

Evolution of global strategic mineral resources trade pattern: a case study of copper

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Abstract. As an important industrial raw material, copper is not only widely used in electrical, light industry, machinery manufacturing, transportation and other fields, but also plays an irreplaceable role in construction, national defense and information and communication fields. In particular, the proportion of electrical and light industry in copper consumption is increasing. This paper combs the copper industry chain, introduces the construction of copper trade network, and analyzes the copper trade pattern and the status of major economies in detail.

Keywords: Mineral resources, Trade patterns, Copper mines.

1. Comb the copper industry chain

As an important industrial raw material, copper is not only widely used in electrical, light industry, machinery manufacturing, transportation and other fields, but also plays an irreplaceable role in construction, national defense and information and communication fields. In particular, the proportion of electrical and light industry in copper consumption is increasing. According to the mineral statistics report of the US Geological Survey (USGS), the global copper deposits are mainly distributed in Zambia, Congo, South Africa, Chile, Peru, Argentina, the United States, Canada, Australia, Indonesia, the Philippines, Mongolia, KazakHStan, Poland, Russia and other countries. China's mineral resources report shows that although China's copper resources are relatively rich, there is a lack of high-grade rich ore that can be easily separated. The average geological grade of China's copper deposits is only 0.87%, and the average grade of porphyry copper deposits is only about 0.5%, which is far lower than that of Chile and other major copper producing countries. In recent years, driven by the strong development of China's copper industry, copper consumption has been rising. At present, China has become the world's largest copper consumer. The gap between supply and demand of copper resources is growing. In the case of insufficient domestic supply, it can only be made up by import.

China mainly imports copper concentrates from countries rich in copper resources such as Chile, Mongolia, Australia, Peru, Canada, Mexico and KazakHStan. The copper concentrates imported from these countries account for 60% ~ 80% of China's total copper concentrate imports. As a very important non-ferrous metal material, copper has a wide range of application value, and copper trade plays a very significant role in Global trade. However, from the perspective of the whole industrial chain, there are differences in the attributes and uses of copper products in the upper, middle and lower reaches, and there are also certain differences in the international trade pattern. This paper analyzes the international trade pattern and relevant indicators of related copper products according to different links in the upper, middle and lower reaches.

The copper industry chain can be divided into upstream, midstream and downstream. The upstream is mainly copper ore mined from mines. The copper ore is processed into copper concentrate with a copper content of more than 13% by mining and dressing. The copper concentrate is roughened and processed into cathode copper in the middle reaches, and then further processed into copper foil, copper plate, copper wire, copper rod and other products. The downstream is applied to electronics, household appliances, transportation, construction and other industries. The finally formed waste copper can be further recycled to the middle reaches for reprocessing.

As there are many copper products and application industries in the upper, middle and lower reaches of the copper industry chain, combined with China's mineral resources report and the United

Nations commodity database, the analysis of the development status of the copper industry chain focuses on the copper ore and copper concentrate in the upper reaches and refined copper in the middle reaches. There are many downstream demand side industries, and as a large infrastructure country, China's copper consumption accounts for more than 50% of the global copper consumption. Therefore, the research on the downstream development status of the copper industry chain in this paper is mainly based on the application industries and waste copper produced in the downstream of the copper industry chain in China.

2. Trade network model

A trade network is a graph composed of some nodes and edges connecting nodes. According to whether the edges between nodes have directions, the network is divided into directed and undirected networks; According to whether the edges in the network are weighted, the network is divided into weighted and non weighted networks; If both the direction and the weight of the edges are considered, the networks can be divided into four types: directed weighted networks, directed weighted networks, undirected weighted networks and undirected weighted networks. In the undirected weight less network, the connecting edges between nodes have no directionality. The connecting edges only represent the relationship between nodes. The edges do not have weight, that is, the thickness of the edges is the same. In the undirected weighted network, the connecting edges between nodes have no directionality, but the edges are weighted. The thickness of the line represents the weight of the edge. The thicker the line, the greater the weight of this connecting edge. In directed weighted networks, the edges between nodes have directionality, but the edges do not have weight. In a directed weighted network, the edges between nodes have both directionality and weight. The connection between nodes shows the transitivity between nodes, and the thickness of the line shows the strength of this relationship.

