Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 242 (2024) 420–427

Procedia Computer Science

www.elsevier.com/locate/procedia

11th International Conference on Information Technology and Quantitative Management (ITQM 2024)

Network analysis of economic sectors in the world economy

Fuad Aleskerov[ab], Yetkin Cinar[c], Ivan Deseatnicov[a], Elena Sergeeva[a], Daniil Tkachev[a], Vyacheslav Yakuba[ab]

[a]*HSE University, 20 Myasnitskaya ulitsa, Moscow 101000, Russia*
[b]*Institute of Control Sciences of Russian Academy of Sciences, 65 Profsoyuznaya ulitsa, Moscow 117997, Russia*
[c]*Ankara Üniversitesi, Dögol Caddesi 06100, Ankara, Turkey*

Abstract

We consider a network of intermediate inputs trade between sectors of OECD Countries' in 2020. Centrality indices are used to identify most vulnerable sectors in the network of intermediate inputs trade between 45 manufacturing and non-manufacturing sectors of 76 countries. The network is based on the official data of inter-country input-output tables published in 2023 by OECD. We apply new centrality indices to identify sectors, which might be under the risk in case of an economic shock.

Keywords: : network analysis; OECD countries; key economic sectors

1. Introduction

The network of intermediate inputs trade between sectors of the economies of the countries can be considered as a directed weighted graph. Each sector and transaction between sectors are considered as a node and an edge in this graph respectively. The arrow direction and weight of each edge show direction and the value of considered transaction.

The network is based on the official data of intermediate inputs trade between sectors of countries in 2020 [1]. OECD provides Inter-Country Input-Output (ICIO) tables for a period 1995-2020. Inter-country input-output tables have been widely used to examine global production structure [2, 3]. An input-output table can be naturally interpreted as a network; in which each sector corresponds to a vertex and trades between each vertex can be considered as edges of that network. We refer to them as OECD-ICIO tables and work with the 2023 edition (OECD 2023). It covers 76 countries (including all OECD, European Union, ASEAN and G20 countries) plus rest of the world and 45 industries.

10.1016/j.procs.2024.08.165

Industry classification aligns to International Standard Industrial Classification (ISIC) of all economic activities revision 4, and covers 17 manufacturing sectors and 28 non-manufacturing sectors. We choose input-output tables for our network analysis as they present transactions in intermediate inputs between sectors which are reported in millions USD in the OECD-ICIO tables, and thus can serve as an ideal source for network construction.

Centrality indices are used to identify most vulnerable sectors, which might be under the risk in case of an economic shock in the network of intermediate inputs trade between economic sectors [4]. New centrality indices take into account properties of vertices and group influence. In this work we apply new centrality indices, which were introduced in [5] with different values of vertices parameters [6].

The economic networks literature explores phenomena like productivity shock diffusion through production networks and their aggregate macroeconomic impact [7-11].

An identification of key sectors via network centrality measures on input-output networks can reveal which sectors are the most vulnerable and should be prioritized for support/intervention. Network analysis and centrality indices are thus frequently applied to input-output tables, both nationally and globally. The paper [12] applied random walk and count-betweenness centralities to cluster countries, while the article [13] used Kleinberg's hub/authority centralities. The paper [14] proposed centrality capturing countries' upstream/midstream/downstream roles in global value chains. Other studies like [15-17] have similarly examined centrality in national/global input-output and value chain networks.

In our study we rely on the OECD-ICIO tables released in 2023. Using similar tables [18] used classical Bonacich-Katz network centrality indices to show the evolution of influential sectors in the global economy. They documented that traditional sectors like motor vehicles have more stable production structure while innovative sectors like IT manufacturing exhibit stronger fluctuations. In this regard, [19] using Japan's firm-level data and classic centrality indices showed that innovation is associated with firms' sector centrality. Another study that is closely related to ours is [20]. The paper investigates global value chains (GVCs) at the country-industry level through a network lens, mapping them into Global Value Networks (GVNs) constructed from the OECD-ICIO tables. Time series of GVN properties like total flow value, edge weights, node/edge counts, geographic integration, and network communicability are analyzed to contrast the evolution of GVC structures for China and Italy textiles, wearing apparel, leather and related products, Germany and United Stated motor vehicles, trailers and semi-trailers, Japan and Ireland chemicals and pharmaceutical products, United States and China computer, electronic and optical products.

