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Social Network Perspective on Trade in Value Added: Focused on the Logistics Industry

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ABSTRACT

This paper examines the network dynamics of the cross-border trades utilizing Social Network Analysis (SNA) based on data obtained from the WTO-OECD Trade in Value Added database from 2000-2011. The main results of this paper are as follows: regarding the top 10 in-degree centrality industries, industries in China, Germany, and the U.S. have emerged as the largest importers of foreign value added, implying that the global production network is dominated by two different types of industries. The first type includes processing and assembling functions in China and Germany. The other type of industry involves foreign value added largely for domestic final demand in the U.S. Secondly, there are also two types of brokerage roles. U.S. industries are operating in a liaison role, while Chinese and German industries are mostly operating as coordinator or gatekeeper. Thirdly, manufacturing industries in China and Germany which have emerged as higher in-degree centrality incur a large portion of their value added from the logistics industry. This suggests that those leading industries with the highest characteristics of hubness in the global production network cannot sustain their network status without efficient utilization of the logistics industry.

1. Introduction

Are there analytical tools for understanding the world trade by examining all the feature of the global production network? With the growing importance of the global production network, world trade is considered a network system composed of interconnection among countries and industries. In this context, using social network analysis (SNA), the comprehensive features of world trade and a specific country's trade flow can be clearly identified.

The global production network has been a major driving force for cross-border trade growth. The traditional Ricardian approach, which emphasizes the role of comparative advantage of a country's industry, has maintained its explanatory power as the fundamental trade theory. From the perspectives of the traditional trade theory, recent changes in the global production network have been mostly due to China's industrial rise, its cost competitiveness of processing trade, and vertical specialization (Dean et al., 2009; Ma and Van Assche, 2010; Yi, 2003). However the growing importance of the global production network requires the social network approach as an alternative tool for international trade. The techniques and methods of social network analysis allow us to understand the dynamics of international trade as a whole.

The increasing role of the global production network in world trade implies that from a social network perspective, preserving a focal or a hub position in the industry could be a key competitiveness factor for international trade. Hence, identifying the social network status of a country's specific industry could be an alternative methodology to understand its competitiveness position in world trade.

In this paper, we try to describe the trends and changes of the world trade in a more simplified way by using social

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network analysis. And we also challenge to examine the role of logistics industry based on the social network analysis. These are the key motivations for this paper. For this purpose, we used an OECD-WTO Trade in Value Added (TiVA) database of 34 industries in 61 countries, and focused on the value added contained in the exports of individual industries.

In Section 2, the descriptive features of world trade from 2000 - 2011 are summarized in terms of centrality and block structure. In Section 3, out-degree centrality and the betweenness centrality of individual industries are compared. Out-degree centrality can be a straightforward index for the comparative advantage of exports in individual industries, while betweenness centrality can be interpreted as the index for the hubness of the individual industries in the global production network. In Section 4, focusing on the logistics industry, the potential deviation between the comparative advantage of industry and its social network implication in the world trade is examined. In Section 5, policy implications for world trade in the perspective of global production networks and social network analysis are drawn.

2. Description of social network methodology

2.1 Data description

Study data was obtained from the TiVA (Trade in Value Added) database published by OECD-WTO in 2015. The TiVA database was constructed using data from the OECD's Inter-Country Input-Output Table based on ISIC Rev.3. The database includes 34 industries in 62 countries, as well as other countries included in 'Rest of World' (RoW), in which there are 2 primary industries, 16 manufacturing industries, 2 non-manufacturing and 14 service industries.

Based on the TiVA database, a 2074×2074 country industry network matrix was constructed in which each node represents the value added embedded in 61 countries' exports involving 34 industries. We reduced the data to a more simplified form while preserving the meaningful network characteristics. Firstly, in order to analyze the inter-country network, the intra-country links between domestic industries were removed. Secondly, links that have the top 5% value added in trade were chosen. For example, in 2000, our network data shows 2,074 nodes and 2,574,630 links, and in 2011, there are 2,074 nodes and 3,034,554 links. From the 5% link reduction criteria, 128,702 links in 2000 and 151,589 links were used for analysis. These links account for 90.4% and 88.8% of the total value-added exports in 2000 and 2011 respectively (Table 1).

2.2 Clustering coefficient and group density

During the period of 2000-2011, using only the top 5% links, the network density^a and average degree^b increased, which means that each industry has a large number of trade relationships and that the global production network is strongly connected (De Benedictis and Tajoli, 2011; Hyun and Lee, 2016; Lee et al., 2015). The clustering coefficient is a measure of the degree to which nodes cluster together. The clustering coefficient increases as the likelihood of neighboring nodes in the center are linked with each other increases. The increased coefficient clustering means that cross-border trading between inter-country industries have converged. The mean distance between nodes, which is calculated by the average geodesic distance between any two nodes in a network has been reduced. This implies that cross-border trades have become so called small world networks.