2.1 Measurement of trade network centrality

Centrality is the key index to analyze social network. Centrality generally indicates the concentration or centralization of the whole network, and also shows the status of specific nodes in the network. The centrality calculation of the network depends on the centrality of each node in the network.

The centrality index corresponding to this definition is the four quantitative tools commonly used in social network analysis: degree centrality, intermediate centrality, proximity centrality and feature vector centrality. These four quantitative tools describe the characteristics of network centrality from different perspectives. The specific measurement methods of degree centrality and intermediary centrality are as follows:

a. Degree centrality

Degree centrality is an important indicator of the centrality of complex networks, and is also the most intuitive and easy to observe. For example, the more the number of adjacent nodes of a node, the higher its degree centrality. It focuses on its own "influence" rather than "control ability". In addition, network scale is also an important factor. If the network scale is larger, the value of degree centrality may be larger.

$$\text{Degree}_i = \frac{\sum_j X_{ji}}{g-1}$$

Where, i is a node in the network, and j is other nodes except for the current year; If it is a network connection, and two countries are connected through at least one country, it is 1; otherwise, it is 0. Because the number of network nodes is different in different years, in order to ensure comparability, this paper uses the maximum possible number of connections to eliminate the scale difference.

b. Intermediary centrality

As an important indicator to measure nodes, intermediary centrality refers to the proportion of the number of shortest paths passing through a node to the number of all shortest paths. It is used to measure the ability of an economy to act as a medium, and to indicate the degree of control of a node

over the flow between other nodes. The greater the intermediary centrality, the stronger the economy's control over trade.

$$BC(i) = \sum_{x \neq i \neq y} \frac{\sigma_{xy}(i)}{\sigma_{xy}}$$

Where, σ_{xy} is the total number of shortest paths between node x and y , $\frac{\sigma_{xy}(i)}{\sigma_{xy}}$ is how many of these shortest paths pass through nodes.

2.2 Measurement of trade network structure hole

Network members at the location of structural holes can get rich heterogeneity information, which is a good indicator of network location. In this paper, the calculation formula of the limit is:

$$C_{ij} = \left(p_{ij} + \sum_q p_{iq} p_{jq} \right)^2$$

Then calculate the structural hole index by the difference between 1 and the limit C_{ij} :

$$CI_i = 1 - C_{ij}$$

i, j have the same definition as before, q represents another country ($q \neq i, j$), p_{ij} represents the strength of the direct relationship between node i and node j , $\sum_q p_{iq} p_{jq}$ is the sum of the indirect relationship strength in all the paths from i to j , and measures the indirect relationship strength between node i and node j . The larger CI_i , the more abundant the positions of the holes representing the trade network structure.

$$\text{Constraint}(n_i) = \sum_{n_j} \left(p_{n_i n_j} + \sum_{n_q: q \neq i, j} p_{n_i n_q} p_{n_q n_j} \right)^2$$

Where $p_{n_i n_j}$ represents the proportion of the external information resources brought by the connection between countries n_j and n_i to all the external information resources obtained by country n_i . Since the weight of the connection in the social network is not considered in this paper, this proportion is the reciprocal of the centrality of the country's n_i degrees. Other symbols have the same meanings. Since the maximum value of structural hole constraint is 1, the difference between 1 and structural hole constraint is often used to measure the abundance of structural holes owned by individuals in social networks. Therefore, this paper uses $\text{Structural_Holes}(n_i) = 1 - \text{Constraint}(n_i)$ to quantify the abundance of structural holes in the mineral trade network of various countries.

