Article

International production and trade in the IC industry based on complex network SNA under COVID-19

Chunnan Teng [1,*], Yungchih Lien [1] and Homin Chen [1,*]

[1] Department of International Business, National Taiwan University; tengchunnan@gmail.com
* Correspondence: tengchunnan@gmail.com (C.T.); hominchun@ntu.edu.tw (H.C.)

Abstract: Social network analysis (SNA) is an effective method for characterizing networks from various specific perspectives. Global trade contracted sharply in 2020 owing to the COVID-19 pandemic, and growth is expected to be lower than the pre-pandemic trends. This study takes countries worldwide as the primary unit of analysis and uses different procedures of social network analysis (SNA), including network density, centrality, and core-periphery structure, and applies them to the field of trade in electronic integrated circuit products (ICPT). In addition to static and descriptive analysis, this study also uses of tools such as Ucinet 6.732 for visual analysis, visual analysis, and more convenient and precise display of the network structure of ICPT. The important countries play a central role in determining the overall structural features. The core-periphery structure in the network from both spatial and temporal perspectives, data on electronic integrated circuit products for the period 2015-2021 were used in SNA. This study found that the ICPT network became denser from 2015 to 2021 but declined and picked up in 2018 and 2020. Moreover, the core-peripheral structure exists in the ICPT network. The main core network countries are Taiwan, Hong Kong, Singapore, mainland China, Malaysia, Japan, the Philippines, Thailand, Vietnam, and other Asian countries, including the United States and Germany.

Keywords: SNA; Foreign Trade; Social network analysis; Electronic integrated circuits; UCINET; COVID-19

1. Introduction

The COVID-19 pandemic has had a significantly negative impact on the global economy. Figure 1 shows the COVID-19 pandemic rapidly diffused from the local Chinese region of Hubei, becoming soon a global health emergency (please see Figure 1). According to the International Monetary Fund (IMF) (2021b), global output grew by -3.2% in 2020, while global trade in goods and services contracted even more at -8.3%, due to weak demand. While merchandise trade volumes have returned to pre-pandemic levels, the World Trade Organization (WTO) (2020) expects trade growth to be moderate and remain below pre-pandemic trends. This study uses the centrality indicator of the social network analysis software Ucinet as a basis for assessing the importance of countries in the semiconductor trade network. Before the COVID-19 pandemic, the world was already struggling to cope with slowing growth across advanced and emerging market economies, escalated trade tensions, including the US-China trade war and Brexit, and the growing urgency of dealing with climate change. The World Bank's January 2019 edition of its global economic prospects termed this situation 'darkening skies'[1]. Then came COVID-19[1], has had a catastrophic impact on the global economy. Global economic growth dropped from 2.6% in 2019 to -3.4% in 2020. Recovery is now underway, with the world's economic output estimated to have grown by 5.5% by 2021.However this growth is projected to slow down to 4.1% in 2022, reflecting continued global uncertainty, a continuation of COVID-19 outbreaks, falling fiscal support, and persistent supply chain disruptions arising from demand and supply imbalances[2].

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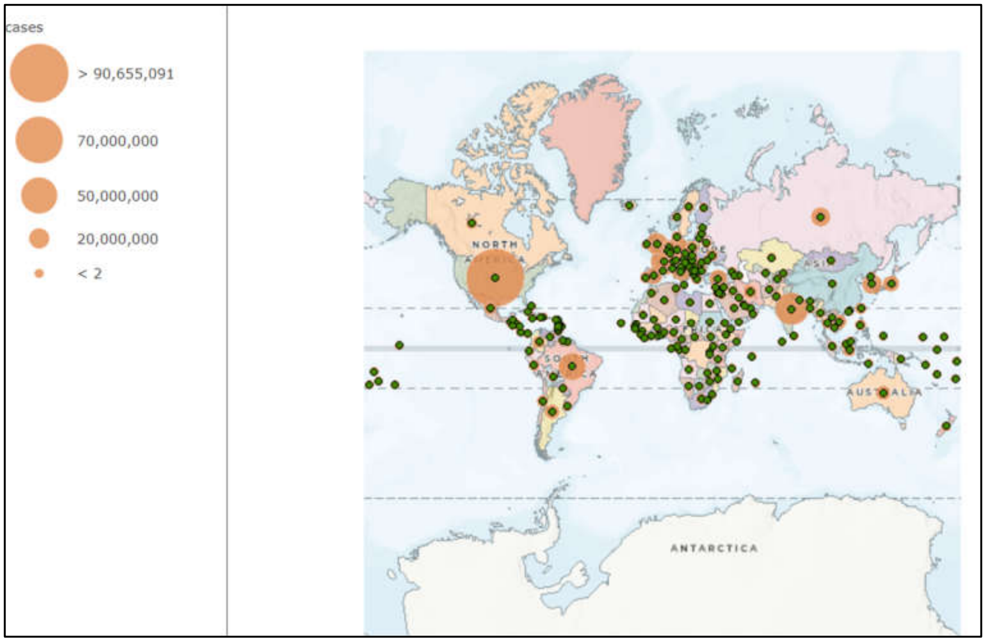

Figure 1. Covid-19 population in the world in 2021

Semiconductors are the brains of modern electronics and are critical for smartphones, computers, transportation, clean energy, military systems, and advances across all these and countless other products. Before the pandemic, the Trump administration launched a trade war against the Chinese semiconductor industry. Then came COVID-19 generated a shortage of semiconductor chips, thanks to people being forced to work from home, and the resultant unforeseen soaring demand for consumer durables, among other things. The knock-on effect was also a widely felt shortcoming of semiconductors for automobiles. In the wake of these shortages, it was perhaps inevitable that Western governments would want to intervene in semiconductor production, given that the currently dominant producers are located 'faraway' such as in South Korea, Taiwan, and other East Asian countries. The potential threat of war between China and Taiwan makes the US nervous about semiconductor supplies. Besides the US and Europe, India also pushes for domestic manufacturing in this sector[3]. In the past half-century, the market pull of bulk commodities has driven the development of laboratory technology of semiconductors. The development of the semiconductor industry is divided into three stage: 1987 to 2000- Moore stage (Moore), 2001 from 2010 to 2010 -More-Moore, 2011 to 2019 -More-than Moore. From the beginning, the United States dominated and spread to Japan, South Korea, Taiwan, and mainland China. After 2010, although the growth of personal computers ceased, with the development of other product applications, such as notebook computers, mobile phones, and Internet applications, the development of the semiconductor industry continued to play a considerable role in international trade. In particular, after 2010, the popularity of 4G smartphones has completely changed the situation in the semiconductor industry[4]. For US$40 billion, it has grown to US$102.8 billion in 2021, with an average growth rate of 4.92% in 2010-2015 and a growth rate of 13.03% in 2016-2021, especially in 2019-2020 export growth rate is 11.67%, 2020-2021 exports The rate increased to 32.23%.