The group density is calculated by the network density among the same industries abroad, and shows which industries have higher cross-border, intra-industry trade characteristics. The service industry has the lowest group density which indicates that the service industry has strong characteristics of non-tradable goods. Manufacturing and primary industries have the highest group density (Figure 1). Interestingly, the group density of the logistics^c industry has the highest value, implying that logistics industries are highly linked with other countries' logistics industries (Table 2).

Table 1. Summary of top 5% network properties

Year	2000	2011
Number of nodes	2,004	2,009
Number of links	128,702	151,589
Density	0.032	0.038
Average degree	64.223	75.455
Clustering coefficient	0.683	0.701
Mean distance	2.313	2.272
Diameter	5	5

^a In a network, density is defined as the ratio of the number of links present to the maximum possible that could exist.

^b The average degree of a network is the average of degrees over all nodes in the network.

^c We refer to the logistics industry as the s3 industry (transportation and storage) in TiVA database.

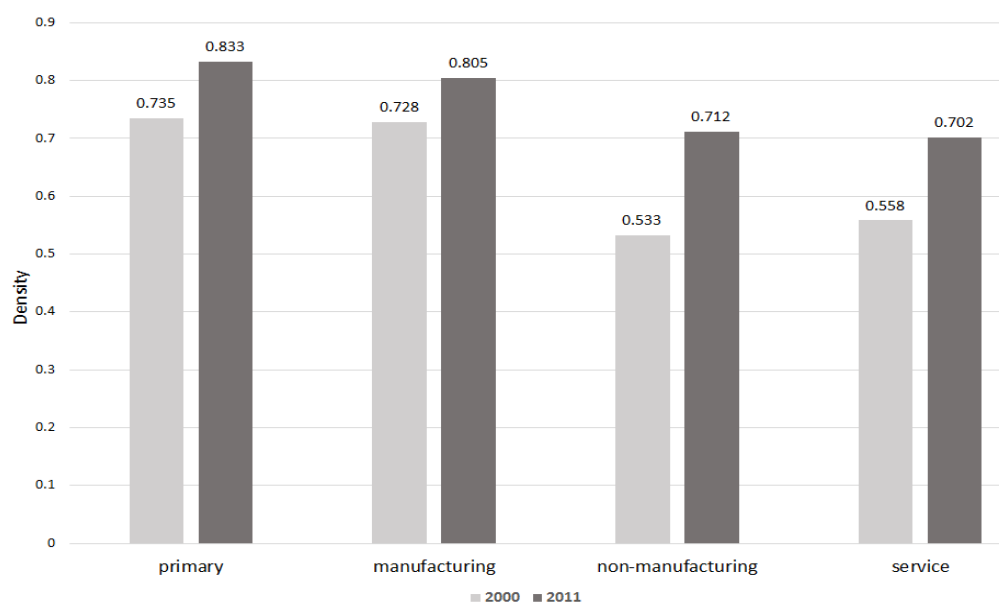


Figure 1. Group density of intra-industry trade (average number of 61 countries)

Table 2. Group density of intra-industry trade in each year

Sector code	Name of the industry	2000	2011
p1	Agriculture, hunting, forestry and fishing	0.848	0.917
p2	Mining and quarrying	0.709	0.814
m1	Food products, beverages and tobacco	0.891	0.945
m2	Textiles, textile products, leather and footwear	0.949	0.94
m3	Wood and products of wood and cork	0.673	0.721
m4	Pulp, paper, paper products, printing and publishing	0.850	0.895
m5	Coke, refined petroleum products and nuclear fuel	0.653	0.740
m6	Chemicals and chemical products	0.926	0.946
m7	Rubber and plastics products	0.822	0.894
m8	Other non-metallic mineral products	0.708	0.761
m9	Basic metals	0.880	0.931
m10	Fabricated metal products	0.823	0.888
m11	Machinery and equipment, nec	0.867	0.915
m12	Computer, Electronic and optical equipment	0.886	0.908
m13	Electrical machinery and apparatus, nec	0.828	0.891
m14	Motor vehicles, trailers and semi-trailers	0.702	0.793
m15	Other transport equipment	0.733	0.819
m16	Manufacturing nec; recycling	0.742	0.829
nm1	Electricity, gas and water supply	0.469	0.634
nm2	Construction	0.585	0.811
s1	Wholesale and retail trade; repairs	0.979	0.991
s2	Hotels and restaurants	0.703	0.858
s3	Transport and storage	0.997	1.000
s4	Post and telecommunications	0.731	0.862
s5	Financial intermediation	0.746	0.878
s6	Real estate activities	0.501	0.713
s7	Renting of machinery and equipment	0.399	0.669
s8	Computer and related activities	0.500	0.734
s9	R&D and other business activities	0.866	0.958
s10	Public admin. and defence; compulsory social security	0.119	0.206
s11	Education	0.091	0.188
s12	Health and social work	0.106	0.213
s13	Other community, social and personal services	0.708	0.854