2.3 Measurement of trade network aggregation

The clustering coefficient indicates the degree of clustering among nodes in a complex network. Specifically, it is the ratio of the actual number of edges between adjacent nodes to the maximum number of possible edges. The index reflects the degree of connection between adjacent nodes of a node. The larger the clustering coefficient of a node, the higher the degree of connection between adjacent nodes. In the weighted directed network, the weighted clustering coefficient comprehensively considers the clustering characteristics of the weighted network structure and the weights of nodes and adjacent nodes. In a weighted directed network, the clustering coefficient of nodes is:

$$\text{Clustering_Coefficient}(n_i) = \frac{N}{C_K^2} = \frac{2N}{K(K-1)}$$

The clustering coefficient of the network is the average of the clustering coefficients of all nodes in the network, which reflects the network structure of the community. In this paper, the larger the clustering coefficient of a node (economy), the stronger the connectivity of the node (economy) in the network, and the greater the connectivity function of the surrounding nodes, which reflects the degree of aggregation of a single node (economy), that is, the degree of close relationship with trade partners.

Therefore, a typical network structure is composed of many nodes and connected edges between nodes. Among them, nodes are used to represent different individuals in the real system, while edges are used to represent the relationship between individuals. It is often that two nodes with a certain relationship are connected to one edge, while on the contrary, they are not connected to one edge. Two nodes connected by edges are regarded as adjacent in the network. In this paper, each copper trading country (region) in each year from 1994 to 2020 is a node, and the direction of trade is import, which is regarded as point in degree, whereas the direction of export is regarded as point out degree. The import trade volume between countries represents the weight of the side.

A network is a collection of nodes and some relationships between nodes. As far as the international trade network is concerned, it is a network composed of different countries and their relationships. In the selection of samples, through the world's major economic and trade organizations and regional trade agreements, combined with the availability of relevant data and other factors, the author selected relevant countries (regions). The selected time span is from 1994 to 2020. The international trade network composed of relevant countries (regions) is studied. Different countries have different development stages and positions in the international trade network, and the same country has different positions in the international trade network in different years.

It should be noted that the international trade network in this paper is a whole network, that is, a network composed of all members of a certain group and their relationships. Therefore, theoretically speaking, the international trade network should cover all countries participating in international trade, thus forming several overall networks. However, some countries (regions) with a low degree of participation in international trade have poor data availability, and it is not significant to study them. Excluding a small number of unimportant countries (regions) from the study will not have a great impact on the results, so some countries (regions) are excluded.

3. Analysis of copper trade pattern

Copper trade plays a significant role in Global trade and has a wide range of application value. From the perspective of the whole industrial chain, there are differences in the attributes and uses of copper products in the upper, middle and lower reaches, and there are also certain differences in the international trade pattern. This paper analyzes the international trade pattern and relevant indicators of related copper products according to different upstream, middle and lower reaches.

3.1 Upstream trade pattern of copper

The upstream products of copper are mainly HS2603 (copper ore and concentrate) and HS7404 (waste copper). Considering the availability of data and the uniformity of statistical caliber, this part of the study takes the copper trade volume of HS2603 and HS7404 products as the research object. The global trade network of copper upstream products in 2020 is shown in Figure 1.

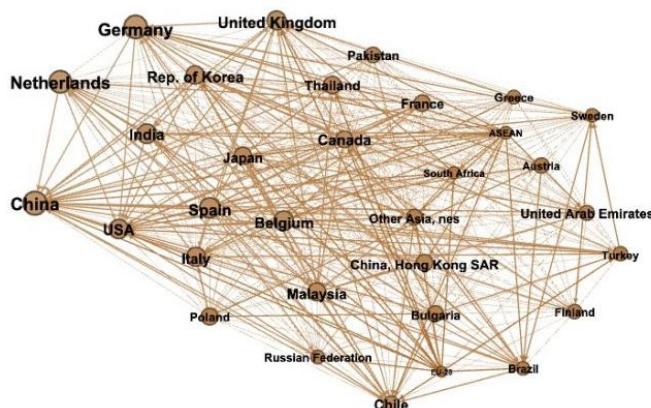


Figure 1. Copper upstream product trade network in 2020
Source: United Nations commodity trade statistics database

3.1.1 Trade overview

From 1994 to 2020, there were a large number of economies participating in copper upstream products trade in the world. Especially after 2005, the number of economies participating in copper upstream products in the world was stable, basically above 200, indicating that many countries (regions) in the world are involved in copper related trade. From 1994 to 2020, the number of global copper upstream products trade was frequent, basically showing a fluctuating growth trend. In 1994, the number of economies participating in trade was 188, with 1031 transactions, while in 2020, the number of economies participating in trade was 204, with 2657 transactions. The trade scope and activity increased significantly.

