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Who Will Establish New Trade Relations? Looking for Potential Relationship in International Nickel Trade

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Abstract: Nickel ore sand and its concentrate are the main sources of raw nickel materials in various countries. Due to its uneven distribution throughout the world, the international trade of nickel ore sand is also unstable. Looking for potential links in the changing international nickel ore trade can help governments find potential partners, make strategic preparations in advance, and quickly find new partners when original trade relationships break down. In this paper, we build an international nickel ore trade network using a link prediction method to find potential trade relations between countries. The results show that China and Italy, China and Denmark, China and Indonesia, and China and India are most likely to establish trade relations within five years. Finally, according to the research results, suggestions regarding the international nickel ore trade are proposed.

Keywords: international trade; nickel ore; link forecast; trade relationship forecast

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1. Introduction

Nickel (Ni) was a rapidly developed metal at the beginning of this century. It is an important raw material for creating stainless steel; high temperature, high strength alloy steel and other alloy materials; and is an indispensable and important metal material for the military and civil industries [1]. At the same time, under the background of vigorously promoting sustainable development, new energy vehicles have developed rapidly. As an important raw material of new energy vehicles, the demand for nickel in various countries is gradually expanding. The world is rich in nickel resources, but their distribution is not balanced. Global movement of nickel ore promotes effective allocation of nickel resources. Countries with insufficient nickel resources meet their nickel resource needs through the global nickel ore trade, while countries with rich nickel resources obtain benefits through the export of nickel ore and its concentrate. Therefore, the nickel ore trade is very important across countries.

With increasing demand for lithium materials, the demand for nickel is also increasing, and scholars have carried out various studies on nickel ore [2,3]. Scholars have paid more attention to price fluctuations and the market demand for nickel ore. Among them, Stollery Kenneth R et al. improved the mineral depletion model and applied it to the nickel industry and showed that the limitation and depletion of nickel resources have become an important determinant of its price [2]. According to the application of social demand for nickel, Anna Hulda Olafsdottir et al. used the WORLD7 model to evaluate the long-term supply of nickel to society and the final recoverable nickel resources [3]. Some scholars have analyzed the environmental problems caused by the development and utilization of nickel resources [1]. With the growing demand for nickel resources and the promulgation and implementation of Indonesia's export ban and the Philippines' mining ban, scholars have studied the security of nickel resource supply and international trade in nickel ore. By constructing the global nickel ore trade network, some scholars found that the global nickel ore trade is unstable and that the pattern of nickel trade are constantly changing [4]. In view of the instability of the trade network, Dong X et al. designed a dynamic programming model to help optimize the network structure and provide an optimal trade mode for the international nickel ore trade [5]. However, the nickel ore trade is restricted by the international environment, national policies, and other aspects. Facing the unstable trade situation, we need to find new trading partners that are most likely to cooperate.

For the prediction of future trade relations, the most popular method is the regression prediction method based on econometrics [6], but it is difficult to find all factors that affect international trade, and some variables are omitted when building the model. Some scholars have also used gravity models to predict trade volume [7,8]. Rongji Huang et al. used the gravity model of international trade as the basis to predict China's export growth potential [8], but this method is not effective at identifying hidden trade relationships.

As a kind of network topology method, the link prediction method can better discover hidden links in a network and possible future links. The link prediction model originally evolved from the Markov chain and machine learning [9]. At present, the model is mainly based on similarities of the network topology structure and the likelihood of network hierarchy. Link prediction methods have also been widely used in various fields, such as in reference to traffic networks [10,11], scientist cooperation networks [12], social networks [13,14], and protein interaction networks [15] and have obtained good prediction results. Currently, link prediction methods have been applied by some scholars to discuss international trade by transforming trade relations into networks. The effectiveness of the algorithm is confirmed by existing trade relations [16–19]. Sida Feng et al. uses the link prediction method to forecast nature trade relations in the oil trade [17], and Sen Liu et al. uses the preferential attachment algorithm to explore the international nickel ore trade rules behind existing trade relations [19]. Therefore, we can find potential connections in the nickel ore trade by constructing an international nickel ore trade network and applying the link prediction method.

It is very important to find the potential trade relations between countries. Although this potential trade is not obvious [20], the trade patterns and interactions between countries form links, which may lead to future trade, and the link prediction method can help find this link. Therefore, we can find possible future trade links and potential trade partners through link prediction method. On the other hand, identifying a possible trade relationship between the two countries helps a country predict the future nickel trade model, which helps the government quickly find new trading partners in the face of various changes leading to the breakdown of cooperation, so as to prevent the shortage or surplus of nickel supply. In summary, this paper studies the potential trade relationship of nickel ore and its concentrate in international trade through link prediction method. This article evaluates potential trade links according to actual cooperative relationship. To more accurately understand the link motivations of the nickel ore trade, this article first calculates the trade score through four mainstream link prediction algorithms and finds an optimal algorithm. Then, the prediction effect is evaluated by comparing the forecast results with the actual trade relations. In addition, the international nickel ore trade participants are divided into two trade roles, and the potential trade links are further analyzed and forecasted.

The remaining research arrangements are as follows. The second part introduces the data sources and research methods of this study. The third part analyzes the empirical results and explores the nickel trade rules. The fourth part discusses and summarizes the research.

2. Materials and Methods

2.1. Data

We use United Nations Statistics Division (https://comtrade.un.org/, accessed on 26 October 2020) data for this study. We downloaded trade data on international nickel ore and its concentrate for 2010 to 2019 on 27 October 2020 under HS code 2604. Data on nickel trade in 152 countries and regions for nearly 10 years were obtained. We obtained data on the trade year, Year, Reporter Code, Trade Flow Code (including imports and exports), Partner Code, Classification, Commodity Code, Quantity Unit Code, Supplementary Quantity, and Net weight (kg). We removed duplicate data, data on trade relations that do not represent specific countries, and data on trade relations where the same code is used for both import and export countries.