Social networks have been used to explore international trade relations between different industries, such as forest industry trade[5], copper raw material trade[6, 7], high-tech Researches on industrial trade[8], aquatic industry trade[9], since the semiconductor industry has a considerable influence on the world trade network, the international social network of the semiconductor industry. There is no relevant research to discuss how it has evolved in the last 10 years and how countries have changed the international trade network under the influence of the COVID-19 epidemic. The global trade network has been affected and reduced owing to the impact of the COVID-19 epdemic [10, 11].

This study used four centrality indicators: degree centrality, closeness centrality, betweenness centrality and eigenvector centrality. Degree centrality measures whether a country trades with many countries, closeness centrality measures how close a country is to all other countries in the network, and betweenness centrality measures whether a country often acts as a bridge in the network. The role of eigenvector centrality is to measure the importance of country's trading partners.

In summary, this study is based on the SNA method and utilizes the tools of Ucinet 6.732 to intuitively describe the ICPT network, presenting the network structure characteristics and dynamic evolution of ICPT from 2015 to 2021. Consider using directed networks in an unweighted form for IC trade between countries. In addition, the researchers also conducted a comparative analysis of the network structure of ICPT and the network structure of the entire IC industry.

2. Materials and Methods

2.1 Data Collection

Generally, goods in international trade vary widely across categories. This study collected ICPT data from the International Trade Centre (ITC) website (https://intracen.org/), including annual data on imports and exports from 2015 to 2021. On this website, ITC has been assigned a defined code (HS Code 854239) and it is clearly stated in the ITC database that this code covers some specific classifications including electronic integrated circuit products (excluding processors, controllers, memory, and amplifiers). The data of electronic integrated circuits trade used in this study come from the International Trade Center (ITC) Database. By consulting the customs HS code, the HS code of the electronic integrated circuit product was found to be 854239. This study selected the top 25 countries electronic integrated circuit trade volume accounts for 97.54% (in 2021) of the world's trade volume as the network node. (USA, Brazil, Mexico, Germany, France, Netherlands, Belgium, Portugal, Poland, Hungary, Ireland, Israel, Japan, Republic of Korea, Singapore, India, Malaysia, Philippines, Thailand, Vietnam, Turkey, Austria, Taiwan, China, and Hong Kong). This study's time interval for network dynamics was 2015-2021. Data were obtained from the ITC online trade database established by the United Nations/WTO (World Trade Organization) ITC, and the COMTRADE database established by the United Nations Statistics Department.

SNA is increasingly looking to combine this approach with tools such as Ucinet 6.732 and ArcGIS online, which facilitate the implementation of visual network analysis[12].Therefore, this study used ICPT data to build a social network, and used the network analysis software Ucinet 6.732, network drawing software Netdraw, ArcGIS online, and other tools to analyze it.

2.2 International trading network construction

A social network is a collection of individual relationships to form a group structure. Social network analysis is used to establish a model to quantify social relationships with specific nodes (nodes) and links (links/ties) and analyze the characteristics of this structure. In social network analysis, nodes represent behavioral individuals (organizations or collective units), and connections represent relationships between individuals. Therefore, the nodes were connected by links to form a network structure. Among them, the behavioral individual may interact with many other individuals, and the number of relationships is reflected in the node degree (Node Degree). Node strength measures the strength of the connection; that is, the greater the node strength, the closer the relationship between individuals. In this study, a node represents a country, and the country asks for the existing trade relationship (import and export) represented by links to form a world trade network. If a country has a greater node degree, it trades with more countries, the more significant the node intensity, the closer the trade relationship with its trading partners greater the flow.

There are many ways to calculate centrality in social network analysis, including degree, closeness, betweenness and eigenvector centralities. Degree centrality is calculated based on the number of direct connections between each node and other nodes, that is, the relative importance of any node to its adjacent nodes, which is the most intuitive neutrality indicator. Closeness centrality is calculated from each node to other nodes. The distance and the number of instances were calculated. The larger the number, the closer the node is to the network core, and the faster it can reach other nodes. Betweenness centrality considers the intermediary function, which uses of an intermediary node between any two nodes. The ratio of passing through the shortest path was calculated. The larger the number, the more nodes are on the path many connections pass. It acts as a bridge and has control over many sources of responsibility. The centrality of the eigenvector is also based on the relationship between each node. Here, the number of node connections is calculated. However, unlike the degree centrality, eigenvector centrality considers the importance of the connected objects. Its centrality can be improved if it is connected to a relatively important node-the construction of an electronic integrated circuit product trade network. The global trade network is used to describe trade relations between countries. The links between countries reveal import and export trade relations between them. According to the composition method of the complex network, the countries engaged in electronic integrated circuit trade are used as nodes and the transnational trade relations of countries are used as edges to construct the ICPT trade network models. In the trade network constructed in this study, Vi=[Vi](i=1, 2,…,25) is the trade exporting country, and Vj=[Vj](j=1,2,…,25) is the trade importing country. The weight matrix W=[Wi, j]=(i=1,2,…,25;j=1,2,…,25) represents the trade volume of electronic integrated circuit products exported by exporting country Vi to the importing country Vj.

2.2 Indicators for analyzing an unweighted network structure

Network density is an indicator of the general level of connectedness in the graph. The paper has a complete graph if every node is directly connected to every other node. The density of a network is defined as the number of links divided by the number of vertices in a complete network with the same number of nodes [9, 13]. The network density can reveal the overall network structure. It is calculated as the ratio of the “total number of relationships that exist” to the “largest number of relationships that may exist in theory.” If the actual number of relationships (links) between countries (areas) in the network is M and the number of the country (area) nodes is N, then the overall network density is $2M/N(n-1)$. The more links between country (area) nodes, the greater the overall density of the network. The density value is between 0 and 1; the closer the value is to 1, the more intensive the link relationships between countries (areas) are.