Specifically, as shown in table 1, in 2020, the number of China's import trade partners ranked first, the United States ranked second, China's import trade volume ranked first, and Japan's import trade volume ranked second. The number of export partners of the European Union ranks first, India ranks second, Chile ranks first and Peru ranks second. The countries ranked in the degree and intensity of upstream products are relatively concentrated, and the United States and European countries are the main ones except China.

Table 1. Ranking of trade degree and intensity of copper upstream products in 2020

Ranking	Input	Value	Output	Value	Degree	Input strength	Value	Output strength	Value	Weighting degree
1	China	64	European union	118	China	China	2.27E+10	Chile	1.31E+10	China
2	USA	63	India	113	Germany	Japan	5.41E+09	Peru	7.92E+09	Chile
3	Germany	55	China	102	India	European union	4.46E+09	Congo	2.46E+09	Peru
4	Britain	46	Germany	102	Netherlands	The republic of korea	2.34E+09	USA	2.14E+09	Japan
5	France	43	The republic of korea	101	The republic of korea	Zambia	2.06E+09	Mexico	1.97E+09	European union
6	Netherlands	40	Belgium	93	Belgium	Germany	1.79E+09	Brazil	1.86E+09	Congo
7	Italy	40	Netherlands	91	USA	Spain	1.38E+09	Australia	1.81E+09	The republic of korea
8	Chile	37	ASEAN	91	European union	Bulgaria	1.06E+09	Canada	1.80E+09	USA
9	Brazil	35	Malaysia	82	Spain	India	7.73E+08	Mongolia	1.30E+09	Germany

Data source: USGS (United States Geological Survey)

In addition, the global trade volume of copper upstream products increased steadily from 1994 to 2004, and then accelerated. Before and after the economic crisis in 2008, the global economy was impacted, and the trade volume of copper upstream products showed a fluctuating trend, and reached a peak in 2018, which has always maintained a large volume.

It shows that between 1994 and 2020, the overall network density of upstream products showed a cyclical fluctuation trend, but generally speaking, it still maintained a certain growth. Specifically, it can be divided into 1994~2004, 2005~2017 and 2018~2020. These cyclical fluctuations are also closely related to the cyclical trend of mineral resources trade.

3.1.2 Analysis of Global trade pattern and status of major economies

In the weighted directed copper trade network, the nodes in the network represent the economies participating in the trade, the edges of the network represent the trade relations, the weights of the edges represent the trade volume, and the weighted input intensity value and the output intensity value represent the total import trade volume and the total export trade volume of an economy respectively. In 2020, the top ten economies in terms of total import and export volume of global copper upstream products are China, Chile, Peru, Japan, the European Union, Congo, South Korea, the United States, Germany and Brazil, which are highly representative in the global copper upstream market. During the period from 1994 to 2004, China's trade volume of copper upstream products was not high, and

the main economies ranked high were France, the United States, Japan, Germany and other developed countries; After 2005, the trade volume of China's copper upstream products increased rapidly, especially the export volume ranked first in the world continuously, and the import volume also increased further.

From 1994 to 1999, the central value of the degree of the United States has always ranked first. For a long time, the economy has a large number of trade partners and a large trade scale in international trade. The degree centrality of China at this stage is close to that of Japan and fluctuates. Since 2000, China's degree center value has risen significantly, far surpassing other countries and ranking second only to the United States. This is closely related to China's accession to the world trade organization, international influence and frequent trade exchanges. Before and after the economic crisis in 2008, the degree centrality of China, the United States and South Korea all showed a downward trend, and China was the most obvious, showing a precipitous decline. After 2010, China's degree centrality continued to rise, and in the following 10 years, it far surpassed the United States and ranked first.