2.2. Method

2.2.1. Establishment of the Nickel Ore Trade Network

As this article aims to forecast the future trade of nickel ore by the existing trade relations, we focus on which trading countries will trade nickel ore within the next few years. We are not concerned with exploring the amount of trade occurring between two parties. Therefore, we constructed two types of networks with one considering the number of transactions and with one not considering the number of transactions. In the network, nodes represent countries participating in the nickel ore trade, and cooperative relationships between countries as edges between nodes. In Figure 1, the arrow points from the trade exporter to the trade importer. In the network considering trade volumes, the thickness of the edge indicates the size of the trade volume. We made predictions based on these two networks. From a total of ten years of data, we obtained 20 trade networks.

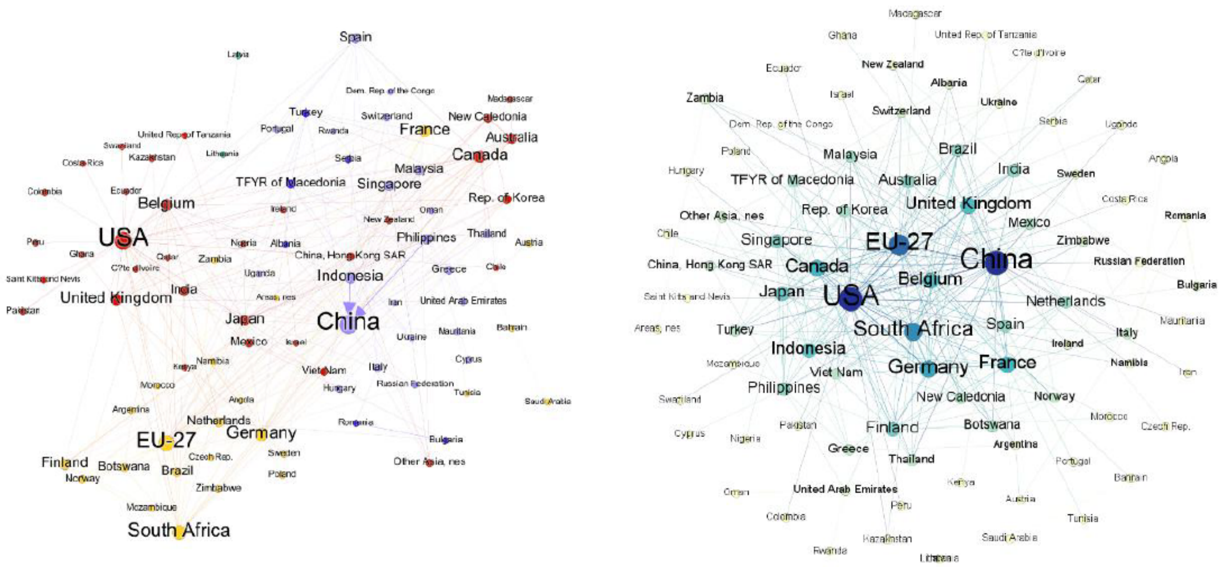

Figure 1. The nickel international trade orientation network in 2019 (**left**, weighted; **right**, nonweighted).

2.2.2. Link Prediction Model

Link prediction, as a method of complex network prediction, has been successfully used for the prediction of international trade. Based on characteristics of the nickel ore trade, this paper reveals its structural motivation and potential links. The study is divided into the following steps, and a schematic diagram of the process used is shown in Figure 2.

Step 1: Optimal Algorithm Selection

To explore accurate hidden information in the trading network of the research object, we need to use the most suitable algorithm. The main algorithms of link prediction include the common neighbor (CN), Adamic/Adar (AA), resource allocation (RA), and preferential attachment (PA) algorithms [13,21], which are as follows:

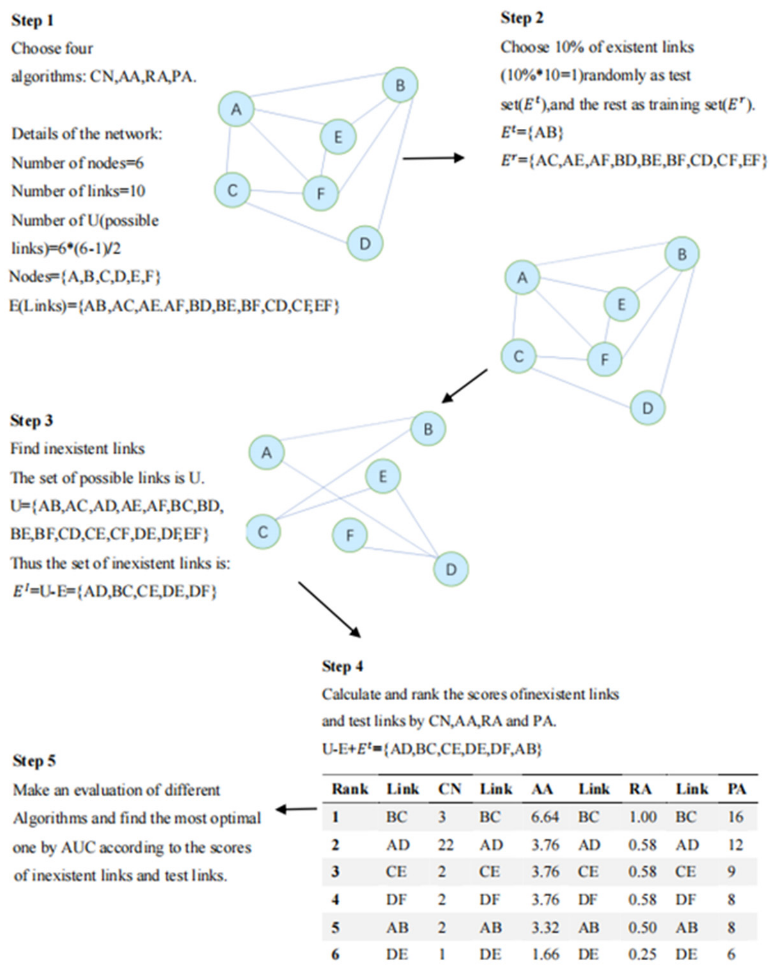

Figure 2. Link prediction algorithm schematic.

