black). The system contains both known information and unknown or unascertained information, which is called grey system. Grey system is ubiquitous,

The research objects of grey system include social system, economic system, engineering technology system, ecological system and so on. The main research contents of grey system theory are: modeling idea, theory and method of grey system; Correlation analysis of grey factors; Grey prediction theory and method; Grey decision theory and method; Grey system analysis; Grey system control and optimization. Modeling is the core of abstract system materialization. It directly transforms time series into differential equations, and it establishes a dynamic model of abstract system development, that is, Gray Dynamic Model (GM)

Grey prediction is to predict the grey system, that is, to predict the grey process of time series changing in a certain range. Although the phenomenon in the grey process is random, it is orderly and traceable after all, so this data set has potential laws. Grey prediction can identify the difference degree of the development trend

between the system factors, that is, make correlation analysis, and generate and process the original data to find the law of the system change, generate the data sequence with strong regularity, and then establish the corresponding differential equation model, so as to predict the future development trend of things. Grey prediction constructs a grey prediction model with a series of quantitative values which reflect the characteristics of the prediction object, and predicts the characteristic quantity at a certain time in the future or the time when it reaches a certain characteristic quantity.

The biggest advantage of grey prediction is that it doesn't need a large number of sample data. Generally speaking, it can be predicted with more than four periods of data. It is suitable for the situation of less original data and increasing data series. By accumulating historical data, it weakens the randomness of data and fully reflects the regularity of data itself. The essence of grey modeling theory is to use the information processing method of "generation" to weaken the randomness of the original random sequence, so that the original grey sequence can be transformed into a new sequence which is easy to model. The generation of grey sequence is not to seek the law of probability and statistics, but to strengthen the utilization of useful information in grey sequence. Because the grey prediction system is essentially a trend judgment, it can not reflect the swing process. If the original data series does not increase exponentially, the prediction error will increase. Grey model can achieve good results in medium and long-term forecasting, and the forecasting accuracy is not high, so its application in the field of economic forecasting is limited. For the iron ore freight rate, gray analysis is one of the most scientific and cost-effective analysis methods in the case of limited data. It can predict the trend and predict the data efficiently.

Gray prediction for iron ore freight data analysis is as follows：

（1）Grading test.

（2）Accumulate the original sequence a to get sequence B, and generate the nearest mean value for sequence B.

（3）Construct data matrix. Here, the ones function is used to construct the sequence.

（4）The least square method was used to calculate the parameters A (Development Coefficient) and B (Ash Dosage). The least square method (also known as the least square method) is a mathematical optimization technology. It finds the best function matching of data by minimizing the sum of squares of errors. Using the least square method, the unknown data can be easily obtained, and the sum of squares of the errors between the obtained data and the actual data can be minimized. The basic idea is as follows：Let

$$f(x) = a_1\varphi_1(x) + a_2\varphi_2(x) + \cdots + a_m\varphi_m(x)$$

In this case, $\varphi_k(x)$is a set of linearly independent functions selected in advance, a_k is the undetermined coefficient$(k = 1, 2, \cdots, m, m < n)$, The fitting criterion is to minimize the sum of squares of distance δ_i between $y_i\ (i = 1, 2, \cdots, n)$ and $f(x_i)$, which is called the least square criterion.

（5）Predict the follow-up data, and reduce the sequence F to get the predicted data.

（6）Model checking.

（7）Calculate the residual sequence. Specific operation is divided into the following three methods：

1. Q test for relative residuals. ABS function is used to calculate the relative error sequence. The mean function is used to calculate the average relative error qdisp (relative residual Q test).