China has a strong influence in the upstream market for a long time. Although the export volume of China's upstream products is not the first in the world, it has long occupied the first place in the import volume. In this process, it has a strong position in the global upstream market through the long-standing good trade relations with Chile, Peru and other resource-based countries. In addition, traditional buyer market economies such as EU and Japan also maintain strong influence, which indicates that the indirect influence of "buyer role" in the upstream market cannot be ignored.

In the transit capacity, the United States ranked first in the world for a long time from 1994 to 2008, and China's transit control capacity continued to rise. From 2009 to 2020, China's ranking in this index rose to the first in the world. In 2012 and 2017, the intermediary centers of the United States and China were on the same level, and both had very strong transit capacity. It is worth noting that South Korea and Japan also occupy a high position in this indicator, especially after 2000, which is closely related to their developed shipping industry and the status of Global trade hub. At the same time, Chile, Peru and Congo, with their superior coastal location and abundant resources, play an important role in the transit of upstream products.

In terms of radiation capacity, the United States occupied the first place for a long time from 1994 to 2008. After 2009, China's influence and radiation on upstream products increased rapidly and gradually surpassed the United States. This may be related to China's accession to the WTO and the implementation of reform and opening up to further enhance its trade influence and improve the level of opening up. From 1994 to 2020, the overall performance of the degree of aggregation in the United States was almost flat and had a slight upward trend. After 2008, it decreased slightly, possibly due to the impact of the economic crisis. The clustering coefficient of China was higher than that of the United States from 1997 to 2001, and then showed a similar trend to that of the United States. In general, the degree of aggregation of Japan is higher than that of the United States. After the 21st century, Japan has maintained the middle level in this indicator. Congo, Peru and Chile, which are known as "resource-based" countries, have a fluctuating degree of convergence, but their status is stable and they have maintained the upstream level for a long time. In 1994, the clustering coefficient of South Korea was second only to that of Congo, followed by a precipitous decline, and remained stable from 1995 to 2020.

3.2 Midstream trade pattern of copper products

Copper midstream products are mainly used for smelting, including HS7401 (copper matte / matte), HS7402 (crude copper / anode copper), HS7403 (electrolytic copper / refined copper) and HS7405 (copper based master alloy). The trade volume of the four products is taken as the research object in this part. The global trade network pattern of copper midstream products is shown in Figure 2.

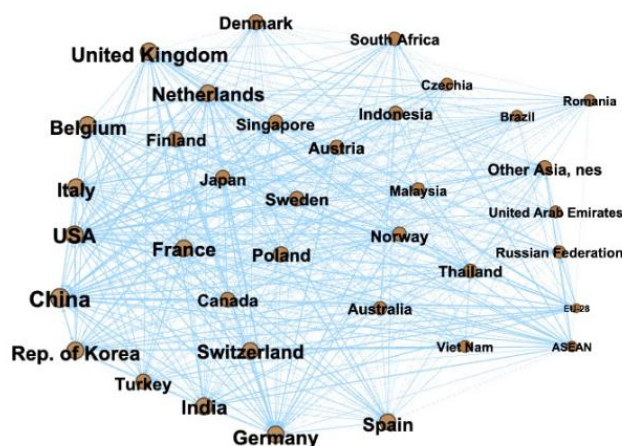


Figure 2. Trade network of copper midstream products in 2020

Source: United Nations commodity trade statistics database

3.2.1 Trade overview

In general, 2004 is the watershed from 1994 to 2020. The first stage was from 1994 to 2004. The overall network density level of copper midstream product trade showed a fluctuating and decreasing trend. The overall network density value in 1994 was 0.059 and that in 2004 was 0.049, indicating that the scale of global copper midstream product trade and the relationship between trading countries showed a downward trend in this stage. However, before 1998, the density level was high, especially 0.063 in 1995. In 1994, 133 countries participated in the copper midstream product trade and 1040 times of trade. In 1998, there were 174 Copper Exporting and importing countries in the world, and 1485 trade between different countries occurred. The trade volume increased slightly compared with that before, and the global copper trade network became closer. It is worth noting that at the time node of 2004, the global copper trade network density in 2004 was 0.049, the lowest level from 1994 to 2020. In 2003, the SARS epidemic situation in China was severe, but its impact on the global mineral resources trade was not great. Taking iron ore as an example, the SARS epidemic had little impact on the direct demand for iron ore, and the output and demand of crude steel showed an upward trend. The reason for the sustained decline is more likely to be related to the global economic downturn.