In comparison to aforementioned papers our work's contribution is three-fold. First, we offer an application of novel Bundle and Pivotal indices to OECD ICIO tables network analysis. As mentioned above these indices take into account node properties and group influences. Second, we uncover the sectors that are vulnerable to disruptions and shocks from the group influence perspective. Finally, we reveal which are those groups that could potentially induce disruptions in the global value chains. To the best of our knowledge there has not been such study before.

2. Network analysis

To construct the process of input-output (I-O) flows we use network analysis. The network is denoted as G^0 countries-sectors are represented as the set of vertices V, and the edges with weights w_{ij} represent the value of outflow/inflow amounts of products sent from country-sector i to country-sector j (or, for the sake of simplicity let us use only "sector" instead of "country-sector".).
For example, consider three sectors (A, B, C) in the I-O network. Sector A sends (or, exports) to sector C goods in \$400 of this product (w^0_{AC}= 100), sector B exports to C goods in \$50 (w^0_{BC} = 50), C exports to D goods in \$200 (w^0_{CD} = 200).
This can be represented as directed weighted graph (see Fig. 1).

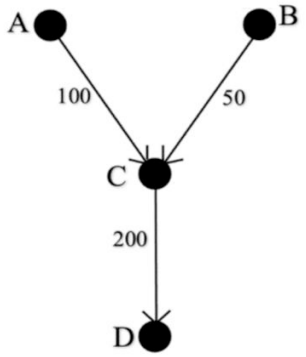

Fig. 1. An example of network.

One of the main aims of network analysis is to identify key vertices. There are serval classic centrality indices such as Eigenvector centrality, PageRank centrality, etc. In [21] it is argued that most of publications on classical centrality indices do not take into account parameters and group influence of vertices.
We consider the following centrality indices, which were introduced in [5].

2.1. In-degree index

For each $i \in V$ it is defined

$$CI^0(i) = \sum_j w_{ji}^0 \tag{1}$$

In other words, $CI^0(i)$ is equal to the value of total import of i..
In other words, $CI^0(i)$ is equal to the value of total import of i. Consider the network in Figure 3. The values of In-degree index are the following.
$CI^0(A) = 0, CI^0(B) = 0, CI^0(C) = 100 + 50 = 150, CI^0(D) = 200$
In [Aleskerov & Yakuba, 2020] new centrality indices (Bundle, Pivotal indices) are introduced taking into account group influence of vertices and the parameters of vertices.

2.2. Bundle index

For each $i \in V$ it is defined the set S, $S \subseteq V \setminus \{i\}, |S| \le k, \forall j \in S, w_{ji}^0 \neq 0$ .The bundle index for $i \in V$ is defined

$$BI^0(i) = \sum_S BI_i^0(S), \tag{2}$$

where $BI^0(i)$ is equal to 1 if $\sum_{j \in S} w_{ji}^0 \ge q_i$, and 0 otherwise.

In other words, $BI^0(i)$ is equal to the number of sets (we call them critical sets), which has not more than k incoming edges and the sum of weights not less than q_i .

Consider the network in Figure 1. Assume that $k = 3, q_A = q_B = 90, q_C = 100, q_D = 150$.Then, critical groups for each sector are the following.

$A: \emptyset, B: \emptyset, C: \{A\}, \{A, B\}, D: \{C\}$
The values of Group influence index are the following.