2. Variance ratio C test.
3. Small error probability P test.

The final gray prediction results are as follows：

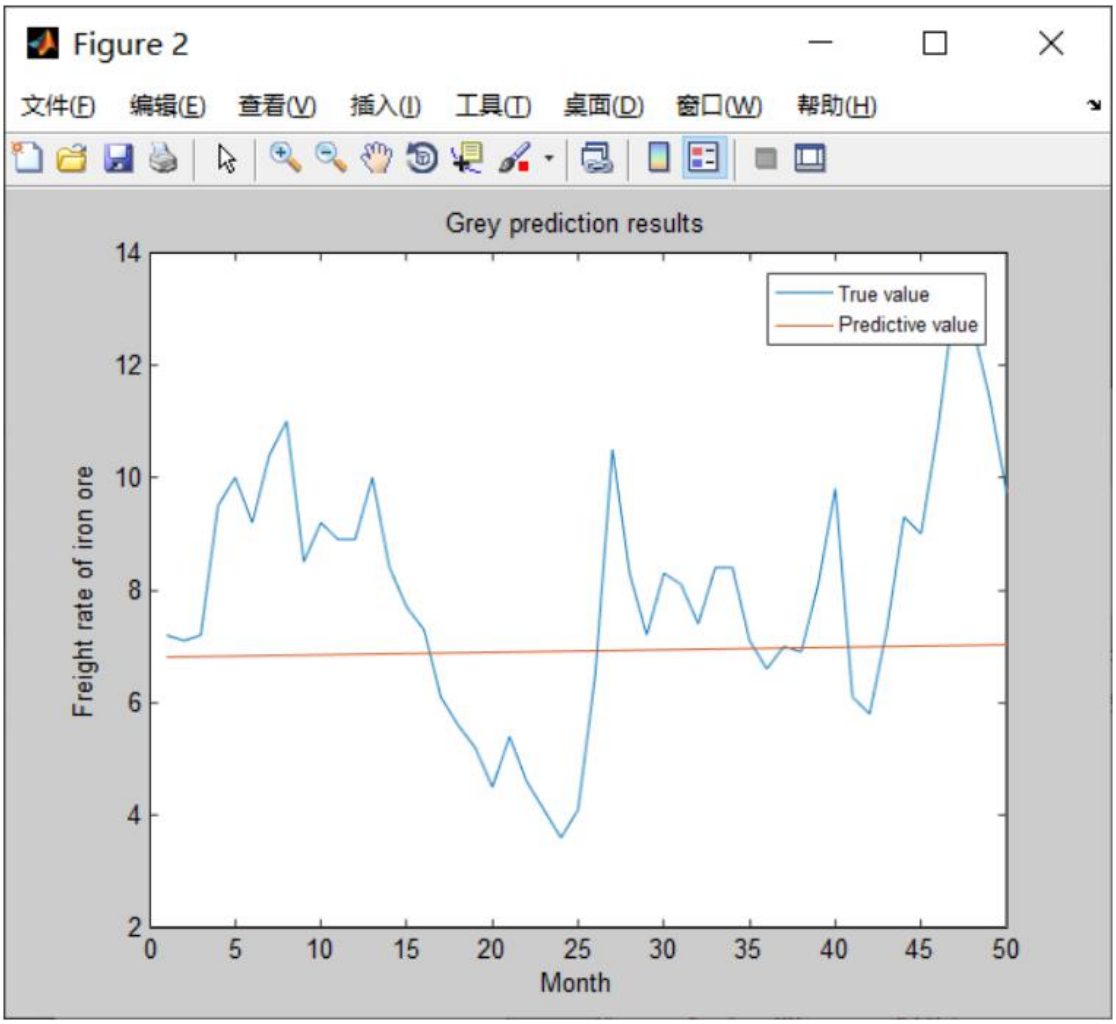

Table 4.3 Gray prediction results

4.3 Neural network prediction

Because the spot shipping price of iron ore is the result of many factors, and its formation mechanism is nonlinear system with high complexity, neural network, which has strong learning ability and can better fit the nonlinear system, is selected for fusion prediction based on wavelet analysis. Based on the existing data, this paper takes the spot shipping price of iron ore and its influencing factors as learning samples, and forecasts the future spot shipping price of iron ore through neural network. On this basis, combined with wavelet analysis, the linkage analysis of iron ore freight rate is carried out, which makes the two complementary in the prediction results and makes the final results more accurate and perfect.

Neural network has the following advantages, which is why this method is selected in this paper.

(1) The accuracy is high. Especially when the test data are non-linear separable, the accuracy of neural network classification is significantly higher than other evaluation methods.

(2) It has strong adaptability. The neural network has a strong ability to adapt to the changes of training samples. When the training samples are added with new data, the neural network can remember the original knowledge well, and adjust it appropriately according to the new data, so that the mapping relationship can better describe the new samples. This enables neural networks to adapt to the uncertainty of classification objects, while other methods are slightly worse at this point.

(3) Strong fault tolerance. The neural network has no strict requirements on the distribution and covariance of samples, and it can still give correct solutions when the system accepts incomplete information.

To sum up, neural network has a wide range of adaptability, learning ability and nonlinear mapping ability. Through learning, we can obtain the dependence relationship between the data, which has certain advantages for the spot freight rate prediction of iron ore.

The neural network model is used to analyze the change of iron ore freight rate：

（1）The number of training set and test set.

（2）The first 75% of the data is used as training data, and the last 25% as test data.

（3）Convert to sequence data needed by narnet.

（4）Calculate latency, i.e. how many values the current value depends on in the past.

（5）The number of hidden layer nodes is 10.

（6）Narnet structure. The following functions are used for data analysis: preparets function prepares input X and target y time series data for neural network simulation or training. The fprintf function outputs the formatted string to the stream and writes the formatted string to the output stream.

（7）The neural network model is used to predict. The cell2mat function is used to convert a cell array composed of multiple matrices into a matrix. That is to say, multiple matrices in the cell array are combined into one matrix.

（8）Drawing and calculating MSE.