3. Industry’s comparative status and social network analysis

3.1 Centrality

To examine the relative network positions among industries in the 61 countries, the degree centralities and betweenness centralities were determined. Degree centrality is calculated using the weighted links directly connected with each node; hence, the heavier the directed linked node, the higher the degree centrality. It is generally recognized as an index for a local network center in that the index of each industry is higher in the case of larger numbers of directly linked foreign industries. Regarding the direction of links, degree centrality is divided into out-degree and in-degree centrality. In our research of cross-border, value added trade, nodes with higher out-degree centrality can be interpreted as a focal value added exporting industry, while nodes with higher in-degree centrality can be regarded as a focal demander of foreign value added (Amador and Cabral, 2016).

Betweenness centrality is calculated by the statistical probability that node A is located in the shortest path between node A and node B. Therefore, it can be interpreted that a country featuring higher betweenness centrality performs a hub role in the trade network (da Rocha, 2009). The more central the node, the larger the number of shortest paths passing through this node (Barthélemy, 2011: 15)^d. Degree centrality and betweenness centrality determine an industry’s influence or its relative status within a complex network (Borgatti and Li, 2009; Ducruet and Lugo, 2013; Kim et al., 2011). Degree centrality measures the numbers of directly connected links and can be regarded as local hubness. In contrast, betweenness centrality is interpreted as global hubness in the sense that it is measured from the whole network system. Hence, when the industry with a higher betweenness centrality has a negative shock, macroeconomic volatility would increase (Sun et al., 2016).

From 2000-2011, the top 10 centrality industries are as follows: Firstly, R&D industries in the U.S, Germany and England (USAs9, DEUs9, GBRs9), U.S. and German wholesale and retail industries (USAs1, DEUs1), U.S. financial intermediation (USAs5), and Saudi mining and quarrying (SAUp2) comprise the group of the highest out-degree centrality, which means these are leading industries of value-added exports. Furthermore in 2011, Russian mining and quarrying (RUSp2), as well as Chinese wholesale and retail industries (CHNs1) emerged in the top 10 value-added exporters.

Secondly, industries such as car manufacturing, machinery, and chemical industry in Germany (DEUm14, DEUm11, DEUm6) as well as computer, electronic and optical equipment industry in China (CHNm12) have maintained the highest in-degree centrality. This implies that these industries are assembling and processing centers using foreign value-added imports. Interestingly, accounting for changes in the top 10 in-degree centrality industries, China has been a driving force in the global trade network. In addition other Chinese industries such as electrical machinery and apparatus (CHNm13), textiles, textile products, leather and footwear (CHNm2), and machinery and equipment (CHNm11) have emerged as top 10 industries (Table 3).

Thirdly, computer, electronic and optical equipment industries in China (CHNm12) has the highest betweenness centrality. German industries such as car manufacturing, machinery, and chemical industry are the in the group of dominant betweenness centrality.

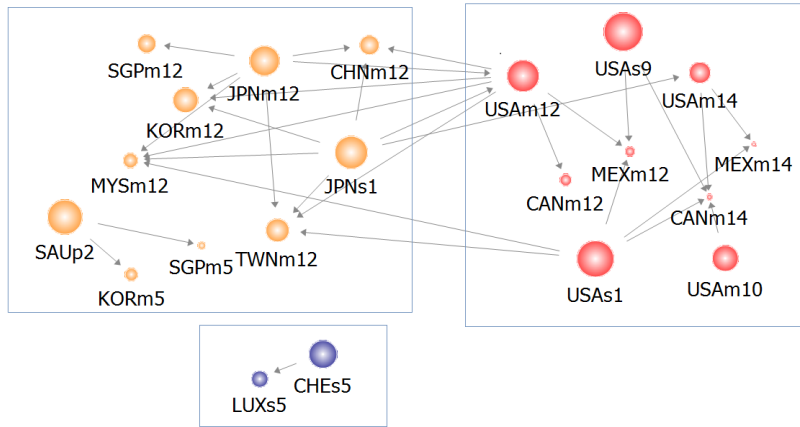
Table 3. The top 10 centrality industries