(1) Common Neighbor (CN algorithm).

In a network, if two nodes without connections have many common neighbors, the two nodes are likely to connect. In the nickel ore trade network, the more common trading partners two countries have, the greater the possibility of future trade becomes. The CN method uses the following two kinds of equations: a nonweighted algorithm not considering trade volume, such as Equation (1), and a weighted algorithm considering trading volume, such as Equation (2).

Regarding the actual international nickel ore trade, a and b in Equation (1) represent two national nodes in the nickel ore trade network. $\Gamma(a)$ is the neighbor set of node a, that is, a group of countries that have trade relations with country a. $\Gamma(a)\Gamma(b)$ denotes the country in the trade network that has trade relations with both a and b countries. S_{ab} represents the total number of countries in trade between a and b. For the trade network of nickel ore sands, c in Equation (2) denotes the international trade partners shared by countries a and b in the network, and $w(a,c)$ denotes the trade volume between countries a and c.

$$S_{ab}^{CN} = |\Gamma(a) \cap \Gamma(b)| \quad (1)$$

$$S_{ab}^{CN} = \sum\nolimits_{z\epsilon\Gamma(a)\cap\,\Gamma(b)} \frac{w(a,c) + w(c,b)}{2} \quad (2)$$

(2) Preferential Attachment (PA algorithm).

When the party involved in trade has more trade partners, it is easier to have new trade cooperation. This method takes two forms: the first does not consider the impact of trade volume, such as Equation (3), and the second considers the impact of trade volume, such as Equation (4).

$$S_{ab}^{PA} = |\Gamma(a) \times \Gamma(b)| \tag{3}$$

$$S_{ab}^{PA} = \sum_{j\epsilon\Gamma(a)} w(a,j) \times \sum_{q\epsilon\Gamma(b)} w(b,q) \tag{4}$$

In Equation (4), j denotes the country engaged in direct cooperate with country a, and q denotes the country engaged in direct cooperates with country b.

(3) Adamic/Adar (AA algorithm).

In the trading network, countries with fewer trading partners make greater contributions to neighboring countries.

$$S_{ab}^{AA} = \sum_{z\epsilon\Gamma(a)\cap\ \Gamma(b)} \frac{1}{logk_z} \tag{5}$$

$$S_{ab}^{AA} = \sum\nolimits_{z\epsilon\Gamma(a)\cap\ \Gamma(b)} \frac{w(a,c) + w(c,b)}{log(1 + P(c))} \tag{6}$$

In Equation (5), k_z represents the number of neighbors of country c, that is, the number of countries with which it engages in direct trade. In Equation (6), $P(c) = \sum_{i\epsilon\Gamma(c)} w(c,i)^{\alpha}$ and i represents a country that trades with country c.

(4) Resource Allocation (RA algorithm)

The premise of this method is similar to that of the AA method. The difference is that this method uses a common trading partner as a medium to connect two countries that do not have a direct trade relationship. The RA method is also divided into two types: a nonweighted algorithm and a weighted algorithm, which are illustrated by Equations (7) and (8).

$$S_{ab}^{RA} = \sum_{c\epsilon\Gamma(a)\cap\ \Gamma(b)} \frac{1}{k_c} \tag{7}$$

$$S_{ab}^{RA} = \sum_{z\epsilon\Gamma(a)\cap\ \Gamma(b)} \frac{w(a,c) + w(c,b)}{S(c)} \tag{8}$$

Step 2: Data set division.

The existing data are divided into dataset E. Ninety percent of the data are used as the training set, expressed by E^r, and 10% are used as the test set and expressed by E^t to verify the accuracy of the algorithm.

$$E = E^r + E^t \qquad E^r = 90\% \times E \tag{9}$$

Step 3: Identifying nonexistent links.

Potential links usually exist in nonexistent links, so we are more likely to predict future trade from nonexistent trade relations. In the trade network, the combination of all possible trade relations between all countries is represented by U, the number of countries with links is represented by Equation (10), and the number of countries without links is represented by Equation (11).

$$U = \frac{n \times (n-1)}{2} \tag{10}$$

$$E^I = U - E \tag{11}$$

Step 4: Using the four algorithms to compute, test, and sort the nonexistent link set.

To sort the nonexistent links, we need to use the four mainstream algorithms to classify the test set and training set, and get the score on the basis of the algorithm. The higher the score is, the more likely the link that does not exist will be translated into actual links in the future, which means that the countries with higher scores are more inclined to form trade cooperation in the future.

Step 5: Evaluating various methods and selecting the optimal method.

Selection of the optimal algorithm involves measurement with more accurate criteria. For link prediction algorithms, the AUC, ranking score, and accuracy level are frequently used evaluation criteria.

Compared with the latter two algorithms, which focus more on partial information, the AUC algorithm pays more attention to local information and can better measure the accuracy of link prediction. This study discusses the trade relationship in the whole nickel trade network, so the AUC is selected as the measurement index of the algorithm.