The second stage is from 2005 to 2020. On the whole, the overall network density in this stage shows an obvious growth trend, that is, the trade scale of copper midstream products and the relationship between trading countries show an upward trend. In 2016, the trade network density of global copper products in the middle reaches reached a small peak of 0.074, with a large decrease in 2018, and the overall network density was 0.069. At the same time, the trade economies and trade times in 2018~2020 decreased significantly compared with those in previous years, which may have been impacted by the global epidemic and affected the occurrence of trade. However, it has shown a rising trend since 2019, reflecting that the global COVID-19 epidemic has eased, The trade volume increased slightly.

Affected by the financial crisis in 2008, the close relationship of the global copper market was significantly reduced, and the number of participating economies and trade times remained unchanged at about 185 and 2200 respectively. However, the trade volume of copper midstream products decreased significantly in 2009. After the global economic recovery in 2008, copper was widely used in emerging strategic industries, and the scale and connection of copper trade showed an upward trend driven by the new industrial development direction.

Specifically, as shown in table 2, in 2020, China, Italy and the United States ranked among the top three in terms of entry value. China, the European Union and the United States rank among the top three in terms of the corresponding input intensity. In terms of output, China, the European Union

and ASEAN rank the top three. In terms of output intensity, Chile, Congo and Japan rank the top three. It is worth noting that China is the largest importer of midstream products, which further confirms the large scale of copper smelting products in China for a long time.

Table 2. Ranking of trade degree and intensity of copper midstream products in 2020

Ranking	Input	Value	Output	Value	Degree	Input strength	Value	Output strength	Value
1	China	93	China	92	China	185	Chile	China	China
2	Italy	85	European union	60	Italy	138	Congo	European union	Chile
3	USA	83	ASEAN	56	Germany	131	Japan	USA	Congo
4	Germany	79	Italy	53	USA	126	Russia	Germany	Russia
5	Britain	71	Netherlands	53	France	117	Zambia	ASEAN	Japan
6	France	69	Germany	52	Netherlands	117	Congo	Italy	Germany
7	Spain	67	France	48	Britain	107	Kazakhstan	Other Asian countries	Zambia
8	Netherlands	64	Thailand	48	India	105	Australia	Arab	European union
9	India	60	Turkiye	47	Spain	104	The republic of korea	Turkiye	USA
10	Bulgaria	55	India	45	Turkiye	101	China	Thailand	The republic of korea

Data source: USGS (USA Geological Survey Bureau)

3.2.2 Analysis of Global trade pattern and status of major economies

This part focuses on the influence of 9 countries including China, Congo, Japan, Zambia, South Korea, Chile, Russia, Germany and the United States. The total copper trade volume of the above countries accounts for the vast majority of the world and is fully representative.

Generally speaking, during the period from 1994 to 2020, China's influence showed a significant upward trend in fluctuations, especially after 2008, it surpassed the United States and was far ahead. In 2020, China has the largest import and export trade partners and also the largest importer, ranking the first in import and export volume, which indicates that China has gradually diversified the trade objects of smelting products in the middle reaches and has an increasingly important and core trade position. The intermediary centrality of the United States fluctuated greatly from 1994 to 2001 and gradually declined from 2002 to 2020. The trend of other countries is stable, maintaining between 0 and 0.02, and the development situation is relatively stable. In fact, both China and the United States attach great importance to their role in the global copper market. China has long played an important "bridge role" in the midstream product market, that is, China has the largest copper production and smelting capacity in the world. At present, most countries and regions in the world must transport copper raw ore to China for further export after separation and smelting in China. Therefore, China is in a strong position in the intermediate centrality index, that is, resource control ability. At the same time, as an important importer of smelting products in the world, the United States also maintains a strong position in the global market and transit market. However, China has shown sustained growth in recent years, indicating that China's intermediate role in the middle reaches of copper products is more prominent and shows a strengthening trend. Among the cluster coefficient indicators, it is worth noting that Congo is the second largest exporter and a country with large-scale production and smelting capacity. As an indispensable part of the global midstream copper product trade, Congo's regional influence and radiation capacity are constantly increasing.