The final neural network prediction results are shown in the figure below：

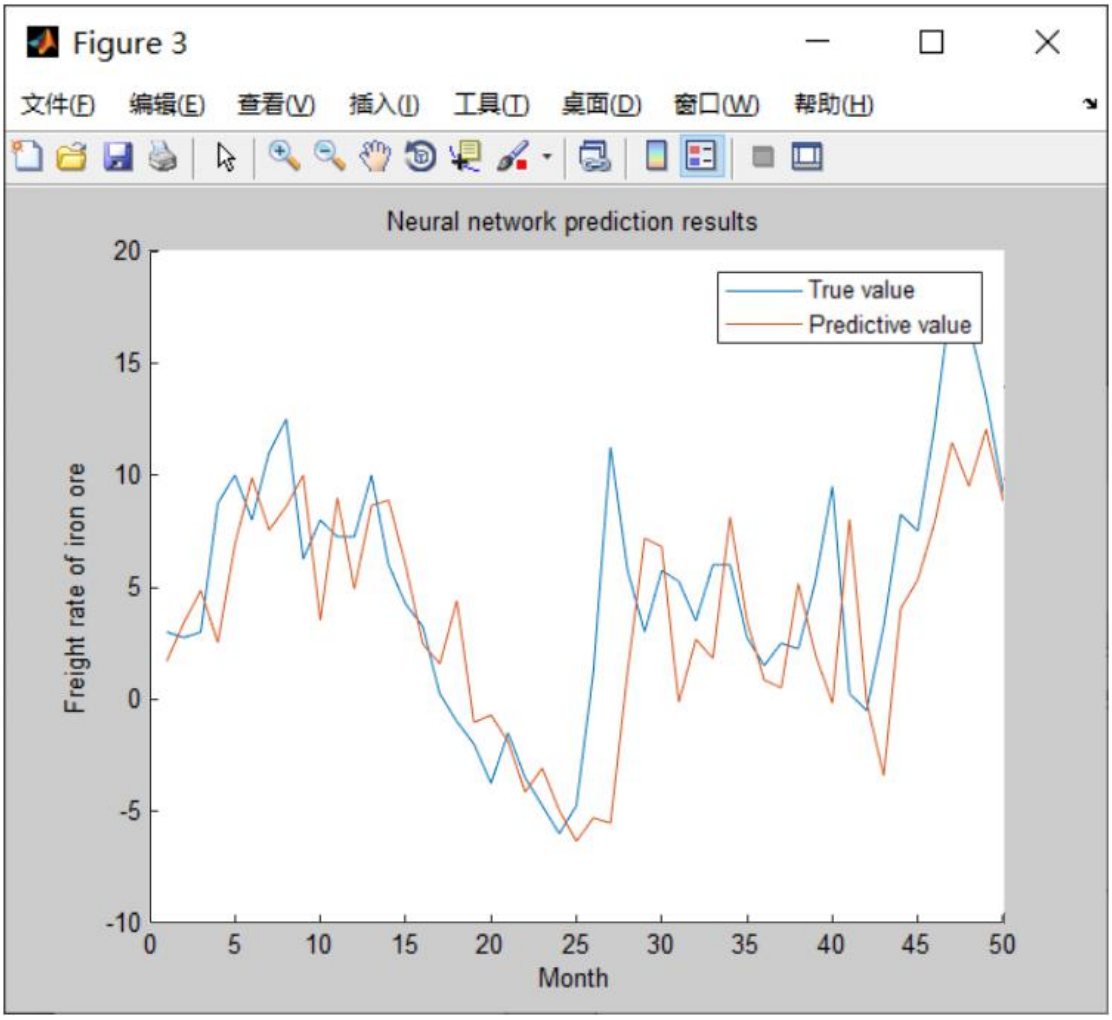

Table 4.4 Neural network analysis results

4.4 Wavelet analysis combined with neural network prediction

Wavelet analys combined with neural network prediction for iron ore freight data processing is as follows：

（1）Set the number of training set and test set. The first 75% data is used as training data, and the last 25% data is used as test data.

（2）The calculation is transformed into the sequence data needed by narnet. In this step, num2cell function is used to convert the numerical array into a heterogeneous array.

（3）Calculation delay, that is, how many values the current value depends on in the past.

（4）The number of hidden layer nodes is 10.

（5）Narnet structure.

（6）Neural network is used for prediction.

（7）Draw a picture and calculate MSE.