Network centrality can be divided into three indicators: degree, closeness, and betweenness. Degree centrality represents the number of nodes directly connected to a node. A directed network is divided into in-degree centrality (IDC) and out-degree centrality (ODC). Betweenness centrality (BS) indicates the ability of a node to control the relationship between other point pairs, that is, the ability of a point to be on the shortest path of other point pairs. The closeness centrality, also known as the overall centrality, represents the sum of the shortest paths between a node and other nodes. A directed network is divided into out-closeness centrality (OCC) and in-closeness centrality (ICC). By analyzing of the above three indicators, we can determine the status and role of each node country in the ICPT trade network.

Core-Periphery structure of core edge structure is mainly divides into core, semi edge and edge areas, which makes the entire ICPT trade network structure be able to present the characteristics of close connections of the core and sparse and scattered edges. This study separates the core structure in the ICPT trade network using the core-periphery algorithm in UCINET

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3. Results

Network density is a crucial indicator that requires visual analysis of the overall structure of an electronic integrated circuit network. Table 1 shows that the overall network density of electronic integrated circuit networks ranges from 0.443 to 0.494, which indicates that from 2015 to 2021, electronic integrated circuit networks have gradually strengthened. Connections between countries have expanded, while the overall network density level has consistently remained at low level, with a value of less than 0.5. This result shows relatively few connections between different electronic integrated circuit countries, and much room for improvement.

Table 1. International electronic integrated circuits network density from 2015-2021

Year	2015	2016	2017	2018	2019	2020	2021
Network Density (Import)	0.443	0.433	0.439	0.451	0.464	0.458	0.494
Network Density (Export)	0.408	0.404	0.391	0.410	0.428	0.425	0.442

Figure 2 shows that the total value of electronic integrated circuits grew from 2015 to 2021. Electronic integrated circuits peaked at $345.727 billion in 2021, compared to $188.327 billion in 2015. A Comparison of the trends in trade volume and network density shows the formation of denser networks in 2015 and 2021. Economic development has important implications for the evolution of ICPT network density. More specifically, trade volumes fell in 2020 due to the impact of the COVID-19 crisis in 2020, as did network density.

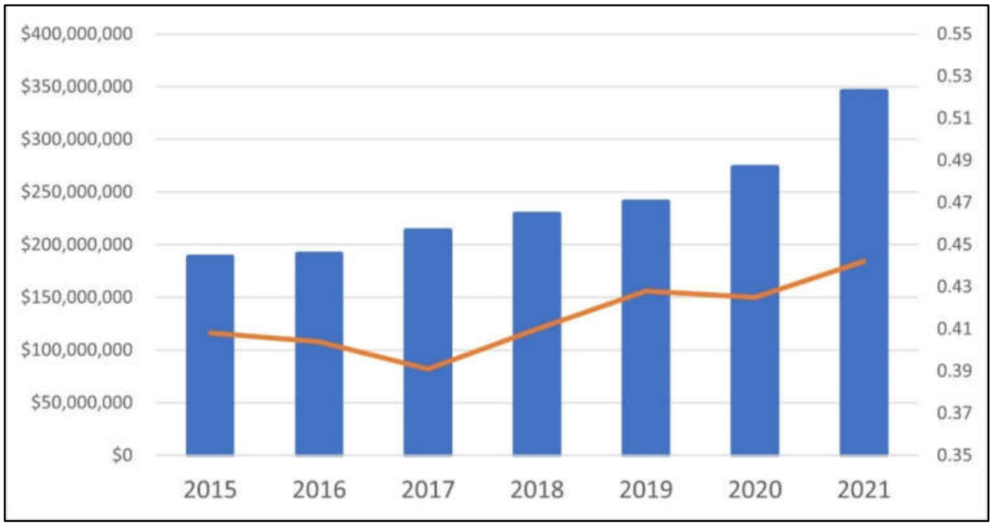

Figure 2. Aggregate export value and network density of international ICPT trade from 2015 to 2021

Figure 3 shows that the total value of electronic integrated circuits grew from 2015 to 2021. Electronic integrated circuits peaked in 2021 at US$ 339,635 million compared with the value of US$ 203,197 million in 2015. A comparison of the changing trends in trade value and network density indicates that a denser network was formed in 2015 and 2021. In addition, economic development matters significantly in the evolution of ICPT network density. Trade volumes continued to rise in 2020 due to the impact of the COVID-19 crisis, but network density decreased.

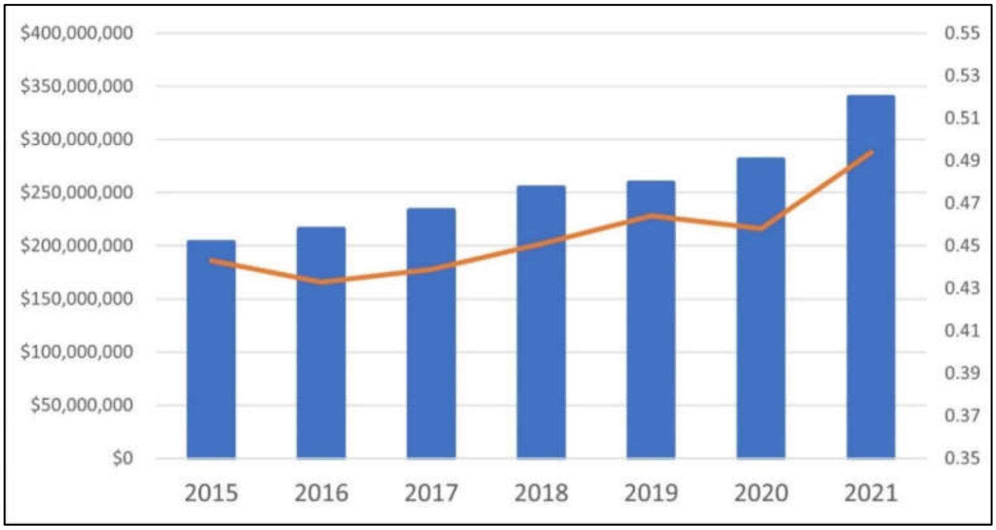

Figure 3. Aggregate import value and network density of international ICPT trade, from 2015 to 2021

Figure 4 shows the overall centrality of the entire export of the ICPT network from 2015 to 2021. Figure 5 shows the overall centrality of the imported ICPT network from 2015 to 2021. The Network concentration index is a suitable indicator. It has decreased from 2015 to 2021, and continues to decline, indicating weakened centrality of some countries. The entire ICPT network is gradually moving towards equalization rather than centralization.