$BI^0(A) = 0, BI^0(B) = 0, BI^0(C) = 2, BI^0(D) = 1.$

2.3. Pivotal index

The node $j_p \in V$ is called pivotal for the node $i \in V$, if

$$\sum_{j \in S} w_{ji}^0 \geq q_i, \sum_{j \in S \setminus \{j_p\}} w_{ji}^0 < q_i \tag{3}$$

The pivotal index for $i \in V$ is defined

$$PI^0(i) = \sum_S PI(S) \cdot |S|, \tag{4}$$

where $PI_i^0(S)$ is the number of pivotal nodes $j_p \in S$. In other words, sector j is called pivotal in crticial group S if the group S without j is not critical.

Consider the network in Figure 1. Assume that $q_A = q_B = 90, q_C = 100, q_D = 150$. Then, pivotal sectors for each critical group are the following.

$\{A\}: \{A\}, \ \{A, B\}: \{A\}, \ \{C\}: \{C\}$

The values of Group influence index are the following.

$PI^0(A) = 0, PI^0(B) = 0, PI^0(C) = PI_i^0(\{A\}) \cdot 1 + PI_i^0(\{A, B\}) \cdot 2 = 3, PI^0(D) = PI_i^0(\{C\}) \cdot 1 = 1.$

3. Data sources

We choose input-output tables for our network analysis as it features transactions in intermediate inputs between sectors which are reported in million USD in the OECD-ICIO tables. Every transaction between two sectors can be considered as an edge in a network. We examine all the country-sector data included in the dataset for year 2020 to show the properties and the results of the evaluation of centrality indices.

4. Results

In this paper critical groups have been calculated for 3 manufacturing industries in 2 countries: Textiles, textile products, leather and footwear (China and Italy), Motor vehicles, trailers and semi-trailers (Germany and United States), Computer, electronic and optical equipment (United States and China). Each group has a size of exactly 3 ($k = 3$), and the minimum share of a participant in the group is 10%.

The data of 2020 and the value of quota q = 100 million USD have been used for the calculation of 3 types of networks (full network, network without the loops, network without the domestic trade).

4.1. Textiles, textile products, leather and footwear (C13T15)

Table 1 shows the top 3 critical groups for the Textile, textile products, leather and footwear (C13T15) industry in two countries China (CHN) and Italy (ITA), for 3 types of networks, in descending order of influence share.

Table 1. Critical groups for CHN_C13T15 and ITA_C13T15.

Full network		Network without the loops		Network without the domestic trade	
CHN_C13T15	**ITA_C13T15**	**CHN_C13T15**	**ITA_C13T15**	**CHN_C13T15**	**ITA_C13T15**
CHN_A01_02 (52.7%), CHN_C20 (24.3%), CHN_G	ITA_C13T15 (62.2%), ITA_G (23.5%), CHN_C13T15	CHN_A01_02 (52.7%), CHN_C20 (24.3%), CHN_G	ITA_G (45.4%), CHN_C13T15 (27.6%), ITA_M (26.9%)	VNM_C13T15 (56.5%), ITA_C13T15 (22.4%),	CHN_C13T15 (76.5%), CHN_G (13.1%), TUR_C13T15