The AUC can be regarded as the probability of randomly selecting an edge in the test set, whose fractional value is greater than that obtained by randomly selecting an edge that does not exist. When conducting numerical estimation, the fractional value of randomly selecting an edge from the test set is compared to the fractional value of a randomly selected edge that does not exist. If the fractional value of an edge in the test set is higher than that of an edge that does not exist, one point is added. If two points are equal, 0.5 of a point is added. When independently comparing l times, l' denotes the number of times that the fractional value of edges in the test set is greater than that of nonexistent edges, and l'' denotes the number of times that the two-point values for comparison are equal.

$$AUC = \frac{l' + 0.5l''}{l} \tag{12}$$

In Equation (12), it is assumed that all of the fractional value are randomly formation, and then the $AUC \approx 0.5$. If the AUC value is higher than 0.5, the mothed has performed well because all of the scores are obtained randomly. When there are more parts greater than 0.5, the corresponding algorithm is more accurate.

2.2.3. International Nickel Ore Trade Analysis Process

Although link prediction method shows good effectiveness in trade forecasting, the trade development of nickel ore is affected by factors such as the international environment. To identify more realistic and valuable trade relations, using the existing transaction network topology structure of the link prediction model, a nickel ore trade analysis model with physical topology and trade characteristics is constructed for more accurate prediction. The model involves two steps:

Step 1: The validity of the model is verified and the practical significance of the model is tested.

Potential and actual trade relations between 2010 and 2019 are compared to further verify the effectiveness of the model. If the optimal algorithm predicts possible trade links in 2010 and the links are verified for the next few years, the algorithm is proven to be successful. If multiple trade links predicted by the algorithm are successfully verified for the next few years, showing that the method is effective for the nickel ore trade. Our purpose is to use this algorithm to find possible trade links in the future. We use the link prediction method to find possible trade cooperation in the future in the nickel ore trade for the past decade and make further evaluations by comparing actual links.

Step 2: Identifying the role of the country and exploring trade rules.

We explore trade rules between nonexistent and potential trade links by defining national roles. On the basis of the trade data for nickel ore, the countries involved in top ten potential links are selected and divided into net exporters and net importers. The division principle is as follows:

$$\begin{array}{c} D_t = E_t, E_{Xt} - I_{Mt} > 0 \\ D_t = I_t, E_{Xt} - I_{Mt} < 0 \end{array} \tag{13}$$

In Equation (13), t denotes the year, D_t denotes the role of a country in trade relations in year t, and if a country's import volume (I_{Mt}) is less than the export value (E_{Xt}) in year t, this country is regarded as a net exporter. If not, this country will be regarded as a net importer.

3. Results and Discussion

3.1. Data

To more accurately find the implicit trade relationship, we predict the nickel ore trade for each year. Four different algorithms are used to calculate for each year to obtain AUC scores. To reduce the impact of randomness on the prediction results, we calculate each network ten times. For this process, each time the network is randomly divided into a 10% test set and a 90% training set, the average AUC scores are obtained. The most accurate algorithm was found by comparing the AUC scores. The results are shown in Figure 3. In the figure, α denotes the type of nickel ore trade network. When α is 0, this indicates that the network type is a directed weighted network; that is, both the trade direction and trade volume are considered. When α is 1, this indicates that the network type is a directed unweighted network; that is, the trade volume is not considered. Through the comparison of AUC scores, we found that in all networks, the AUC scores of the PA algorithm were the highest at greater than 0.9 and close to 1. Therefore, the PA method is identified as the best method in our study. Based on the calculation results for this decade, the AUC score of the network without considering trade volume is higher in terms of predictions. Therefore, we use the PA algorithm for the directed and unauthorized network to predict potential trade relations.

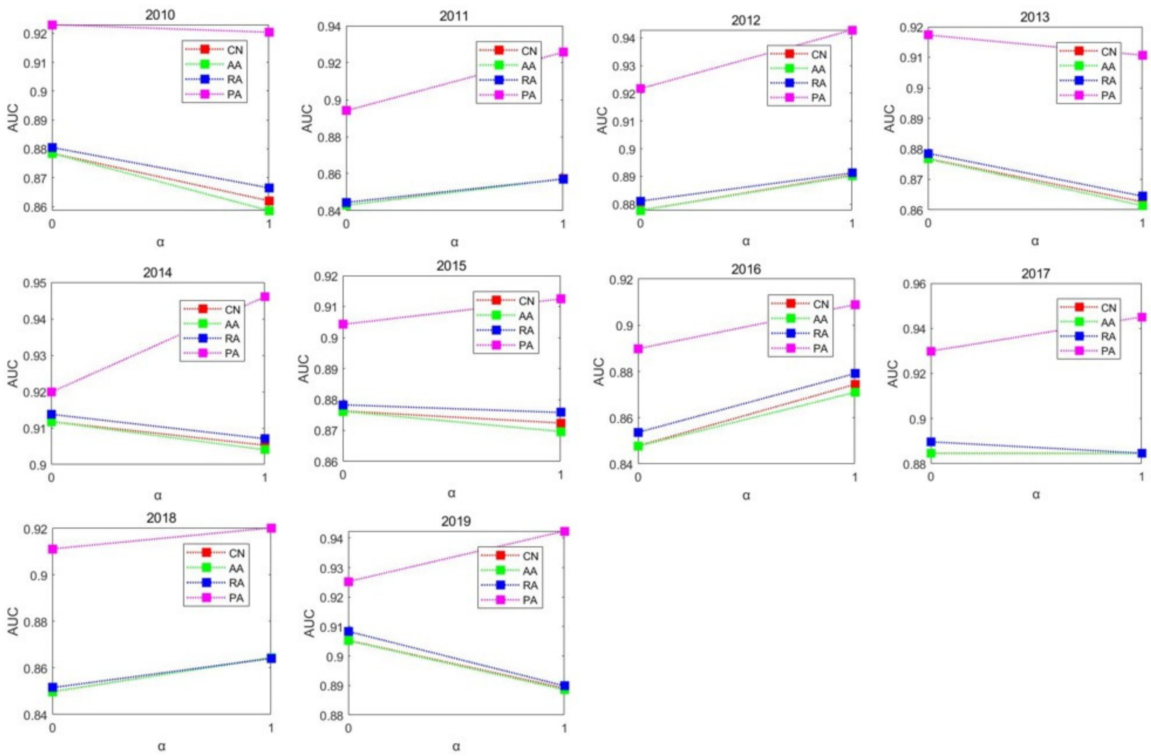

Figure 3. Evaluation of the four methods in 2010–2019 (dotted line indicates the change trend).