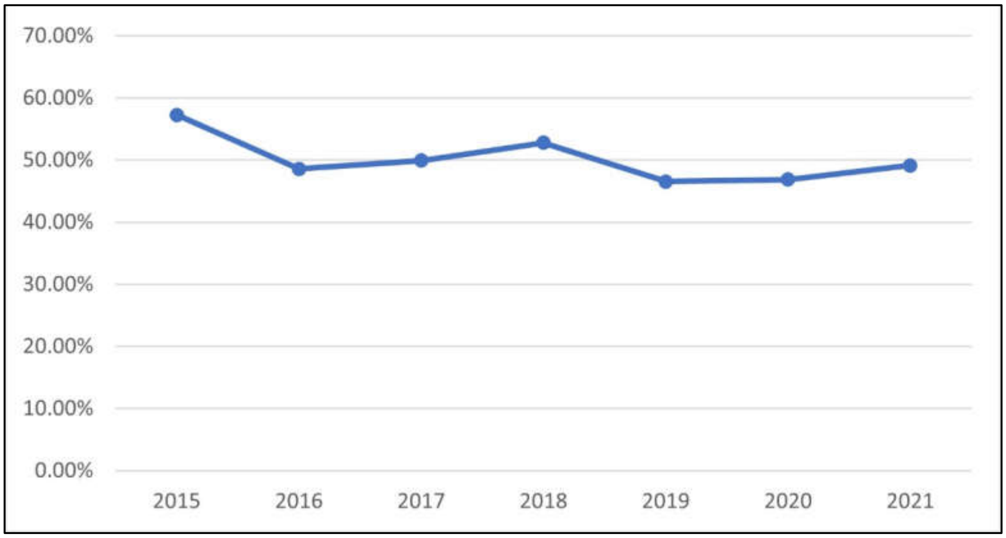

Figure 4. Indicates the overall degree of centrality of the entire export ICPT network from 2015 to 2021

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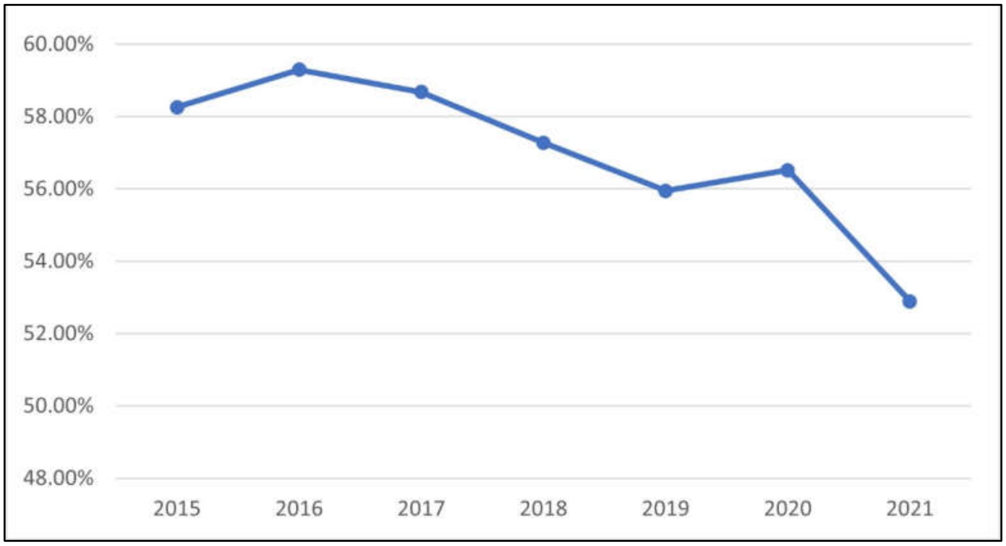

Figure 5. Indicates the overall degree of centrality of the entire import ICPT network from 2015 to 2021

Table 2 and 3 present the results of the trade network analysis. Degree, closeness, betweenness, and eigenvector parameters were derived from the network analysis where degree and closeness indicate interconnectivity and geodesic distance, respectively. Betweenness measures the number of times a countries lies on the shortest path between other countries. The eigenvectors measure the network connectivity. The network was constructed by preparing an undirected network matrix of the top 11 countries for 2019, 2020, and 2021. Regarding the network centrality of the exported IPTC, the IPTC network centrality from 2019 to 2020 will be led by Taiwan, and the IPTC network centrality by 2021 will be China, Taiwan, the United States, and Malaysia. In terms of network centrality of the imported IPTC network, both China and Hong Kong led the IPTC network centrality from 2019 to 2021. All parameters such as degree, closeness, betweenness, and eigenvectors are from 2019 to 2021. These have not been affected by the COVID-19 pandemic.

Table 2. IPTC network centrality parameters of import in 2019, 2020 and 2021

	Degree			**Closeness**			**Betweenness**			**Eigenvector**		
	2019	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
China	0.917	0.917	0.957	0.874	0.875	0.827	0.066	0.068	0.053	0.328	0.335	0.329
Germany	0.792	0.708	0.783	0.814	0.778	0.753	0.049	0.041	0.034	0.289	0.265	0.273
Hong Kong	0.292	0.250	0.304	0.614	0.614	0.583	0.005	0.004	0.004	0.113	0.102	0.111
Japan	0.625	0.583	0.609	0.745	0.729	0.691	0.028	0.025	0.020	0.229	0.223	0.206
Korea	0.875	0.833	0.870	0.854	0.833	0.788	0.056	0.052	0.042	0.319	0.311	0.302
Malaysia	0.875	0.875	0.957	0.833	0.854	0.827	0.051	0.057	0.052	0.318	0.320	0.326
Philippines	0.833	0.792	0.913	0.833	0.814	0.807	0.051	0.047	0.047	0.305	0.298	0.314
Singapore	0.750	0.750	0.870	0.778	0.761	0.788	0.040	0.039	0.043	0.275	0.274	0.301
Taiwan	0.958	0.958	0.957	0.897	0.897	0.827	0.071	0.073	0.052	0.341	0.349	0.326
Thailand	0.750	0.792	0.913	0.795	0.814	0.807	0.040	0.046	0.045	0.274	0.297	0.316
USA	0.833	0.833	0.957	0.814	0.814	0.827	0.046	0.050	0.052	0.308	0.313	0.327