Rank	2000			2011		
	OC	IC	BC	OC	IC	BC
1	USAs9	DEUm14	DEUm14	USAs9	CHNm12	CHNm12
2	USAs1	USAm12	USAm12	RUSp2	DEUm14	RUSp2
3	USAs5	CHNm12	USAs1	SAUp2	DEUm11	DEUm14
4	DEUs1	DEUm11	DEUm11	DEUs9	CHNm13	DEUm11
5	SAUp2	MYSm12	USAs9	USAs1	DEUm6	USAs9
6	DEUs9	GBRm12	RUSp2	RUSs1	CHNm2	DEUm6
7	JPNs1	DEUm12	DEUm6	CHNs1	CHNm11	RUSs1
8	GBRs9	TWNm12	USAs3	DEUs1	DEUm9	CHNm2
9	USAs3	USAm14	DEUs1	GBRs9	KORm12	GBRs9
10	DEUs3	DEUm6	USAm6	USAs5	ITAm11	DEUs1

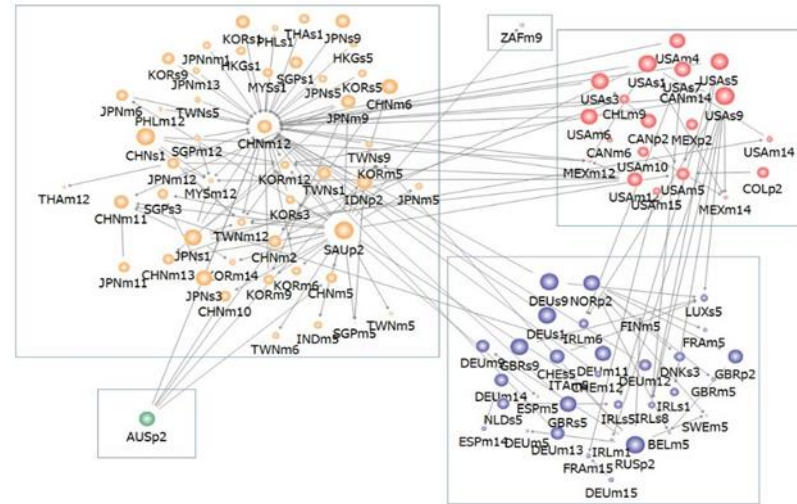
Note: OC, IC and BC are out-degree centrality, in-degree centrality and betweenness centrality, respectively.

^d The betweenness centrality of node i is calculated by $\sum_{j < k} g_{jk}(n_i) / g_{jk} / ((g-1)(g-2) / 2)$. In this equation, $(g-1)(g-2) / 2$ is the number of node pairs that does not pass node i , $\sum_{j < k} g_{jk}(n_i) / g_{jk}$ is the probability the node i is located in the shortest path between node j and node k (Wasserman and Faust, 1994).

In 2000



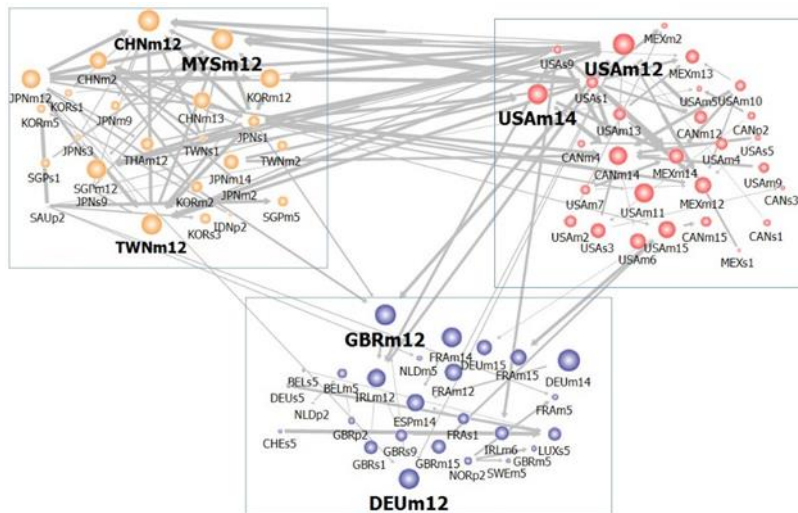
In 2011



Note: The circle size signifies out-degree centrality.