This arrangement also means that in the process of finding potential trade links, countries with large trading volumes and those with small trading volumes have the same level of importance. In addition, we know that a country with more partners has a greater probability of establishing nickel ore trade cooperation with other countries.

3.2. Validation of Algorithm Effectiveness

We show that the PA algorithm has a better prediction effect in this study and generates the highest score for the directed unweighted network. Therefore, we sorted the test set and nonexistent link relationships by PA values. Since a country with more partners has a greater probability of establishing trade cooperation with other countries, trade cooperation among the countries with the highest score values are more inclined to be established in the future. To explore the effectiveness of the algorithm and find the potential rules of the nickel ore trade, we selected nonexistent links from the top ten PA values of each year for 2010 to 2019 and observed whether these links actually established cooperation after prediction.

Taking 2015 as an example, Table 1 shows the top 15 trading countries with the highest score values, including nonexistent test links and potential links. The first column represents the PA value ranking, "Country A" and "Country B" represent trade exporters and importers, the fourth column shows the possible PA values for the connections between pairs of countries or regions, and the last column shows the types of links where T represents the link in the test set and P represents the link in the potential link. The test set shows that two pairs of trade relations have existed. The remaining links are potential links that do not exist. To further analyze whether these potential links will result in future trade, we selected the top ten potential links from the results of the PA algorithm for ten years.

Table 1. Top 15 potential trade relations in 2015.

No.	Country A	Country B	PA Value	Type of the Link
1	China	Germany	768	P
2	China	Japan	288	P
3	China	South Africa	288	P
4	China	United Kingdom	288	P
5	Germany	Rep. of Korea	288	P
6	China	India	256	T
7	China	Australia	256	P
8	China	Finland	224	T
9	China	Botswana	224	P
10	China	Spain	224	P
11	China	Brazil	224	P
12	Germany	South Africa	216	P
13	China	Czech Rep.	192	P
14	China	Italy	192	P
15	China	Switzerland	192	P

We sorted the top ten potential link country pairs for 2010 to 2019 and obtain 36 nonrepetitive country pairs because some potential trade relations have repeated over the decade. As shown in Figure 4 below, pairs of countries are listed as potential trade partners. The area shaded in light yellow indicates that there are no potential trade relationships among the top ten PA values. The orange-shaded section indicates that the two countries engaged in nickel ore trade in the same year.

We in turn obtained 36 pairs of trade links, and we can observe the links between actual and potential trade. In the same line, if at least one orange-shaded area appears after a light yellow-shaded area, the predicted trade relations predicted did occur after trade. Thus, the corresponding country pair are regarded as successful forecasts.

We take China and Canada listed in the first row of the figure as examples. For 2013, we projected potential trade relations between the two countries, followed by genuine trade cooperation between the two countries in 2014, making this a successful link prediction. When there is no orange-shaded area following a yellow-shaded area, an invalid prediction has been made. For example, on the sixth line of Figure 4 pertaining to China and Japan, we predicted that these countries would have trade relations in the future, but there has been no nickel ore trade between these countries in the past decade, denoting an invalid prediction.

Furthermore, we can further verify the effectiveness of the prediction algorithm by calculating the prediction success rate. The graph shows that 22 of 36 countries' trade relations are successfully predicted, and the number of successful predictions accounts for 61% of all potential links, which indicates that the PA method is effective at predicting potential cooperation in nickel ore trade.