Finally, the prediction results of wavelet analysis and neural network are shown in the figure below：

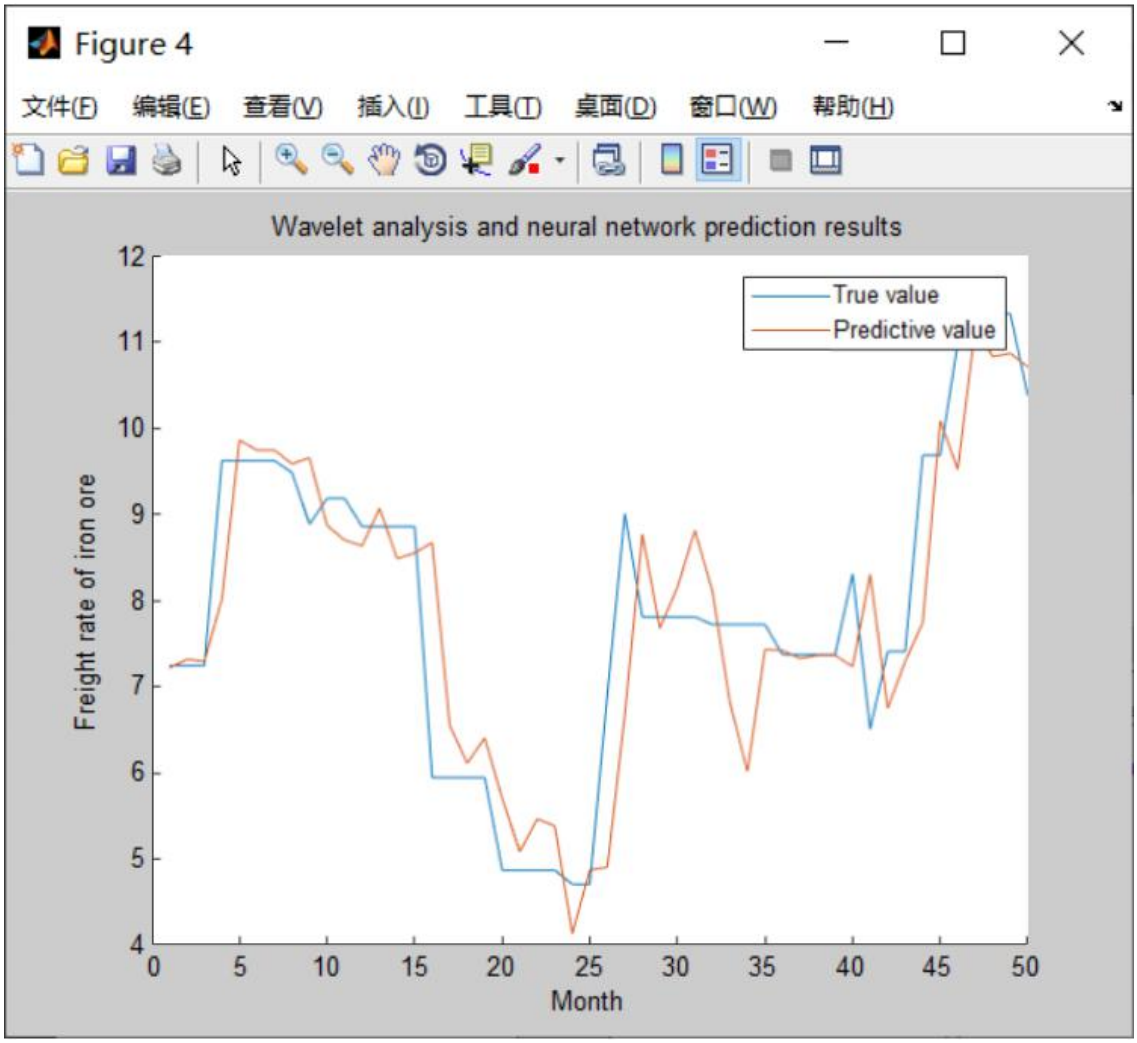

Table 4.5 Results of wavelet analysis and neural network analysis

Chapter 5: Conclusion and research prospect

5.1 Conclusion

This paper analyzes the international iron ore freight rate from the quantitative point of view, and qualitatively analyzes the supply and demand situation of dry bulk shipping market. In the quantitative aspect, wavelet analysis and neural network prediction model are combined to output the data after multi-resolution processing of wavelet analysis, which gives better play to the simulation and prediction role of neural network model.

The conclusion and experience are as follows：

（1）In this paper, a large number of historical data are used, that is, 372 ship types from Western Australia to Qingdao Strait have been selected since 2006, and the data are taken from the 1st and 15th of each month.

（2）Wavelet analysis is used to denoise the original data of iron ore freight rate, and Haar series wavelet is used to decompose the original data into 5 layers. The results show that the selection of 5 layers can remove the noise information better, and the obtained low-frequency signal can better reflect the trend of the original signal, that is, the effective information of the original signal is preserved, which fully reflects the trend of iron ore freight rate; However, the high-frequency signal changes violently, and most of them are composed of noise factors. With the increase of scale, the fluctuation and change trend of noise can be observed more clearly.

（3）The default threshold denoising method is used to denoise the original data of iron ore freight rate. Compared with the original data, the trend is smoother and the

degree of "dissociation" is lower. The data comparison shows that the mean value decreases slightly and the sample standard deviation decreases.