(23.0%) **19.3%**	(14.3%) **39.9%**	(23.0%) **19.3%**	**20.6%**	BRA_A01_02 (21.2%) **1.43%**	(10.4%) **7.45%**
CHN_A01_02 (60.5%), CHN_C20 (27.8%), CHN_H49 (11.7%) **16.9%**	ITA_C13T15 (62.4%), ITA_G (23.6%), ITA_M (14.0%) **39.7%**	CHN_A01_02 (60.5%), CHN_C20 (27.8%), CHN_H49 (11.7%) **16.9%**	ITA_G (49.5%), CHN_C13T15 (30.1%), ITA_N (20.4%) **18.9%**	VNM_C13T15 (57.8%), ITA_C13T15 (22.9%), JPN_G (19.3%) **1.40%**	CHN_C13T15 (76.8%), CHN_G (13.2%), FRA_G (10.0%) **7.41%**
CHN_A01_02 (61.3%), CHN_G (26.8%), CHN_H49 (11.9%) **16.6%**	ITA_C13T15 (65.2%), ITA_G (24.6%), ITA_N (10.2%) **38.0%**	CHN_A01_02 (61.3%), CHN_G (26.8%), CHN_H49 (11.9%) **16.6%**	ITA_G (49.8%), ITA_M (29.6%), ITA_N (20.6%) **18.8%**	VNM_C13T15 (58.5%), BRA_A01_02 (21.9%), JPN_G (19.6%) **1.38%**	CHN_C13T15 (78.9%), TUR_C13T15 (10.8%), FRA_G (10.3%) **7.22%**

The total deliveries, including loops, to the CHN_C13T15 sector amount to 1208742.85 million USD. The largest critical group (CHN_A01_02, CHN_C20, CHN_G) holds a share of 19.3%. At the same time, a maximum critical group of only foreign suppliers (VNM_C13T15, ITA_C13T15, BRA_A01_02) has an impact of 1.43%. The most significant suppliers to CHN_C13T15 are Agriculture, hunting, forestry (CHN_A01_02), Chemical and chemical products (CHN_C20), Wholesale and retail trade; repair of motor vehicles (CHN_G) and Land transport and transport via pipelines (CHN_H49) with shares 10.2%, 4.7%, 4.45% and 2.0%, respectively. Also, Textiles, textile products, leather and footwear (C13T15) of Viet Nam (VNM) and Italy (ITA) have a value of 0.81% and 0.32% of the total inflow. BRA_A01_02 (Brazil, Agriculture, hunting, forestry) and JPN_G (Japan, Wholesale and retail trade; repair of motor vehicles) are 0.3% and 0.27%.

The sector ITA_C13T15 has different critical groups in the full network and the network without the loops. The total inflow is equal to 53235.98 million USD. The most influential groups are ITA_C13T15, ITA_G, CHN_C13T15 (the share is 39.9%), ITA_G, CHN_C13T15, ITA_M (20.6%) and CHN_C13T15, CHN_G, TUR_C13T15 (7.45%) in each type of network. The sector itself is one of the most important suppliers, having a share of 24.8%. The following Italian sectors are also important: Wholesale and retail trade; repair of motor vehicles (ITA_G) with a share of 9.4%, Professional, scientific and technical activities (ITA_M) with a share of 5.6% and Administrative and support services (ITA_N) with a share of 3.9%. Of the foreign sectors, the most influential ones are Textiles, textile products, leather and footwear of China (CHN_C13T15 – 5.7%) and Türkiye (TUR_C13T15 – 0.78%), Wholesale and retail trade; repair of motor vehicles of China (CHN_G – 0.98%) and France (FRA_G – 0.74%).

4.2. Motor vehicles, trailers and semi-trailers (C29)

The top 3 critical groups for Motor vehicles, trailers and semi-trailers (C29) of Germany (DEU) and United States (USA) in descending order of the share of influence, for 3 types of networks, are shown in Table 2.

Table 2. Critical groups for DEU_C29 and USA_C29.