Figure 2. Links over 1 billion U.S. dollar value added export

In 2000



In 2011

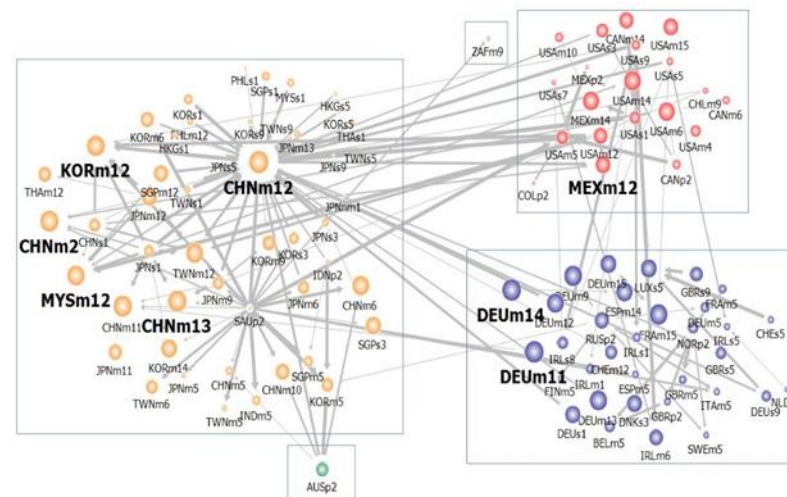
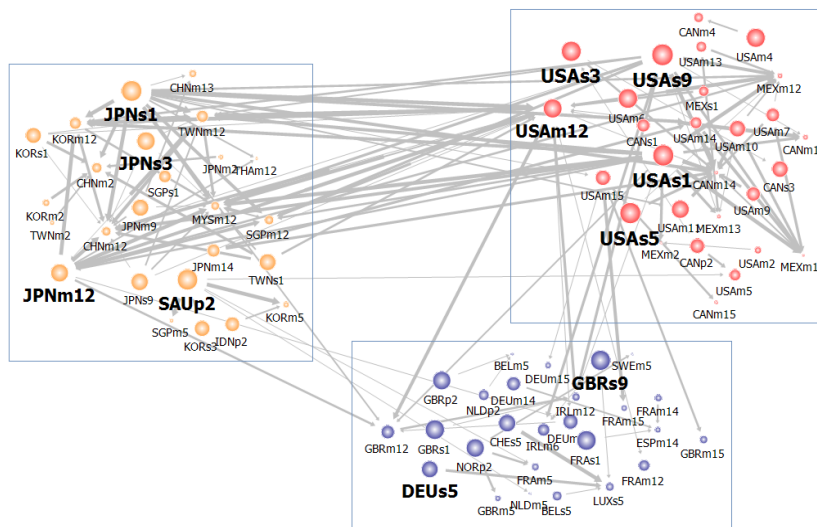


Figure 3. In-degree centrality with top 158 links

In 2000



In 2011

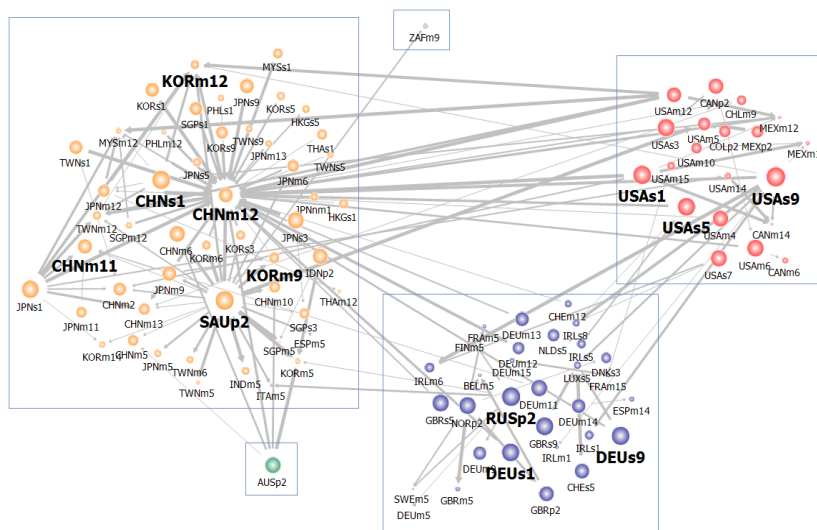


Figure 4. Out-degree centrality with top 158 links

A simplified structure of the cross-border trade network is shown in Figure 2, in which links accounting for in excess of 1 billion U.S. dollars are visualized. The remarkable phenomenon is that the world value-added trade had grown rapidly, establishing a highly integrated global production network encompassing most major industries.

To examine the changing status among principal nodes and links in world trade, the top 158 links and corresponding nodes are comparably visualized. In regard to higher in-degree centrality, major industries that imported and processed value added products were industries in the U.S., Germany, Taiwan, and Malaysia in 2000 (Figure 3). However, in 2011, industries in China and Germany rose as the largest importers of foreign value added. These changes imply that in the early period of globalization, the global production network was mainly organized by two different groups of industries. The first type includes processing and assembling processes utilizing cheap labor and assembling facilities. This includes the computer and electronic industries in China and Malaysia, as well as textiles and textile products, and footwear industries in China. China's role and its repercussions for world trade was examined in previous studies (Fung et al., 2015). The other industry type includes imported foreign value added for domestic final demand such as the computer industries in the U.S.

Concerning the out-degree centrality, there has also been significant changes (Figure 4). In 2000, developed countries such as the U.S., Japan, and Germany had industries that were dominant in value-added exports. However, in 2011, several major industries in China and Korea, such as computer, electronic and optical equipment and machinery and equipment sectors became the cores in value-added exports. As the global production network has developed, the East Asian manufacturing countries have played an increased role in global value-added trade.