（4）The comparison and analysis of the results of iron ore shipping price forecast under the two ideas show that the combination of wavelet analysis and neural network model can better grasp the change law of iron ore shipping price, the deviation degree between the predicted value and the true value is low, the fluctuation is gentle, and the error rate is obviously low.

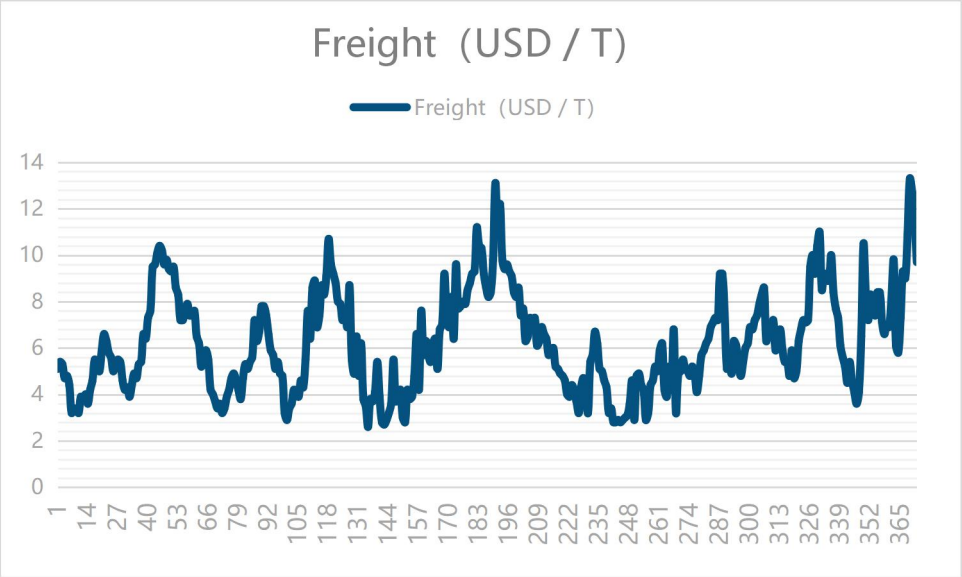

Table 5.1 Change of iron ore sea freight rate

From January 2006 to June 2021, the freight rate change of channel type ships from Western Australia to Qingdao is shown in the figure above. The composition mechanism of iron ore spot sea freight is a complex nonlinear system, which is affected by many aspects. In addition to the factors that can be quantitatively analyzed to a certain extent, it is also affected by many emergencies, such as war, natural disasters, changes in iron ore trade policy, etc, Increase the difficulty of iron ore spot sea freight forecast. In this paper, the first mock exam is used to predict the

effect of the model. Especially this time, COVID-19 has made an immeasurable impact on the whole international maritime field.The experimental results show that the prediction model has good prediction ability. Through the combination of wavelet analysis and neural network modeling prediction and analysis, the change of iron ore sea freight rate follows the following rules to a certain extent:

(1) Tendency. From the data and chart analysis, it can be concluded that the freight rate of iron ore by sea has been increasing in the past 5 years. This is partly due to the vigorous development of the international shipping industry. From 2006 to 2015, the overall freight rate showed a trend of dynamic balance and slowly rising.

(2) Periodicity. According to the data analysis, it can be concluded that the sea freight rate of iron ore has a certain periodicity in the past 20 years, and the change cycle is from 2 to 5 years. COVID-19, which broke out in 2020, also has the greatest probability to become the watershed of the new change cycle. It is also possible to have a big shuffle on the cyclical changes of the freight rate. The global economic crisis that broke out in 2007 also had a great impact on the shipping industry in the past two years. To a certain extent, it can serve as a reference for COVID-19 and marine analysis.

(3) Seasonality. From the data fluctuation in the past 20 years, it can be concluded that the fluctuation of international iron ore sea freight rate presents a certain seasonality. After comprehensive chart analysis, excluding the influence of some special factors and emergencies, the freight rate of iron ore in a year is affected by the first quarter of the off-season, and it reaches the lowest level in a year in March and April. Then, in the second quarter and the third quarter continued to shock higher, and finally peaked in the fourth quarter. Due to the influence of special events in different years, the period of change may fluctuate, but most years still follow the above rule.

Moreover, with the rational development of the international dry bulk market, the iron ore transportation market is becoming more mature, and the number of emergencies is gradually decreasing. On this basis, the prediction results of this model will be more accurate.

5.2 Research prospects

（1）The prediction samples in this paper are only one-dimensional time series, and the variables are only the historical data of iron ore sea freight. If there are certain conditions to increase the data samples, the prediction model will be more accurate, and the samples of Renmin can better reflect the change law of iron ore freight rate, but it increases the difficulty for wavelet de-noising processing and the establishment of the model. If we consider other main factors that affect the freight rate of iron ore, we can transform the sample into two-dimensional sequence, and use multivariate wavelet to decompose it, and use wavelet packet to denoise. This will greatly increase the complexity of the problem and the difficulty of solving it, but adding a major influencing variable will better reflect the trend of iron ore shipping price, and the prediction effect will be better.