Table 3. IPTC network centrality parameters of export in 2019,2020 and 2021

	Degree			Closeness			Betweenness			Eigenvector		
	2019	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
China	0.840	0.840	0.875	0.901	0.901	0.921	0.085	0.095	0.086	0.336	0.330	0.333
Germany	0.600	0.560	0.542	0.753	0.737	0.761	0.035	0.036	0.029	0.246	0.226	0.217
Hong Kong	0.840	0.840	0.875	0.901	0.901	0.921	0.081	0.081	0.093	0.342	0.342	0.336
Japan	0.520	0.560	0.542	0.737	0.737	0.761	0.026	0.026	0.023	0.229	0.246	0.235
Korea	0.680	0.680	0.750	0.82	0.785	0.854	0.047	0.045	0.054	0.283	0.280	0.303
Malaysia	0.600	0.640	0.542	0.737	0.753	0.761	0.037	0.033	0.026	0.238	0.271	0.228
Philippines	0.480	0.520	0.542	0.695	0.723	0.761	0.015	0.021	0.020	0.219	0.236	0.244
Singapore	0.680	0.600	0.625	0.768	0.737	0.795	0.048	0.036	0.033	0.271	0.242	0.257
Taiwan	0.640	0.680	0.667	0.785	0.785	0.814	0.052	0.051	0.040	0.265	0.278	0.278
Thailand	0.520	0.520	0.500	0.753	0.737	0.745	0.025	0.024	0.025	0.239	0.236	0.220
USA	0.800	0.760	0.792	0.880	0.859	0.875	0.076	0.067	0.064	0.321	0.312	0.311

The top 24 trade-network centrality index countries were obtained by calculating the four centralities of ICPT trade network (please see Tables 4, 5, 6, and 7). China, Germany, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and the USA ranked among the top ten of the three centrality statistical indicators. Table 6 shows the results-for degree centrality; the top ten countries with the highest degree centrality from 2015 to 2021 are listed. From the perspective of out-degree centrality (ODC), China, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, Vietnam, and USA are all connected to other countries in the network, indicating that these exporters are relatively widespread among all economies. They perform most actively in the entire network and exhibit strong communicative competence. From the perspective of in-degree centrality (IDC), Germany, Malaysia, and the UK still rank among the top three, indicating that the three countries take the core position in the trade of IC products and other countries are willing to have contact with them, which enjoy a high reputation. From the perspective of out-closeness centrality (OCC), the out-closeness centrality (OCC) indicators of China, Taiwan, and the USA are all 1.00, indicating that these countries have the highest ease of reaching other countries and a strong radiation capacity. From the perspective of in-closeness centrality (ICC), Israel, Ireland, and the UK have more apparent advantages and relatively strong integration ability, making it easier for other countries to contact them. From the perspective of betweenness centrality (BC), Germany, Malaysia, Taiwan, the USA, and Thailand rank among the top five, indicating that these countries mainly act as "intermediaries" and "bridges" in the whole trade network of ICPT.

Table 4. The out-degree and in-degree of participants in ICPT import network from 2015 to 2021

	2015		2016		2017		2018		2019		2020		2021	
	ODC	**IDC**	**ODC**	**IDC**	**ODC**	**IDC**	**ODC**	**IDC**	**ODC**	**IDC**	**ODC**	**IDC**	**ODC**	**IDC**
Taiwan	22	10	22	9	22	10	23	12	23	12	23	12	22	12
China	21	8	19	8	21	8	22	8	22	8	22	8	22	8
USA	21	11	21	11	20	11	20	11	20	12	20	11	22	11
Korea	19	9	20	8	18	10	20	11	21	11	20	11	20	10
Singapore	19	10	19	8	17	8	20	9	18	9	18	9	20	9
Japan	14	8	15	8	14	8	15	10	15	9	14	9	14	9
Viet Nam	0	8	0	8	1	8	2	8	4	7	4	8	NA	NA

Malaysia	20	11	19	11	18	11	22	12	21	15	21	15	22	12
Germany	20	13	18	14	19	12	18	13	19	11	17	13	18	13
Philippines	NA	NA	NA	NA	NA	NA	19	9	20	10	19	10	21	10
Thailand	17	8	16	9	16	9	18	9	17	10	19	9	21	9
France	10	10	9	9	10	9	11	10	11	10	10	9	9	12
Italy	4	9	5	8	4	8	5	9	4	11	4	11	4	12
Israel	0	10	1	10	2	11	2	11	1	13	1	13	0	12
Mexico	2	10	3	10	2	9	1	10	1	11	1	11	2	10
Netherlands	7	12	7	9	9	10	9	10	9	12	8	12	9	12
Ireland	4	8	6	9	6	7	4	11	6	12	7	11	5	13
Hong Kong	6	8	5	8	7	8	7	8	7	9	6	9	7	9
Canada	1	9	1	10	1	10	0	11	1	10	0	10	0	10
Austria	5	10	3	8	4	9	2	10	1	11	3	7	3	11
Portugal	0	10	0	8	0	9	0	9	0	9	0	9	0	11
Belgium	2	11	2	11	2	13	2	12	7	9	6	9	7	9
Sweden	1	11	0	12	1	11	0	10	0	10	1	11	0	11
UK	9	10	8	13	8	13	7	16	8	15	9	16	2	15

Table 5. The out-degree and in-degree of participants in ICPT export network from 2015 to 2021

	2015		2016		2017		2018		2019		2020		2021	
Country	ODC	IDC	ODC	IDC	ODC	IDC	ODC	IDC	ODC	IDC	ODC	IDC	ODC	IDC
Taiwan	17	9	18	9	18	9	19	10	16	10	17	9	16	9
China	22	6	20	7	20	7	22	9	21	8	21	9	21	9
Hong Kong	18	5	17	5	19	5	21	5	21	6	21	5	21	6
Singapore	16	12	17	12	17	12	16	14	17	14	15	14	15	14
Korea	18	11	18	12	18	9	18	7	17	7	17	7	18	5
Japan	12	10	12	10	11	10	12	11	13	10	14	10	13	9
Malaysia	15	11	13	11	14	11	16	12	15	14	16	14	13	12
Philippines	NA	NA	NA	NA	NA	NA	10	11	12	13	13	13	12	10
USA	20	11	20	12	20	12	20	13	20	13	19	12	19	13
Thailand	10	9	9	9	10	9	14	10	13	11	13	12	12	12
Germany	16	16	16	15	14	15	16	17	15	18	14	18	13	17
Viet Nam	5	10	6	10	7	9	8	11	9	12	9	12	NA	NA
Netherlands	10	11	10	9	8	11	8	11	10	13	12	12	13	11
Israel	3	14	1	9	2	11	3	14	3	15	2	15	4	4
Belgium	2	12	2	11	2	11	2	12	5	14	5	14	4	13
Portugal	2	9	1	5	1	3	3	2	1	3	1	4	4	10
France	10	9	13	9	8	10	11	10	13	11	12	11	10	6
India	4	9	3	8	3	10	5	6	7	8	5	6	5	23
Mexico	4	5	5	5	3	4	6	7	8	9	9	8	6	6
Brazil	3	8	3	15	2	8	3	9	3	10	1	11	2	6
Poland	5	8	6	8	5	10	5	9	6	8	7	9	7	7
Austria	4	9	5	10	3	10	1	13	2	12	2	12	5	13