Among the intermediary centrality indicators, the stronger economies are China, the United States and Germany. On the whole, the intermediary centrality of other countries is relatively stable, between 0 and 0.02. Before 2008, the intermediary centrality of Germany and the United States fluctuated and then gradually declined. From 1994 to 2020, China's intermediary centrality increased significantly, from 0.03 in 1994 to 0.18 in 2020. Among them, the periods of rapid growth are 2002~2004 and 2018~2020, indicating that the transformation capacity is also rapidly improved with

trade exchanges. After 2004, China's transit capacity in the copper midstream product trade market was very prominent, and the intermediary centrality soared, playing a core role in trade exchanges.

In the cluster coefficient index, Congo, Zambia, Chile and Russia rank in the top in 2020, which indicates that Congo, Zambia, Chile and Russia have a high degree of aggregation in the region and their trade partners are closely linked. Among them, the aggregation coefficient of South Korea and China developed in an "L" shape. Around 2004 was the turning point. The aggregation coefficient of the United States remained at about 0.1~0.2 from 1994 to 2020. The development was relatively slow, and the degree of close ties between trade partners did not change much. In general, Congo plays a core role in the trade of copper downstream products, and its trade partners are closely linked. However, in the past 15 years, China, the United States and South Korea have not ranked prominently in this index, indicating that their trade partners have a low degree of aggregation, the trade relations within the community are not intensive, and the degree of dependence on relevant trade partners is small.

3.3 Trade pattern of copper downstream products

Copper downstream products are mainly used for processing and play an indispensable and important role in daily production and life, mainly including HS7406 (powder), HS7407 (bar), HS7408 (wire), HS7409 (plate), HS7410 (foil) and HS7411 (pipe). Therefore, the above products are taken as the research objects of copper downstream products in this part. The global trade network of copper downstream products is shown in Figure 3.

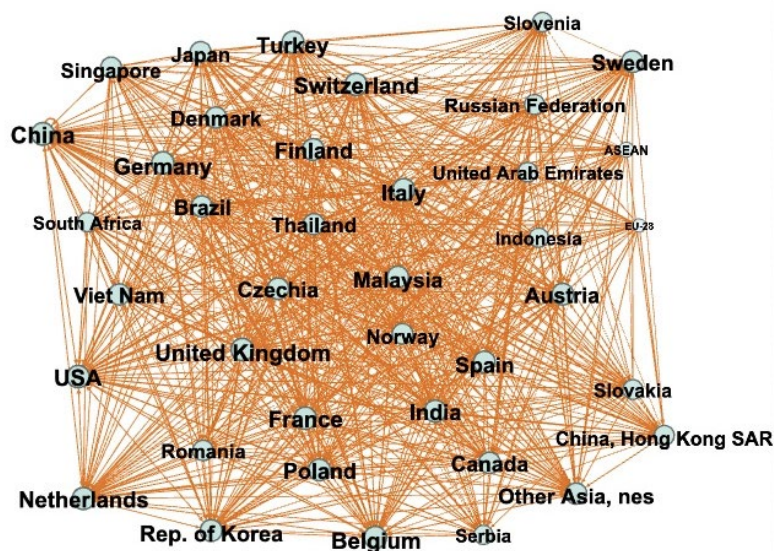


Figure 3. Trade network of copper downstream products in 2020

Source: United Nations commodity trade statistics database

3.3.1 Trade overview

The global participation in the trade of copper downstream products has developed in a small inverted "U" shape, basically maintained between 150 and 200, and showed differentiation around 2013. The number of economies participating in the trade has decreased. However, the number of trade among economies gradually increased from 1994 to 2016, and decreased from 2017 to 2020. The analysis shows that the global epidemic may have affected the trade between countries. The global trade volume of downstream products was basically stable from 1994 to 2003. In 2008, after the global trade volume reached its peak, it showed a "U" shaped growth. Overall, the scale of trade has increased significantly.