Full network		Network without the loops		Network without the domestic trade	
DEU_C29	**USA_C29**	**DEU_C29**	**USA_C29**	**DEU_C29**	**USA_C29**
DEU_C29 (71.0%), DEU_G (17.1%), DEU_C25 (11.8%) **38.8%**	USA_C29 (45.9%), USA_G (33.7%), USA_C25 (20.4%) **47.4%**	DEU_G (43.6%), DEU_C25 (30.1%), DEU_M (26.3%) **15.2%**	USA_G (52.6%), USA_C25 (31.8%), USA_M (15.6%) **30.4%**	CZE_C29 (42.5%), HUN_C29 (29.7%), ESP_C29 (27.8%) **3.43%**	MEX_C29 (52.7%), JPN_C29 (26.5%), CAN_C29 (20.7%) **7.1%**
DEU_C29 (72.1%), DEU_G (17.4%), DEU_M (10.5%) **38.2%**	USA_C29 (51.2%), USA_G (37.6%), USA_M (11.2%) **42.5%**	DEU_G (44.9%), DEU_C25 (31.0%), DEU_C28 (24.1%)	USA_G (53.6%), USA_C25 (32.4%), USA_C24 (14.0%)	CZE_C29 (42.7%), HUN_C29 (29.8%), POL_C29	MEX_C29 (56.3%), JPN_C29 (28.3%), KOR_C29

		14.8%	**29.8%**	(27.4%) **3.41%**	(15.3%) **6.7%**
DEU_C29 (76.2%), DEU_C25 (12.7%), DEU_M (11.1%) **36.2%**	USA_C29 (60.2%), USA_C25 (26.7%), USA_M (13.1%) **36.2%**	DEU_G (45.3%), DEU_C25 (31.4%), DEU_C22 (23.3%) **14.7%**	USA_G (54.3%), USA_C25 (32.9%), MEX_C29 (12.8%) **29.4%**	CZE_C29 (43.5%), ESP_C29 (28.5%), POL_C29 (27.9%) **3.35%**	MEX_C29 (57.5%), JPN_C29 (29.0%), CHN_C26 (13.5%) **6.5%**

In total, the supplies to DEU_C29 is 266219.24 million USD. The group of DEU_C29, DEU_G, DEU_C25 has a group influence of 38.8% on the total trade in this sector, and DEU_G, DEU_C25, DEU_M group has a share of 15.2%. CZE_C29, HUN_C29, ESP_C29 with a share of 3.43% is a significant group in international trade. The sector is a deliver for itself, having a share of 27.6%. The major suppliers are the following German sectors: Wholesale and retail trade; repair of motor vehicles (DEU_G), Fabricated metal products (DEU_C25), Professional, scientific and technical activities (DEU_M), Machinery and equipment, nec (DEU_C28) and Rubber and plastics products (DEU_C22). Motor vehicles, trailers and semi-trailers of Czechia (CZE_C29), Hungary (HUN_C29), Spain (ESP_C29) and Poland (POL_C29) present foreign industries.

The total input value of USA_C29 is 459186.49 million USD. The group USA_C29, USA_G, USA_C25 has a 47.4% impact on the supply of this sector. Additionally, the influence of the groups of USA_G, USA_C25, USA_M and MEX_C29, JPN_C29, CAN_C29 is 30.4% and 7.1%, respectively. This sector is also delivering a large share of 21.8% for itself. The predominant influence is exerted by domestic industries, such as Wholesale and retail trade; repair of motor vehicles (USA_G), Fabricated metal products (USA_C25), Professional, scientific and technical activities (USA_M) and Basic metals (USA_C24). Motor vehicles, trailers and semi-trailers of Mexico, Japan, Canada, Korea (MEX_C29, JPN_C29, CAN_C29, KOR_C29) and Computer, electronic and optical equipment of China (CHN_C26) have the most impact from other countries.

4.3. Computer, electronic and optical equipment industry (C26)

The 3 most influential groups of the Computer, electronic and optical equipment industry (C26) in the United States (USA) and China (CHN) are given in descending order of importance in Table 3.

Table 3. Critical groups for USA_C26 and CHN_C26.