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Ireland	0	6	1	6	2	7	1	7	2	7	2	8	2	8
Turkey	2	6	1	7	2	6	0	9	1	5	1	6	1	6
Hungary	7	9	6	9	7	7	6	7	7	6	7	4	7	4

Table 6. The part list of closeness centrality in 2015, 2017, 2019 and 2021

	2015		2017		2019		2021	
	OCC	ICC	OCC	ICC	OCC	ICC	OCC	ICC
Taiwan	1.00	0.489	1.00	0.537	1.00	0.59	1.00	0.55
China	0.957	0.468	0.957	0.512	0.958	0.511	1.00	0.478
USA	0.957	0.5	0.917	0.55	0.885	0.575	1.00	0.537
Korea	0.88	0.478	0.846	0.537	0.92	0.561	0.917	0.512
Singapore	0.88	0.5	0.815	0.5	0.821	0.548	0.917	0.512
Japan	0.733	0.468	0.733	0.512	0.742	0.535	0.733	0.5
Viet Nam	0.2	0.458	0.468	0.478	0.548	0.479	NA	NA
Malaysia	0.917	0.512	0.846	0.564	0.92	0.639	1.00	0.55
Germany	0.917	0.55	0.88	0.611	0.852	0.59	0.846	0.564
Philippines	NA	NA	NA	NA	0.885	0.548	0.957	0.512
Thailand	0.815	0.468	0.786	0.55	0.793	0.575	0.957	0.512
France	0.647	0.489	0.647	0.524	0.657	0.561	0.629	0.55
Italy	0.55	0.489	0.55	0.512	0.548	0.575	0.55	0.55
Israel	0.2	0.55	0.393	0.595	0.39	0.622	0.25	0.579
Mexico	0.512	0.489	0.512	0.524	0.479	0.561	0.524	0.512
Netherlands	0.564	0.524	0.595	0.537	0.575	0.605	0.595	0.55
Ireland	0.524	0.478	0.537	0.512	0.575	0.605	0.564	0.564
Hong Kong	0.579	0.431	0.595	0.489	0.59	0.523	0.595	0.489
Canada	0.5	0.478	0.489	0.537	0.479	0.548	0.25	0.537
Austria	0.564	0.5	0.55	0.564	0.489	0.59	0.537	0.537
Portugal	0.2	0.512	0.2	0.579	0.25	0.548	0.25	0.564
Belgium	0.386	0.524	0.293	0.611	0.479	0.535	0.5	0.512
Sweden	0.367	0.512	0.367	0.595	0.25	0.59	0.25	0.564
UK	0.595	0.512	0.611	0.629	0.605	0.657	0.524	0.595

Table 7. The list of normalized values of betweenness centrality from 2015 to 2021

Rank	2015	2016	2017	2018	2019	2020	2021
1	Germany	USA	Germany	Hong Kong	Malaysia	UK	Germany
2	USA	Germany	Hong Kong	Germany	USA	Malaysia	Malaysia
3	Netherlands	Malaysia	USA	USA	UK	Germany	Taiwan
4	Malaysia	Taiwan	Malaysia	Taiwan	Germany	USA	USA
5	Austria	Korea	Korea	Thailand	Taiwan	Thailand	Thailand
6	Singapore	Thailand	Thailand	Malaysia	Thailand	Taiwan	Italy
7	Taiwan	Hong Kong	Austria	Korea	Korea	Italy	Ireland
8	Korea	Singapore	Israel	Japan	Italy	Korea	Singapore
9	Italy	France	Taiwan	Singapore	Singapore	Ireland	Philippines

10	Hong Kong	Italy	Singapore	Netherlands	Netherlands	Singapore	Korea

Table 8 presents the core members and the final fitness for the ICPT import trade network. The core degree of the ICPT network in 2015, 2018, and 2021 was calculated through using Ucinet 6.732 software. The core-core (CxC) high-density scores of 0.854 (2015), 0.939 (2018), and 0.913 (2021) indicate that there is a small, tightly connected group of countries, which accounts for most of the trade within this sector, surrounded by countries loosely connected to the core, not connected to other countries at the core, and not connected to other countries outside the core. The low periphery-periphery (PxP) density, points towards members of the periphery excluded from a high number of trading relationships and dependent on trade with the core. Asia nations and the USA dominate the core regarding demand in the sector.

Table 8. The list of normalized values of betweenness centrality from 2015 to 2021

	2015	**2017**	**2019**	**2021**
Germany	13.527	13.521	5.091	5.929
USA	10.385	10.269	9.727	4.882
Netherlands	5.521	1.433	1.364	0.946
Malaysia	5.441	6.309	12.344	5.562
Austria	4.62	5.075	0.534	0.728
Singapore	4.086	1.496	1.583	1.506
Taiwan	3.023	3.547	4.691	5.549
Korea	1.834	6.271	2.555	1.084
Italy	1.671	0.815	2.123	2.204
UK	1.446	10.368	6.682	1.034
France	1.199	1.359	1.342	1.035
China	0.749	1.182	0.849	0.319
Ireland	0.402	0.406	0.984	1.702
Belgium	0.387	0.444	0.48	0.148
Thailand	0.368	5.163	3.933	4.259
Japan	0.317	0.375	0.348	0.17
Hongkong	0.21	0.261	0.113	0.041
Mexico	0.209	0.134	0.049	0
Sweden	0.018	0.132	0	0
Israel	0	4.492	0.015	0
Portugal	0	0	0	0
Viet Nam	0	0.108	0	N/A
Canada	0	0	0	0
Philippines	N/A	N/A	1.321	1.213

Table 9 presents the core members and final fitness of the network. A core-core high density score of 0.913 indicates a small group of countries that are closely connected and account for most of the trade within the sector, surrounded by countries that are loosely connected to the core and have no ties to other cores. The peripheral-periphery density is low, indicating that peripheral members are excluded from substantial trade relationships and depend on trade with the core. The core is dominated by Asian countries, the USA and Germany, critical industrial demand areas.