3.2 Brokerage positions

Nodes could be differentiated by their roles in the network even though they have higher centrality similarly. Evaluating the types of brokerage roles, top brokering nodes are classified into 4 brokerage roles: coordinator, gatekeeper, representative, and liaison (Figure 5). Each industry plays a distinctive role in connecting various regional groups (America, Asia, Africa, Europe, Oceania) even though all nodes actively participate in global production networks in exporting value added (Gould and Fernandez, 1989).

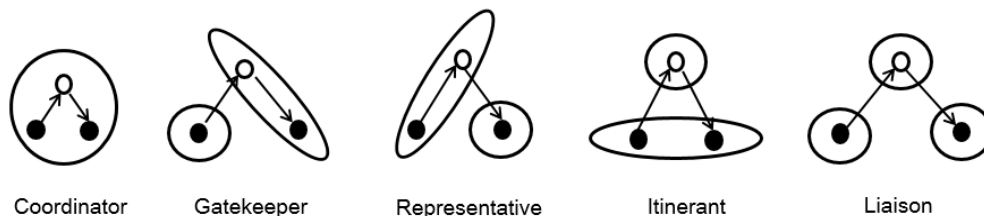


Figure 5. Types of brokerage role (based on white circle)

The brokerage index is measured based on its roles of brokering between regions. During 2000- 2011, the brokerage index increased on average. The coordinator index rose significantly, while the liaison index marginally increased (Figure 6). From this trend, the majority of nodes are operating as coordinator, indicating that cross-border trade is apparently composed of nodes and links which are brokering in the same region. Gatekeeper and representative roles fall in second place, increasing the pattern of these roles reflects the importance of export or import hub industries in the region.

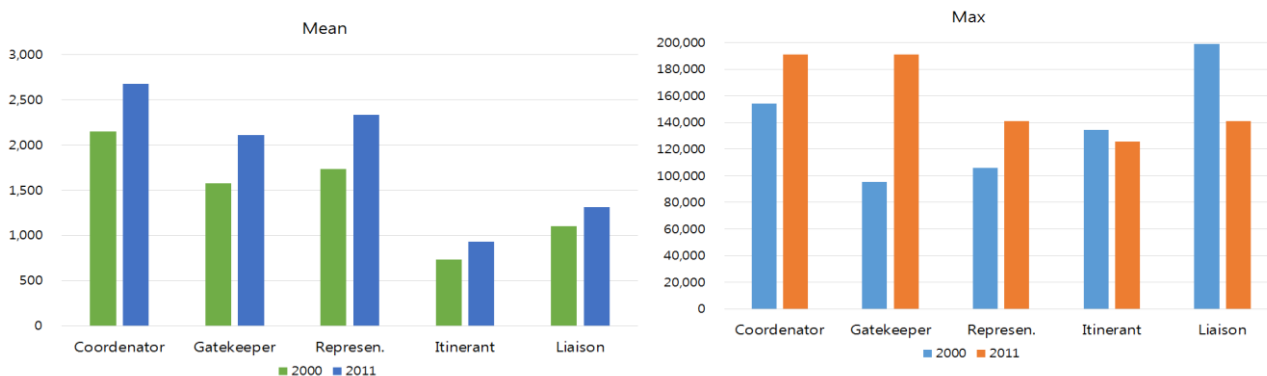


Figure 6. Mean and maximum brokerage index

The top 10 brokering industries are listed in Table 4. During the period of 2000- 2011, German machinery, chemical, wholesale and retail have maintained the highest brokerage index in coordinator, gatekeeper, and representative roles. In addition, the German service industries, such as wholesale and retail (DEUs1), and transport and storage (DEUs3), ranked in the top 10.