Full network		Network without the loops		Network without the domestic trade	
USA_C26	**CHN_C26**	**USA_C26**	**CHN_C26**	**USA_C26**	**CHN_C26**
USA_M (63.8%), USA_C26 (21.8%), USA_G (14.4%) **54.7%**	CHN_C27 (40.3%), CHN_G (30.9%), TWN_C26 (28.8%) **13.3%**	USA_M (72.7%), USA_G (16.4%), CHN_C26 (10.9%) **48.0%**	CHN_C27 (40.3%), CHN_G (30.9%), TWN_C26 (28.8%) **13.3%**	MEX_C26 (58.9%), KOR_C26 (22.1%), TWN_C26 (18.9%) **3.26%**	TWN_C26 (45.5%), KOR_C26 (38.6%), JPN_C26 (15.9%) **8.4%**
USA_M (67.0%), USA_C26 (23.0%), CHN_C26 (10.0%) **52.1%**	CHN_C27 (41.0%), CHN_G (31.5%), CHN_C24 (27.5%) **13.0%**	USA_G (45.0%), CHN_C26 (29.9%), USA_L (25.2%) **17.5%**	CHN_C27 (41.0%), CHN_G (31.5%), CHN_C24 (27.5%) **13.0%**	MEX_C26 (60.0%), KOR_C26 (22.6%), GBR_M (17.4%) **3.20%**	TWN_C26 (47.6%), KOR_C26 (40.4%), VNM_C26 (12.0%) **8.0%**
USA_M (72.7%), USA_G (16.4%), CHN_C26 (10.9%) **48.0%**	CHN_C27 (41.9%), TWN_C26 (30.0%), CHN_C24 (28.1%)	USA_G (46.7%), CHN_C26 (31.0%), USA_N (22.3%) **16.9%**	CHN_C27 (41.9%), TWN_C26 (30.0%), CHN_C24 (28.1%)	MEX_C26 (60.7%), KOR_C26 (22.8%), CHN_G (16.6%) **3.17%**	TWN_C26 (48.2%), KOR_C26 (40.9%), MYS_C26 (10.9%)

12.8%	**12.8%**	**7.9%**

The total receiving value of USA_C26 is 115229.27 million USD. The most significant group (USA_M, USA_C26, USA_G) holds a share of 54.7%. In the network without the loops, USA_M, USA_G, CHN_C26 have the most group influence of 48.0%, and in the network without the domestic trade – MEX_C26, KOR_C26, TWN_C26 with 3.26%. In-country deliveries from Professional, scientific and technical activities (USA_M), itself (USA_C26), Wholesale and retail trade; repair of motor vehicles (USA_G), Real estate activities (USA_L) and Administrative and support services (USA_N) are crucial for the sector. Besides, Computer, electronic and optical equipment of China, Mexico, Korea and Chinese Taipei (CHN_C26, MEX_C26, KOR_C26, TWN_C26), Professional, scientific and technical activities of the United Kingdom (GBR_M) and Wholesale and retail trade; repair of motor vehicles of China (CHN_G) are substantial.

CHN_C26 input value is equal to 1357206.56 million USD. The group of CHN_C27, CHN_G, TWN_C26 accounts for 13.3% of the inflow to CHN_C26, and TWN_C26, KOR_C26, JPN_C26 – 8.4%. Vital domestic supplying sectors are Electrical equipment (CHN_C27), Wholesale and retail trade; repair of motor vehicles (CHN_G) and Basic metals (CHN_C24). Also, Computer, electronic and optical equipment of Chinese Taipei, Korea, Japan, Viet Nam and Malaysia (TWN_C26, KOR_C26, JPN_C26, VNM_C26, MYS_C26) are substantial.

The description of sectors names can be downloaded by https://www.oecd.org/sti/ind/inter-country-input-output-tables.htm

5. Conclusion

In this work we consider a network of intermediate inputs trade between sectors of the economies of the countries based on the official data of exchange of goods between sectors in 2020 from OECD. As an example we construct critical groups for 3 manufacturing industries in 2 countries and identify most vulnerable sectors, which might be under risk in case of economic shock in the network of exchange of goods between economic sectors.