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Table 9. Core-periphery analysis of the IPTC network in 2015, 2018, and 2021

Year	Core	Density Matrix				Final Fitness
		CxC	CxP	PxC	PxP	
2021	China, Germany, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, USA	0.913	0.926	0.262	0.048	0.84
2018	China, Germany, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, USA	0.939	0.776	0.198	0.125	0.775
2015	China, Germany, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, USA	0.854	0.912	0.235	0.037	0.785

The study provided the network structure results of top 24 countries in 2015 and 2020 to identify the connected directions between countries (please see Figure 6 and 7) were 23 countries (2015) and 25 countries (2020) provided the most valuable flows on the overall network. Most of the connections are mutual and bidirectional. The overall trade density declined in 2020 compared to 2015, but trade volumes were not affected by COVID-19. As shown in Figure 7, there are ten core countries, accounting for 67%, mainly involving North America represented by the USA; Europe represented by the United Kingdom; and East Asia, represented by China.

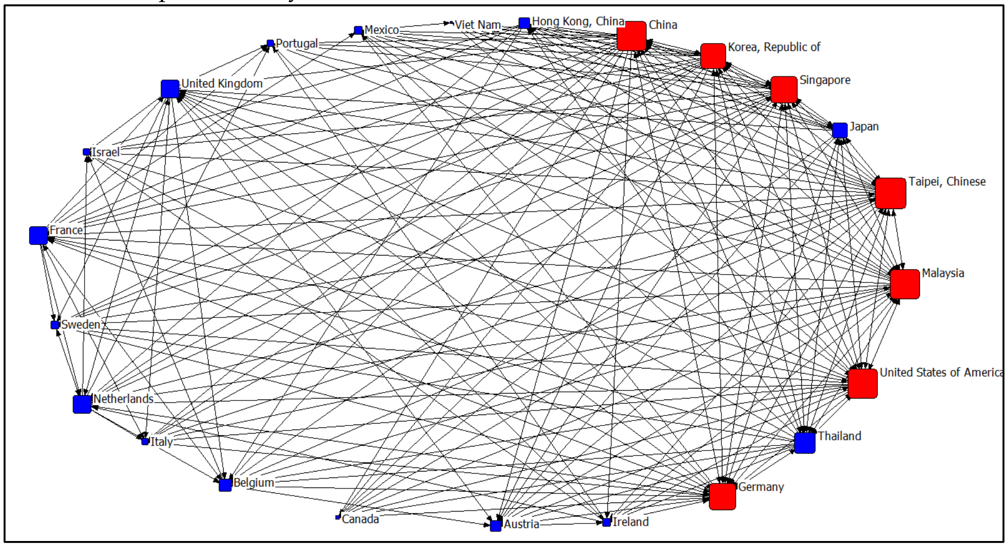

Figure 6. The partial ICPT network structure in 2015. This figure shows the network graph derived from Network Analysis for 2015. The countries included are China, Korea, Singapore, Japan, Taiwan, Malaysia, USA, Thailand, Germany, Ireland, Austria, Canada, Belgium, Italy, Netherlands, Sweden, France, Israel, UK, Portugal, Mexico, Viet Nan, and Hong Kong.

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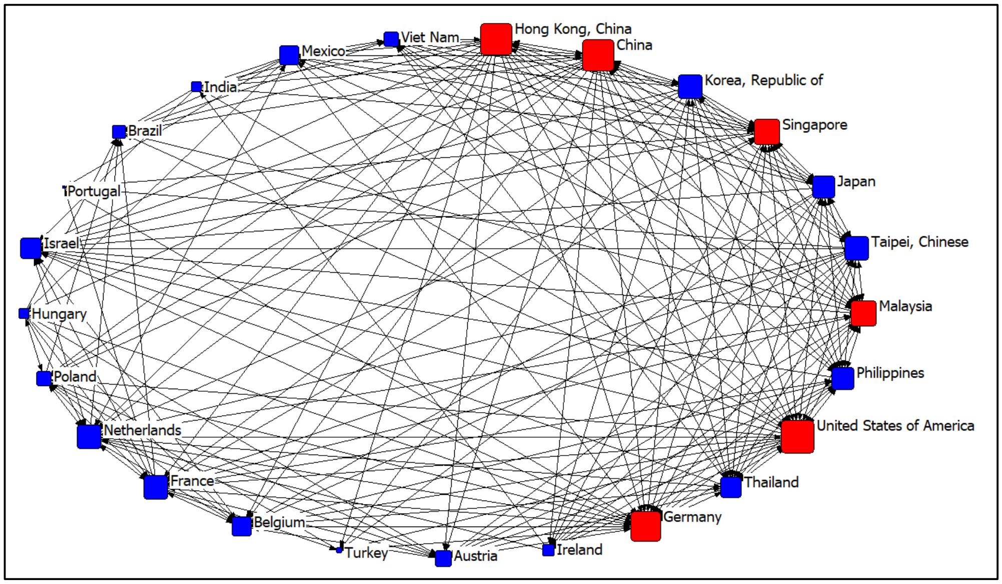

Figure 7. The partial ICPT network structure in 2020. This figure shows the network graph derived from Network Analysis for 2020. The countries included are China, Korea, Singapore, Japan, Taiwan, Malaysia, Philippines, USA, Thailand, Germany, Ireland, Austria, Turkey, Belgium, France, Netherlands, Poland, Hungary, Israel, Portugal, Brazil, India, Mexico, Viet Nan, and Hong Kong.

4. Discussion

A significant part of world trade is characterized by global production networks that can benefit many developing economies and contribute to progress in industrialization, which in turn increases productivity. The gap between the central and peripheral regions has narrowed because of the influence of the global production network. In other words, trade diversification and production decentralization have led to an increase in middleman trade, becoming global market leaders and export hubs for commodities in countries such as India, China, and South Korea [14]. China, Japan, and South Korea, in particular, end up in the global supply chain for most manufactured goods because of their comparative advantages in production and distribution. China eventually became a supplier of industrial components and factory worldwide. Similarly, Japan, South Korea, and India have emerged as hubs for information and communications technology (ICT) to serve Asian factories [15]

This study shows the network characteristics of ICPT in the trade network, tracing its development over the period 2015-2021 on a timeline. During the past ten years, from 2011 to 2020, the global trade balance of semiconductor products was negative (please see Figure 8). The WTN structure in 2015-2021 and the network trade structure during the COVID-19 outbreak were evaluated. In 2021, the global trade in semiconductors had become positive. The trade balance declined sharply in 2020-2021 (please see Figure 9) in most of the products due to the impact of COVID-19. However, the tread of semiconductors was the opposite due to an increased demand for consumer electronics and ICT Products by people working from home [3]. Previous studies have shown that the overall network of WTN is on the rise [16], but from the network density centrality of ICPT exports, the network density in 2017 and 2020 has dropped significantly. In 2017, the Donald Trump administration launched a trade war against the Chinese peninsula industry, and the Donald Trump administration launched an unfair trade investigation into opaque subsidies to Chinese semiconductor companies. U.S. companies were banned from selling to Huawei, Semiconductor Manufacturing International Corporation (SMIC), and other Chinese companies for national security reasons. It also restricts US technology's sale to foreign companies that supply semiconductors to these entities[3]. In 2020, the centrality

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of export network density was affected by the new crown pneumonia, which also decreased significantly; however, it will show an increasing trend in 2021.