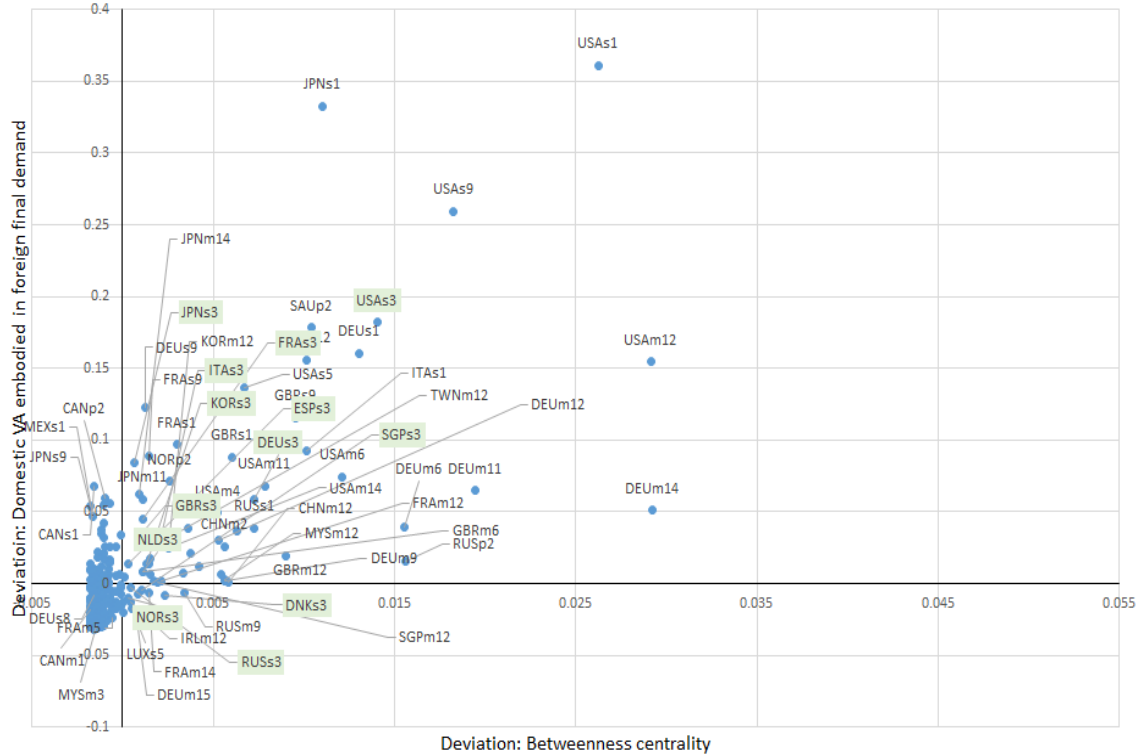
Table 4. The top ranking brokers in the networks of foreign value added in export

Rank	Coordinator		Gatekeeper		Representative		Liaison	
	2000	2011	2000	2011	2000	2011	2000	2011
1	DEUm11	DEUm6	DEUm11	DEUm6	DEUm11	DEUm11	USAm12	USAm6
2	DEUm6	DEUm11	DEUm6	DEUm11	DEUm6	DEUm6	USAm6	CHNm12
3	DEUs1	DEUs1	DEUm14	DEUm14	DEUs1	CHNm12	USAs1	USAs1
4	DEUm14	DEUm14	GBRm12	CHNm12	JPNm12	DEUs1	USAs3	AUSp2
5	DEUs3	RUSp2	ITAs1	RUSp2	DEUs3	DEUm14	USAm11	USAs9
6	ITAs1	DEUm9	DEUm12	DEUs1	GBRs1	RUSp2	USAm15	USAs3
7	DEUm9	DEUs3	DEUs1	RUSs1	ITAs1	DEUs3	USAm4	USAm11
8	DEUm12	DEUm13	USAm12	GBRs9	JPNs1	CHNs1	USAs9	USAm12
9	DEUm13	GBRs9	DEUs3	CHNm11	USAs1	DEUm9	JPNm12	CHNm11
10	GBRs1	DEUm1	GBRs1	CHNm6	USAs3	RUSm9	USAm14	CHNm2

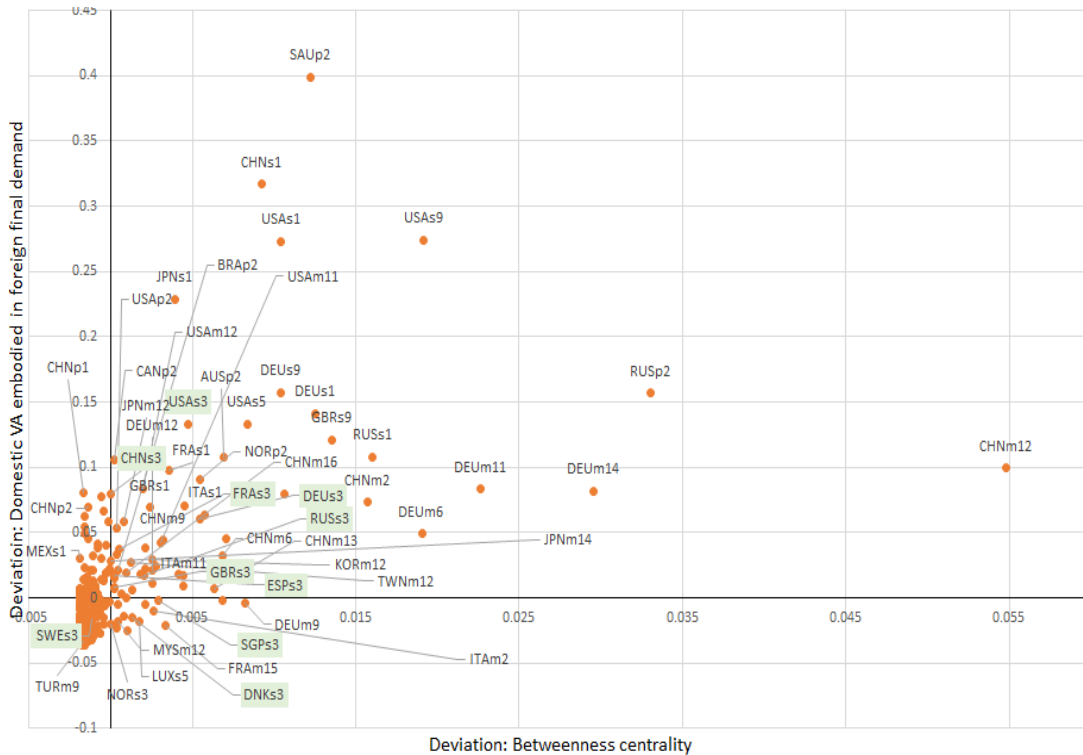
Interestingly, regarding the liaison role, U.S. industries, such as chemicals and chemical products (USAm6), wholesale and retail trade (USAs1), R&D (USAs9), transport and storage (USAs3) have surpassed that of other