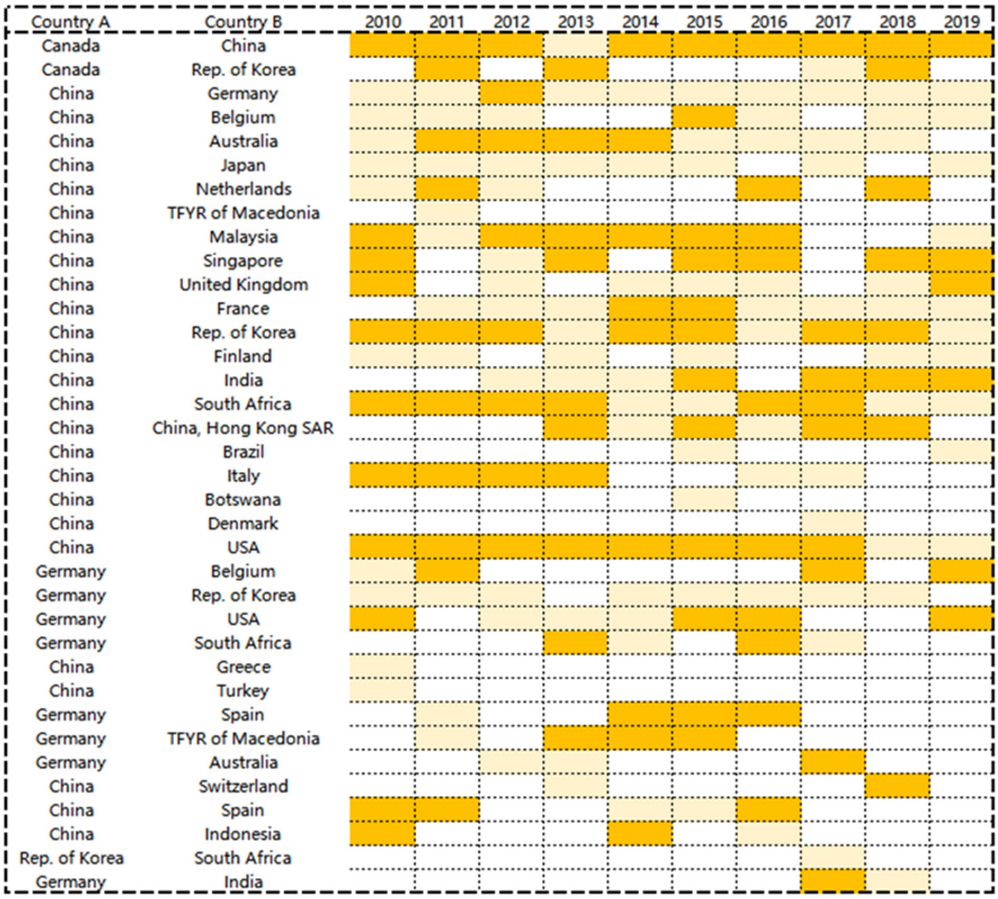

Figure 4. Comparison of actual trade relations and potential links from 2010 to 2019 (yellow-shaded represents potential links, orange-shaded represents actual trade relations).

3.3. Further Assessment of Potential Trade

A comparison of actual trade from 2010 to 2019 to potential links shows that although majority of potential trade relations were successfully forecasted, some potential links were not confirmed for the next few years. We further classify these countries with potential trade relations according to whether these potential connections have successfully established nickel ore trade relations. We divide these potential trade relations into three categories for further analysis.

The first category is for successfully predicted trade relations, including 22 trade countries.

As shown in Figure 5, nine of the countries started cooperation ties with each other in the second year following their first appearance among the top ten potential relations. The other successfully predicted countries also successfully established cooperation in the next five years after the first appearance of the top ten potential relations. Therefore, we can assume that if a group of countries appears among the first ten potential connections in one year even though the countries do not cooperate in the second year, trade relationships between these countries form five years after the forecast. We can therefore infer that a pair of countries that have emerged among the top 10 potential trade relations since 2015 but have not yet established cooperation are inclined to trade in the coming years. These country pairs include China and Brazil, China and the United States, Italy and China, China and Denmark, China and Indonesia, South Korea and South Africa, and Germany and India.

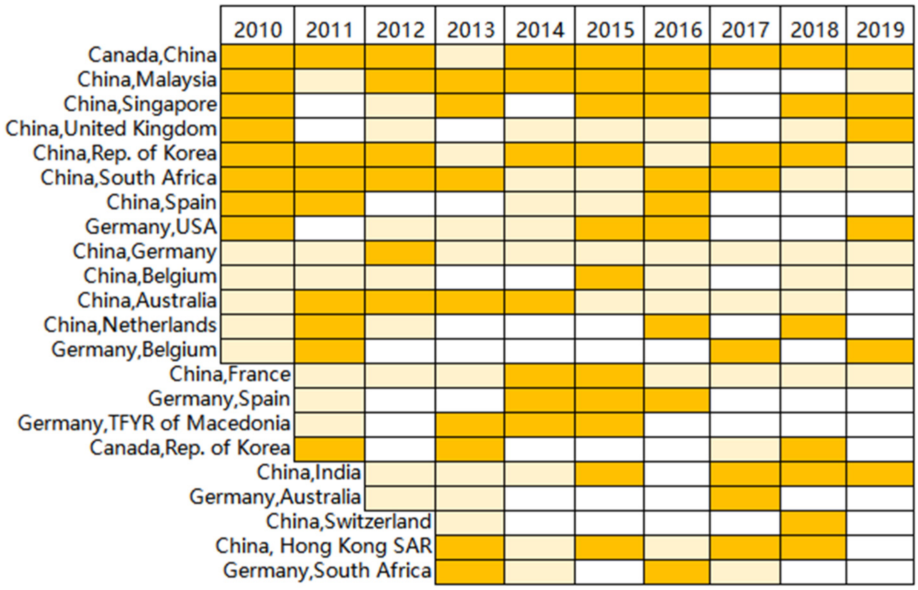

Figure 5. Countries that have been successfully forecasted (yellow-shaded represents potential links, orange-shaded represents actual trade relations).

The second type of trade relations refers to the top ten potential trade relations predicted in 2019, as we lack actual trade data for after 2019 and cannot know whether the connections shown in Table 2 can be proven effective. However, from the existing data, we believe that at least half of these potential trade relations will be confirmed in the next few years; that is, these countries will build cooperation.

Table 2. Top 10 Potential Links in 2019.

Number	Country A	Country B
1	China	Belgium
2	China	France
3	China	Germany
4	China	Finland
5	China	South Africa
6	China	Japan
7	China	Rep. of Korea
8	China	Brazil
9	China	USA
10	China	Malaysia

The third kind of trade relationship is found between countries among the top ten potential relations but not establishing nickel ore trade relations. In Figure 6, the yellow-shaded area represents that the country is among the top ten potential relations in the year denoted by the column, and the orange-shaded area represents that a country has trade relations in the year denoted by the column. There are 14 countries that have not yet established cooperative relations, and we thus further assess the reasons for their failure to establish cooperation in the next analysis.