（2）At present, although wavelet analysis has been widely used in various fields, there is no rule or method to guide the selection of wavelet and denoising methods. In this paper, Haar wavelet is selected according to relevant experience, but it is not necessarily the best method. And the original attempt to use ARMA model combined with wavelet analysis for quantitative calculation, but the effect is not satisfactory, can only change the research direction, use neural network model for combination analysis. And in the three ways of wavelet de-noising, the given threshold de-noising method is the best, and its threshold is obtained by empirical formula, but in this

study, there is still a lack of de-noising experience, so the de-noising threshold still needs to accumulate experience and improve the method.

Due to the limited level of the author, there must be some deficiencies in the article. I sincerely ask all teachers and experts to criticize and correct.

Appendix

Appendix I: Freight rate of imported iron ore

Freight of channel type ship from Western Australia to Qingdao between 2006 and 2021（USD / T）:

Year	Month	Freight （USD / T）
2021	6.09	9.7
	6.01	11.4
	5.15	12.7
	5.01	13.3
	4	10.9
		9.0
	3	9.3
		7.3
	2	5.8
		6.1
	1	9.8
		8.1

2020	12	6.9
		7.0
	11	6.6
		7.1
	10	8.4
		8.4
	9	7.4
		8.1
	8	8.3
		7.2
	7	8.3
		10.5
	6	6.5
		4.1
	5	3.6
		4.1
	4	4.6
		5.4
	3	4.5
		5.2
	2	5.6
		6.1
	1	7.3
		7.7

2019	12	8.4
		10.0
	11	8.9
		8.9
	10	9.2
		8.5
	9	11.0
		10.4
	8	9.2
		10.0
	7	9.5
		7.2
	6	7.1
		7.2
	5	6.8
		6.3
	4	5.0
		4.7
	3	5.9
		4.8
	2	5.4
		5.4
	1	5.9
		6.8

2018	12	6.2
		5.9
	11	7.2
		6.8
	10	6.7
		6.3
	9	8.6
		8.3
	8	7.9
		7.4
	7	7.2
		6.8
	6	6.9
		6.2
	5	6.0
		5.4
	4	4.8
		5.2
	3	6.1
		6.3
	2	4.9
		5.2
	1	5.1
		7.5

2017	12	9.2
		9.2
	11	7.2
		7.3
	10	7.1
		6.9
	9	6.4
		6.2
	8	5.9
		5.7
	7	4.8
		4.1
	6	4.9
		5.2
	5	4.8
		5.0
	4	5.1
		5.5
	3	5.0
		4.9
	2	3.2
		6.8
	1	4.2
		5.2

2016	12	3.9	2015	12	3.4	2014	12	5.2
		4.2			3.2			6.0
	11	6.2		11	4.3		11	5.8
		5.9			4.6			5.7
	10	5.0		10	5.0		10	6.4
		5.2			5.1			6.6
	9	4.6		9	6.2		9	6.9
		4.4			6.7			6.3
	8	3.2		8	5.7		8	6.1
		2.9			5.4			7.3
	7	4.2		7	3.2		7	6.8
		4.4			3.8			7.3
	6	4.9		6	4.7		6	6.5
		4.8			4.3			6.3
	5	2.9		5	3.2		5	7.7
		4.6			3.7			7.4
	4	3.6		4	4.2		4	8.6
		3.1			4.4			8.2
	3	3.0		3	3.9		3	8.4
		2.9			4.0			9.1
	2	2.8		2	4.6		2	9.3
		2.9			4.8			9.6
	1	2.8		1	4.9		1	9.4
		2.8			5.1			9.8

2013	12	12.2	2012	12	9.2	2011	12	3.2
		11.3			7.0			2.9
	11	13.1		11	6.8		11	2.7
		9.8			5.1			2.8
	10	8.4		10	6.4		10	3.9
		8.2			6.2			5.4
	9	8.6		9	5.4		9	4.1
		9.2			5.7			3.7
	8	10.3		8	6.3		8	3.8
		10.4			5.7			2.6
	7	11.2		7	7.6		7	3.5
		9.3			4.2			3.8
	6	9.2		6	6.6		6	6.2
		8.8			4.8			4.8
	5	8.5		5	3.9		5	6.5
		7.9			3.8			4.9
	4	8		4	4.2		4	5.5
		7.8			2.8			8.7
	3	7.7		3	3.0		3	6.9
		9.6			4.2			7.6
	2	6.4		2	3.9		2	7.2
		8.2			3.7			7.9
	1	6.9		1	5.5		1	8.0
		7.4			3.6			8.8