countries. The unchanged status of U.S. industries implies that U.S. industries have maintained the overwhelming power to coordinate a global production network across at least three different continents. However, specific industries in emerging countries have threatened U.S. industries such as Chinese computer, electronics, and optical equipment (CHNm12), Australian mining and quarrying (AUSp2), and Chinese machinery and equipment (CHNm11).

In 2000



In 2011



Note: The vertical axis is a mean value of value-added export, the horizontal axis is a mean value of betweenness centrality index.

Figure 7. Value-added exports and betweenness centrality

In order to examine the relative role in the global production network, the nodes and links whose value added originated from the logistics industry of each country (the s3 industry), among the top 5% of foreign value added links, were extracted from the network. Subsequently, the in-degree centrality is calculated. From this analytical structure, a higher in-degree centrality corresponds with a larger value added incurred from the logistics industry. In figure 8, a simplified network with higher in-degree centrality, and includes in excess of 100 million U.S. dollar links are visualized.

In 2000, the higher in-degree centrality industries are as follows: Danish transport and storage (DNKs3), German transport and storage (DEUs3); Singaporean transport and storage (SGPs3); German computer, electronic and optical equipment (DEUm12). In 2011, these industries included Chinese computer, electronic and optical equipment (CHNm12), Singaporean transport and storage (SGPs3), Danish transport and storage (DNKs3), German motor vehicles, trailers and semi-trailers (DEUm14), Chinese electrical machinery and apparatus (CHNm13), and machinery and equipment (CHNm11).

Logistics industries which reveal higher in-degree centrality such as Danish transport and storage (DNKs3), German transport and storage (DEUs3), Singaporean transport and storage (SGPs3), have the characteristics of utilizing the logistics industries of other countries as an important source of their value added.

Notably, manufacturing industries could incur a large portion of their value added from the logistics industry. Manufacturing industries include Chinese computer, electronic and optical equipment (CHNm12), German motor vehicles, trailers and semi-trailers (DEUm14), Chinese electrical machinery and apparatus (CHNm13), and machinery and equipment (CHNm11). This argument is a microeconomic version of Lean et al. (2014) in which logistics infrastructure Granger causes the economic growth with feedback effect.

5. Concluding remarks

Using social network analysis (SNA), this paper examines the inter-country, inter-industry, value-added relationships. Based on the TiVA database during the period of 2000-2011, the degree of interconnectedness of industries could imply major structural changes and intensified trends in global production networks. That is to say, world value-added trade has grown rapidly, establishing highly integrated global production networks encompassing the majority of major industries.

The main results of this study are as follows:

Firstly, regarding the top 10 in-degree centrality industries, China has been a driving force in the global trade network. China's computer, electronic, and optical equipment industries (CHNm12) have become the highest in-degree centrality industries.

Secondly, industries in China, Germany, and the U.S. have emerged as the largest importers of foreign value added, implying that the global production network is dominated by two different types of industries. The first type of industry includes processing and assembling facilities in China and Germany. The other type of industry involves importing foreign value added largely for domestic final demand such as computer industries in the U.S.

Thirdly, for various types of brokerage roles, there are also two different types of industries that have significant roles in the world trade network. U.S. industries are acting as liaisons that import from and export to countries belonging to different continents. It indicates that the overwhelming power to mediate the global production network should be important among disconnected groups, while Chinese and German industries are mostly operating as coordinator or gatekeeper.

Lastly, manufacturing industries in China and Germany have emerged as featuring higher in-degree centrality, and incur a large portion of their value added from the logistics industry. This finding strongly suggests that those leading industries playing the role of hubness in the global production network cannot sustain their network status without efficient utilization of the logistics industry.

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