The degree of Global trade prosperity is cyclical. The overall network density shows an upward trend, indicating that the degree of Global trade closeness and prosperity are improving during this period. In this process, China, the United States, France, Germany, Spain and other countries are the

main importers of copper downstream products, with the largest number of trading partners, of which Germany, China and South Korea rank among the top three. In the export market, the European Union, China, the Netherlands, the Arab States, France and other countries occupy a high position, and the number of trade partners is the largest. In particular, China, ASEAN and the United States have long been among the top three in export trade volume in recent years.

Specifically, as shown in table 3, China ranks first in the ranking of entry in 2020, and ranks second in the corresponding ranking of entry intensity, indicating that the number of China's import trading partners and trade volume are among the top in 2020. In terms of export volume and export intensity, the EU has 74 export trading partners, ranking first in terms of export volume. Germany has the largest export volume and occupies the first position in terms of export intensity. China ranks the second in terms of export degree and export intensity. Generally speaking, the number of import trade countries of China's downstream copper products is nearly twice that of export trade countries, and the import trade volume is also higher than the export trade volume, which reflects the great demand for copper downstream products and fully reflects the importance and necessity of Global trade.

Table 3. Ranking of degree and strength of copper downstream products in 2020

Ranking	Input	Value	Output	Value	Degree	Input strength	Value	Output strength	Value
1	China	134	European union	74	Germany	8.72E+08	China	6.09E+08	China
2	USA	121	China	69	China	6.62E+08	ASEAN	4.66E+08	Germany
3	France	113	Netherlands	68	The republic of korea	3.91E+08	USA	3.90E+08	Italy
4	Germany	113	Arab	67	Other Asian countries	3.60E+08	Italy	3.15E+08	The republic of korea
5	Spain	111	France	65	Japan	3.26E+08	Germany	2.32E+08	USA
6	Italy	110	ASEAN	65	Italy	2.38E+08	European union	1.92E+08	Other Asian countries
7	India	110	Italy	64	Arab	2.32E+08	India	1.88E+08	Japan
8	Britain	104	Germany	63	Malaysia	2.25E+08	France	1.77E+08	Thailand
9	Turkiye	100	Turkiye	62	Thailand	1.81E+08	Thailand	1.74E+08	France
10	The republic of korea	96	Canada	60	Turkiye	1.80E+08	Saudi Arabia	1.57E+08	Southeast Asia

Data source: USGS (United States Geological Survey)

3.3.2 Analysis of Global trade pattern and status of major economies

This part mainly compares the relevant indicators of 8 countries including China, Italy, the United States, Japan, France, Germany, South Korea and Thailand, and conducts research and analysis. It is found that the trade volume of the above countries in 2020 accounts for a prominent proportion of the global trade volume and trade volume, which is highly representative. The stronger economies are China, the United States and South Korea. In general, the intermediary centrality of other countries is relatively stable, ranging from 0 to 0.05. From 2003 to 2005, China's intermediary centrality increased significantly. In 2004, China's transit capacity was very prominent, and the intermediary centrality soared, playing a core role in trade exchanges.

In the cluster coefficient index, South Korea, the United States and Japan rank in the forefront in 2020, which indicates that in the copper downstream product trade, South Korea, the United States and Japan have a high degree of aggregation in the region, and their trade partners are closely linked. Among them, the trend of the aggregation coefficient of South Korea and China shows an "L" shape, which tends to be flat after 2002. The aggregation coefficient of the United States remained around 0.2 before 2016, soared to 0.22 in 2017, and then declined steeply. From 2016 to 2018, the United States played a core role in the trade of copper downstream products, and its trade partners were very close. However, China does not rank prominently in this index, which shows that its trade partners have a low degree of aggregation, the degree of trade relations within the community is not high, and the degree of dependence on relevant trade partners is small.

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