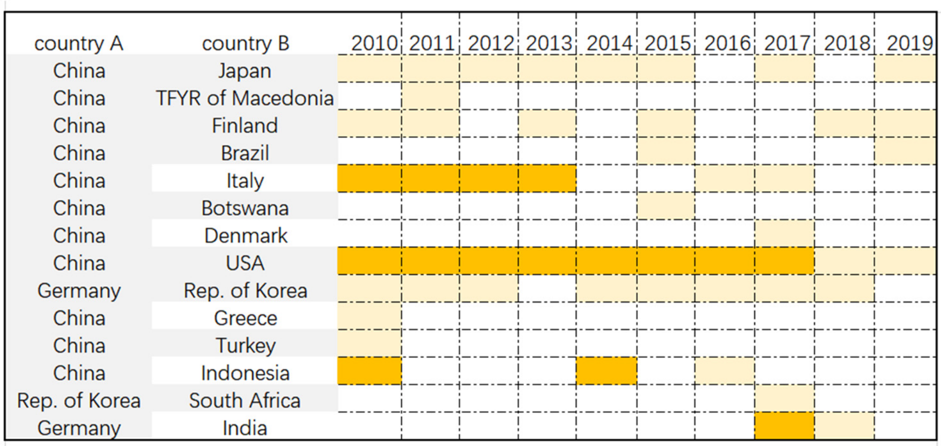

Figure 6. Pairs of countries that have not yet established trade cooperation (gray-shaded countries are net importing countries and unshaded are net exporting countries; yellow-shaded represents potential links, orange-shaded represents actual trade relations).

3.4. The Division of Trade Roles

Although the link prediction in view of the PA method has certain effectiveness, there are still 14 countries that have not established trade relations. We must make improvements based on the existing trade forecast results. Therefore, we divide the countries or regions participating in international nickel ore trade into different trade roles, including net importing countries of nickel ore and net exporting countries of nickel ore. Then we can generalize trade rules by observing the role of trade.

A country may have many nickel ore trading partners, but in cases of actual trade, we also need to consider the country's import and export volume to judge the country's role in the nickel ore trading network. Based on the downloaded trade data, we calculate countries' total trade imports and total exports for a given year to obtain the trade role of each country for the corresponding year. If a country's export volume is greater than its import volume within a year, it is defined as a net exporting country; otherwise, it is a net importing country. For example, in Table 2, the country shown with shading was net importing countries, while the country shown without shading was net exporting countries. In addition, the ultimate role of every country must be based on the trade situation over ten years. If the role of a country's trade imports and exports changes over ten years, we consider the import and export situation of recent years and then define the country type. We analyzed the imports and exports of countries emerging among the top ten potential relations over the past ten years. As shown in Table 3 below, we denote a net exporting country with "E" and list it in green. Net importing countries are indicated by "I" and shown in yellow, and "0" means equal import and export volume.

The above table shows that countries such as China, South Korea, and Japan are ultimately regarded as net importers, and countries such as Malaysia and Spain are regarded as net exporters. When a country's import and export roles change within ten years, we define the country's role according to actual conditions. For example, as shown on the last line of the table, Indonesia's trade volume in the 2017 and 2018 biennium was higher in imports than in exports but higher in other years. Since the volume of trade exports is higher than that of trade imports in most past years of the decade, we define this country as a trade exporter.

Table 3. Import and export roles of potential cooperating countries from 2010 to 2019 (gray-shaded countries represent net importing countries and unshaded represent net exporting countries; yellow-shaded countries represent net importing countries, green-shaded countries represent net exporting countries).

No.	Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Final Role
1	Canada	E	E	E	E	E	I	I	I	E	I	I
2	China	I	I	I	I	I	I	I	I	I	I	I
3	Germany	I	I	I	I	I	I	I	I	I	E	I
4	Rep.of Korea	I	I	I	I	I	I	I	I	I	I	I
5	Belgium	E	I	E	I	E	I	I	I	I	I	I
6	Australia	E	E	E	E	I	I	I	E	E	I	E
7	Japan	I	I	I	I	I	I	I	I	I	I	I
8	Netherlands	I	I	I	I	E	I	E	I	I	I	I
9	TFYR of Macedonia	I	I	I	I	I	I	I	I	I	I	I
10	Malaysia	E	E	E	E	E	E	E	E	I	E	E
11	Singapore	I	E	I	E	I	I	I	E	E	E	E
12	United Kingdom	E	I	E	E	E	I	I	E	I	I	I
13	France	I	I	I	I	I	E	E	I	E	E	E
14	Finland	E	I	I	E	I	I	I	I	I	I	I
15	India	E	I	I	I	I	I	I	I	I	E	E
16	South Africa	E	I	E	E	I	E	E	I	I	0	I
17	China, Hong Kong	E	E	I	I	I	I	I	I	I	E	E
18	Brazil	I	I	I	E	E	E	E	I	I	I	I
19	Italy	I	I	I	I	I	E	E	E	E	E	E
20	Botswana	E	I	I	I	I	I	I	E	E	I	I
21	Denmark	I	I	E	E	I	I	I	0	I	E	E
22	USA	E	E	E	E	E	E	I	E	E	I	I
23	Greece	I	I	I	I	I	I	I	E	E	E	E
24	Turkey	E	E	E	E	E	E	E	E	I	I	I
25	Spain	E	I	E	E	E	E	E	I	E	E	E
26	Switzerland	I	I	I	I	I	I	E	I	I	I	I
27	Indonesia	E	E	E	E	E	E	E	I	I	E	E

3.5. Exploring Link Rules for Potential Trade

From the PA values, successfully predicted trade relationships, unsuccessfully predicted links, and divided trade import and export roles, we summarize the following potential link rules. From these rules, we can find links that are more inclined to establish cooperation. The trade link rules are as follows:

(1) In the international nickel trade, countries that have established cooperation relations over a decade are tend to have a disposition to continue trade cooperation in the future. Among the 22 pairs of trading countries successfully identified, 11 groups of countries have experienced trade cooperation, indicating that countries participating in nickel ore trade have a disposition to cooperate with familiar partners. In Table 3, there are 14 pairs of countries that have never been successfully forecasted, and 10 have never experienced trade cooperation; that is, if there has been no trade cooperation between two countries, we believe that they are unlikely to cooperate.