2010	12	9.2	2009	12	5.4	2008	12	3.2
		9.6			5.1			3.6
	11	10.7		11	5.7		11	3.4
		9.1			5.9			3.7
	10	8.3		10	6.6		10	4.0
		8.7			7.4			4.2
	9	7.4		9	7.8		9	5.5
		6.9			7.8			5.9
	8	8.9		8	6.7		8	5.7
		8.6			6.3			5.2
	7	6.4		7	7.2		7	6.2
		7.6			5.6			6.5
	6	5.5		6	5.4		6	7.6
		4.3			5.1			7.4
	5	4.6		5	5.3		5	7.4
		3.9			4.7			7.9
	4	4.0		4	3.8		4	7.6
		4.2			4.2			7.2
	3	3.6		3	4.6		3	7.2
		3.4			4.9			8.3
	2	2.9		2	4.7		2	8.6
		3.2			4.2			9.5
	1	4.8		1	3.9		1	9.3
		4.9			3.4			9.4

2007	12	9.8	2006	12	5.6
		9.6			5.8
	11	10.2		11	6.3
		10.4			6.6
	10	10.1		10	5.9
		9.6			5.0
	9	9.5		9	5.3
		7.6			5.5
	8	7.3		8	4.6
		6.4			4.2
	7	6.6		7	3.6
		5.4			4.0
	6	5.3		6	3.8
		4.7			3.9
	5	4.9		5	3.2
		4.4			3.3
	4	3.9		4	3.4
		4.3			3.2
	3	4.2		3	4.4
		4.6			4.8
	2	5.4		2	4.7
		5.5			5.3
	1	5.3		1	5.4
		5.0			5.1

Appendix II: Code

Basic operation:

```
%% Clear variable space and command line
clc
clear
close all

%% Read in raw data
data=xlsread('Appendix I Import tariff of iron ore.xlsx');

%% Data analysis
data1=data(:,8);
data1=fliplr(data1');
data2=data(:,3);
data2=fliplr(data2');

%% Remove the value of nan
data_sum=[data1 data2];
z=find(~isnan(data_sum));
data_sum=data_sum(z);
```

Wavelet threshold denoising:

```
%% Wavelet threshold denoising
E=data_sum;
%Wavelet decomposition
[c,l]=wavedec(E,5,'haar');
%Using wavelet 'haar' to extract approximation coefficient(cA) of the nth layer and detail coefficient (cD) from decomposition coefficient [C,L]
ca4=appcoef(c,l,'haar',5);
cd1=detcoef(c,l,1);
cd2=detcoef(c,l,2);
cd3=detcoef(c,l,3);
cd4=detcoef(c,l,4);
cd5=detcoef(c,l,5);
%Using stein's unbiased likelihood estimation principle to select the threshold of each layer
%'rigrsure' is the threshold type of unbiased likelihood estimation
thr1=thselect(cd1,'rigrsure');
thr2=thselect(cd2,'rigrsure');
thr3=thselect(cd3,'rigrsure');
thr4=thselect(cd4,'rigrsure');
thr5=thselect(cd5,'rigrsure');
%Threshold of each layer
TR=[thr1,thr2,thr3,thr4,thr5];
```

```
%'s' is the soft threshold;'h'is the hard threshold
SORH='s';
[XC,CXC,LXC,PERF0,PERF2]=wdencmp('lvd',E,'haar',5,TR,SORH);
figure
plot(data_sum,'r')
hold on
plot(XC,'b')
legend('True value','Predictive value')
xlabel('Month'); ylabel('Freight rate of iron ore');
title('Wavelet analysis results');
hold off
```

Gray prediction:

```
%% Gray prediction
syms a b;
c = [a b]';
%Primitive sequence
A = data_sum;
%Grading test
n = length(A);
min=exp(-2/(n+1));
max=exp(2/(n+1));
for i=2:n
    ans(i)=A(i-1)/A(i);
end
ans(1)=[];
for i=1:(n-1)
    if ans(i)<min
    else
        fprintf('The %d ratio is not in the standard range',i)
        disp(' ');
    end
end
%Accumulate the original sequence A to get the sequence B
B = cumsum(A);
```

```
%Generating the nearest mean value of sequence B
for i = 2:n
    C(i) = (B(i) + B(i - 1))/2;
end
C(1) = [];
%Constructing data matrix
B = [-C;ones(1,n-1)];
Y = A; Y(1) = []; Y = Y';
%The parameters a (development coefficient) and b (ash dosage) were calculated by the least square method
c = inv(B*B')*B*Y;
c = c';
a = c(1);
b = c(2);
%Forecast follow-up data
F = []; F(1) = A(1);
for i = 2:(n+10)
    F(i) = (A(1)-b/a)/exp(a*(i-1))+ b/a;
end
```

```
%Log column F is reduced to get the predicted data
G = []; G(1) = A(1);
for i = 2:(n+10)
    G(i) = F(i) - F(i-1); %Get the predicted data
end
disp('The forecast data is: ');
G
%Model checking
H = G(1:n);
%Calculating residual sequence
epsilon = A - H;
%Method 1: relative residual Q test
%Calculating relative error sequence
delta = abs(epsilon./A);
%Calculate the average value of relative error Qdisp('Q test for relative residuals: ')
Q = mean(delta)
%Method 2: variance ratio C test
disp('Variance ratio C test: ')
C = std(epsilon, 1)/std(A, 1)
```

```
%Method 3: small error probability P test
S1 = std(A, 1);
tmp = find(abs(epsilon - mean(epsilon))*0.6745 * S1);
disp('Small error probability P test: ')
P = length(tmp)/n
figure
plot( A(end-49:end),'r'); hold on;
plot( G(end-49:end),'b');
legend('True value','Predictive value')
xlabel('Month'); ylabel('Freight rate of iron ore');
title('Grey prediction results');
hold off
```