Acknowledgements

This article is an output of a research project “Study of the models and methods of decision-making under conditions of deep uncertainty. Extension and testing of developed methods” implemented as part of the Basic Research Program at the National Research University Higher School of Economics (HSE University).

References

[1] OECD (2023), OECD Inter-Country Input-Output Database. Retrieved from http://oe.cd/icio.

[2] Antràs, P., & Chor, D. (2022). Global value chains. Handbook of international economics, 5, 297-376.

[3] Deseatnicov, I., Kucheryavyy, K., & Fukao, K. (2021). Exports, trade costs and FDI entry: evidence from Japanese firms. Transnational Corporations Journal, 28(3).

[4] Acemoglu, D., Carvalho, V. M., Ozdaglar, A., & Tahbaz-Salehi, A. (2012). The network origins of aggregate fluctuations. Econometrica, 80(5), 1977-2016.

[5] Aleskerov F., & Yakuba V., Matrix-vector approach to construct generalized centrality indices in networks. Higher School of Economics Publ. House, 2020.

[6] Aleskerov, F., Shvydun, S., & Meshcheryakova, N. (2021). New Centrality Measures in Networks: How to Take into Account the Parameters of the Nodes and Group Influence of Nodes to Nodes. Chapman and Hall/CRC.

[7] Horvath, M. (1998). Cyclicality and sectoral linkages: Aggregate fluctuations from independent sectoral shocks. Review of Economic Dynamics, 1 (4), 781–808.

[8] Horvath, M. (2000). Sectoral shocks and aggregate fluctuations. Journal of Monetary Economics, 45 (1), 69–106.

[9] Carvalho, V. M. (2008). Aggregate fluctuations and the network structure of intersectoral trade. The University of Chicago.

[10] Carvalho, V. M. (2014). From Micro to Macro via Production Networks. Journal of Economic Perspectives, 28 (4): 23-48.

[11] Acemoglu, D., Akcigit, U., & Kerr, W. (2016). Networks and the macroeconomy: An empirical exploration. Nber macroeconomics annual, 30(1), 273-335.
[12] Blöchl, F., Theis, F. J., Vega-Redondo, F., & Fisher, E. O. N. (2011). Vertex centralities in input-output networks reveal the structure of modern economies. Physical Review E, 83(4).
[13] Soyyiğit, S., & Çırpıcı, Y. A. (2017). An input-output network structure analysis of selected countries. Yildiz Social Science Review, 3 (2), 65-88.
[14] Cingolani, I., Panzarasa, P. & Tajoli, L. (2017). Countries' positions in the international global value networks: Centrality and economic performance. Appl Netw Sci 2, 21.
[15] Bhattacharya, K., G. Mukherjee, J. Saramaki, K. Kaski, and S. S. Manna (2008). The international trade network: weighted network analysis and modelling. J. Stat. Mech. 2008(02), P02002.
[16] Wang Z, Wei S-J, Zhu K (2013) Quantifying international production sharing at the bilateral and sector levels. NBER Working Paper No. 19677
[17] De Benedictis L, Nenci S, Santoni G, Tajoli L, Vicarelli C (2014). Network analysis of world trade using the BACI–CEPII dataset. Glob Econ J 14(3–4):287–343.
[18] Criscuolo, C., & Timmis, J. (2018). The changing structure of global value chains: Are central hubs key for productivity?. International Productivity Monitor, (34), 64-80
[19] Ito, H., Chang-Leung, C., & Poudyal, H. (2023). Inclusion of students with developmental disabilities in Japan: barriers and promising practices in primary and secondary education. Asia Pacific Education Review, 24(3), 415-431.
[20] Piccardi, C., Tajoli, L., & Vitali, R. (2024). Patterns of variability in the structure of global value chains: a network analysis. Review of World Economics, 1-28.
[21] Newman, M. E. J. (2003). The Structure and Function of Complex Networks. SIAM Review, 45(2), 167–256.