(2) For potential trade links, trade in nickel ore is unlikely to occur between two net exporters. According to the PA score results obtained by calculation, there is no case in which two countries are net exporters among the top ten potential links of each year. Most net exporters are rich in nickel ore resources and are more inclined to trade with net importers of nickel ore.

(3) In terms of potential trade relations, a net importing country and a net exporting country have a disposition to have trade relations, such as China and Spain, and Germany and Spain. In addition, Figure 6 shows that net importer China and net exporter Denmark, and net importer China and importer and exporter Indonesia, though not establishing trade relations after potential links, used to maintain trade cooperation.

In addition, although China is a net importer among potential trading countries, the country accounts for 69% of potential links as an exporter. This is the case because in terms of actual trade, although China's exports are far lower than its imports, China has a large number of import and export partners. This result shows that countries with a large number of partners are more inclined to establish new trade links.

4. Conclusions

Nickel is not only an indispensable metal material for military and civil industries, but also an indispensable raw material for the development of new energy industry. Therefore, it is very important to ensure stability in the supply of nickel resources in a given country. In this paper, by identifying hidden relationships in the international trade network to assist governments formulate strategies for international nickel trade in advance and find possible trading partners in the future, this study uses new methods of link prediction to find trade relations that are not obvious. According to the research results, the following conclusions and suggestions are presented.

(1) In the top ten potential trade contacts, countries involved in the nickel ore trade are more likely to reestablish cooperation with countries they have previously traded with. The role of a country in international nickel ore also affects the establishment of trade cooperation. For instance, if the roles of two countries are different, they are more inclined to establish trade links, while for two net exporters, there is little possibility of nickel trade occurring between them. In addition, countries with a large number of existing cooperative partners prefer to establish new cooperation. Therefore, in the known potential nickel ore trade relations, we can also first identify countries that are more likely to establish trade cooperation based on the number of existing trading partners.

(2) Figure 7 lists potential trade relations for 2015 to 2019 that were not predicted to succeed. These country pairs are inclined to have cooperation within next few years. Our purpose is to provide references for governments to find new trading partners and not to predict the specific time at which trade will occur. Under the trade rules shown in the previous sections, we predict that China and India, China and Italy, China and Denmark, and China and the United States are most inclined to establish cooperation within few years. On the one hand, for each of these pairs, one country is a net trade importer, and the other is a net trade exporter. On the other hand, more than half of global nickel consumption occurs in China. China has numerous trading partners and is more inclined to cooperate with other countries. Among these countries, although the United States and China are net importers of trade, they have maintained trade cooperation in the past and are more inclined to cooperate again. Since Indonesia is a significant nickel exporter globally, the likelihood of this country importing nickel ore from other countries is very low. Therefore, we believe that China will not export nickel ore to Indonesia in the next few years and that trade between the countries will not occur. In addition, under the influence of Indonesia's export ban on nickel-aluminum ore, one of China's main sources of nickel ore has been removed, and China will thus be more inclined to seek diversification in trading partners and to cooperate with other countries.

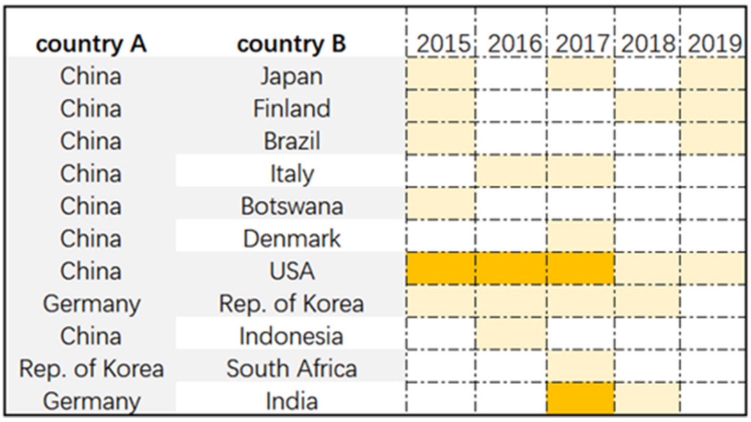

Figure 7. Potential links of nickel mines (gray-shaded represents net importing countries, yellow-shaded represents potential links, and orange-shaded represents actual trade relations).

(3) This article mainly has two aspects of practical significance. First, when the nickel ore trading environment changes, such as through demand for diverse trading partners or the breakdown of existing trading relationships, governments of various countries can quickly find new cooperative partners according to the predicted potential links, which can prevent the supply problems of military, new energy and other related industries caused by demand interruption and ensure the orderly development of related industries. In addition, a country that trades in nickel ore can establish more feasible trade relations in advance from the research presented in this article to secure more trading partners. In this way, such a country can guarantee the diversity of its trading partners and reduce the risks presented by certain countries. The risks brought about by the termination of trade can quickly establish new trade relations when other risks protect the security of a country's nickel ore supplies.

This article studies the international nickel ore trade relationship from the perspective of link forecasting and discusses the trade rules of international nickel ore trade. However, the establishment of international nickel ore trade relations may be affected by some causes, such as the trade volumes and nickel ore foreign trade policies of two countries. Therefore, in the future, we will consider more influencing factors to further analyze international trade relations of nickel ore and conduct more in-depth research.

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