Neural network prediction:

```
%% Neural network prediction
pressure=data_sum';
%The number of training set and test set
num_all_data = length( pressure );
% The first 75% of the data is used as training data
num_train = floor( num_all_data * 0.75 );
% The last 25% of the data were used as test data
num_test = num_all_data - num_train;
% Convert to sequence data needed by narnet
y_train_nn = num2cell( pressure(1:num_train) )';
y_test_nn = num2cell( pressure(1+num_train:end))';
%Delay, that is how many values the current value depends on in the past
feedback_delays = 1:10;
% The number of hidden layer nodes
num_hd_neuron = 10;
% Construction of narnet
net = narnet(feedback_delays, num_hd_neuron);
[Xs,Xi,Ai,Ts] = preparets(net,{},{}, y_train_nn);
net = train(net,Xs,Ts,Xi,Ai);
view(net)
Y = net(Xs,Xi);
perf = perform(net,Ts,Y);
fprintf( 'neural network: mse on training set : %.6f\n', perf );
```

```
%Neural network prediction
yini = y_train_nn(end-length(feedback_delays)+1:end);
[Xs,Xi,Ai] = preparets(net,{},{},[yini y_test_nn]);
y_pred_nn = net(Xs,Xi,Ai)';
y_pred_nn = cell2mat( y_pred_nn );
y_test_nn = cell2mat( y_test_nn )';
%Drawing and calculating mse
figure
title('Neural network prediction results')
hold on
plot( y_test_nn(end-49:end),'r');
plot( y_pred_nn(end-49:end),'b');
xlabel('Month'); ylabel('Freight rate of iron ore');
legend({ 'True value', 'Predictive value'})
```

Neural network and Wavelet analysis:

```
%% Neural network and Wavelet analysis
pressure=XC';
%The number of training set and test set
num_all_data = length( pressure );
% The first 75% of the data is used as training data
num_train = floor( num_all_data * 0.75 );
% The last 25% of the data were used as test data
num_test = num_all_data - num_train;
% Convert to sequence data needed by narnet
y_train_nn = num2cell( pressure(1:num_train) )';
y_test_nn = num2cell( pressure(1+num_train:end))';
%Delay, that is how many values the current value depends on in the past
feedback_delays = 1:10;
% The number of hidden layer nodes
num_hd_neuron = 10;
% Construction of narnet
net = narnet(feedback_delays, num_hd_neuron);
[Xs,Xi,Ai,Ts] = preparets(net,{},{}, y_train_nn);
net = train(net,Xs,Ts,Xi,Ai);
view(net)
Y = net(Xs,Xi);
perf = perform(net,Ts,Y);
fprintf( 'neural network: mse on training set : %.6f\n', perf );
```

```
%Neural network prediction
yini = y_train_nn(end-length(feedback_delays)+1:end);
[Xs,Xi,Ai] = preparets(net,{},{},[yini y_test_nn]);
y_pred_nn1 = net(Xs,Xi,Ai)';
y_pred_nn1 = cell2mat( y_pred_nn1 );
y_test_nn = cell2mat( y_test_nn )';
%Drawing and calculating mse
figure
title('Wavelet analysis and neural network prediction results')
hold on
plot( y_test_nn(end-49:end),'r');
plot( y_pred_nn1(end-49:end),'b');
xlabel('Month'); ylabel('Freight rate of iron ore');
legend({ 'True value', 'Predictive value'})
```

Results summary:

```
%% Results summary
figure
plot( A(end-49:end),'-ro'); hold on;
plot( G(end-49:end),'-g>');hold on
plot( y_pred_nn(end-49:end),'-b*');hold on
plot( y_pred_nn1(end-49:end),'-k^');hold off
legend('True value','Predictive value')
xlabel('Month'); ylabel('Freight rate of iron ore');
title('Algorithm comparison');
```

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