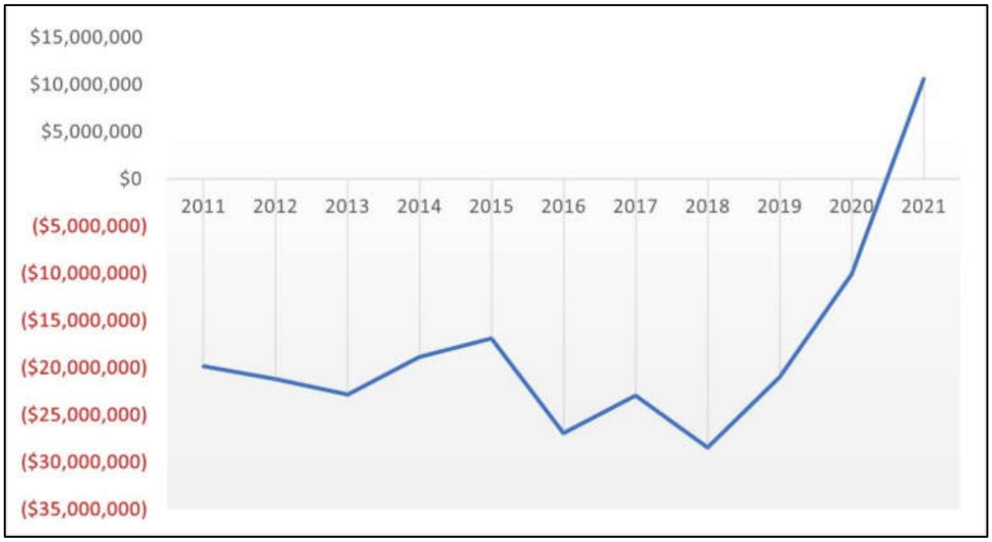

Figure 8. Balance of Trade (BOT) of electronic integrated circuits in the world

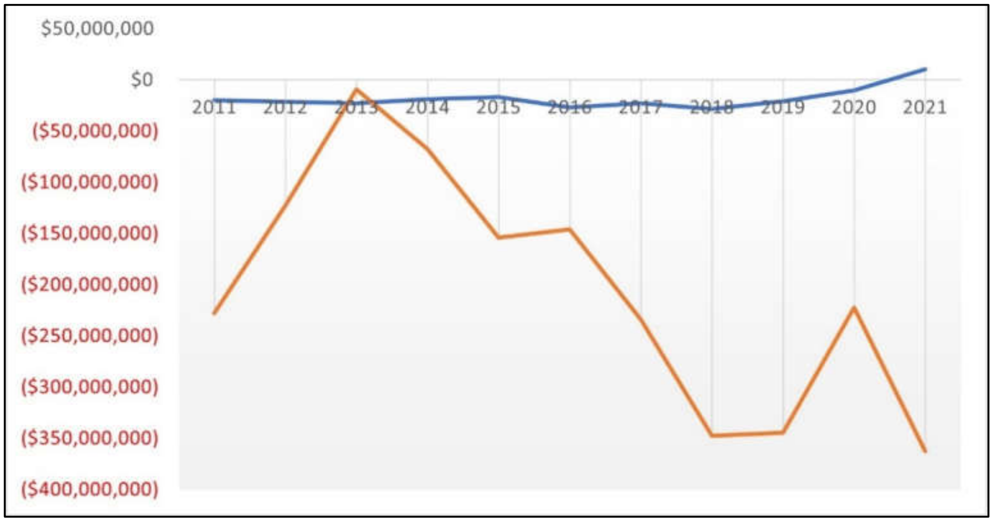

Figure 9. Balance of Trade (BOT) of electronic integrated circuits and all product in the world

From the analysis of the core-surrounding network, in 2020, the core of the ICPT's trade network will be China, Germany, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand and the USA as the major countries, which are similar to Varas Antonial [17] in the global semiconductor manufacturing market share in 2020. Taiwan accounted for 22%, South Korea accounted for 21%, Japan accounted for 15%, China accounted for 15%, the United States accounted for 12%, Europe accounted for 9%, other countries and the 6% of the survey results. China, Japan, South Korea, Taiwan, and the United States are all at the center of the core network, and the rest are in Malaysia, the Philippines, Singapore, and Thailand. Companies with these primary core network members locally have semiconductors import and export value of industrial companies.

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5. Conclusions

This article uses 2015 to 2021 global ICPT country import and export trade data provided by the ITC to build an ICPT network. This study uses social network analysis to discuss the structural characteristics of the ICPT network and the interdependence of countries in trade. First, the global trade network for IC products is stable with light variation. Overall trade efficiency is high, with typical small-world characteristics. Second, the Asian region occupies a central position in the global ICPT network, among which the top ten ICPT cores are China, Germany, Japan, Korea, Malaysia, Philippines, Singapore, Taiwan, Thailand, and USA-the eight countries of Asian regions. Asia is the country that bears the brunt of the outbreak of the COVID-19 pandemic. However, from the network architecture diagram, when the core peripheral network connection is in 2021, the USA, Malaysia, Korea, the UK, and China will drop significantly, whereas Taiwan and Thailand will increase significantly. The Asian region acts as a bridge to connect closely with other countries, and acts as a bridge in Malaysia, Taiwan, Thailand, Singapore, Philippines, and Korea. Overall, IC product trade presents a trade pattern dominated by developed countries and an uneven spatial distribution. Undeniably, that the trade pattern of IC products after the COVID-19 pandemic is changing in the direction of increasing regional trade networks. After the post-pandemic period, the relevant centrality of China's semiconductor core network has been, and the trade network has also gradually played a larger role.

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