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The Information and Communication Technology Cluster in the Global Value Chain Network

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Abstract

Global value chains (GVCs) are among the critical factors shaping the world economy nowadays. Within cross-border production networks an increasingly important role has been played by the information and communication technology (ICT) sectors. Based on the multi-country input-output database recently developed by the Vienna Institute for International Economic Studies, covering the period 2005–2018, this policy brief examines the structure and the dynamics of global value chains associated with the ICT sectors. To this end we use complex network analysis techniques to characterise the overall topology of the international ICT cluster in the GVC network, identify the key countries and sectors therein from the perspective of their connectivity. The analysis shows that the ICT GVC network is dominated by the mutual value-added trade linkages between China, South Korea and Taiwan in the Computers and electronics manufacturing sector. These sectors are heavily interlinked via backward and forward GVC linkages with a large number of ICT and non-ICT sectors, many of which are located in the USA, China and Germany. In the recent decade, there has been a major shift in terms of importance to the GVC network from ICT manufacturing towards ICT services, especially prominent for the ICT services sector in Ireland, which has become among the most interconnected sectors in the global ICT cluster.

Keywords: global value chains; ICT sector; network analysis; digitalisation

JEL classification: F10, F14, F15

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1 Introduction

Information and communication technology (ICT) sectors play a highly important role nowadays in economic growth and development. In the age of digitalisation effective use of ICT has become an essential ingredient of competitiveness. This is yet more important given that ICT is capable of transforming a wide range of economic activities, in other words, constitutes a general-purpose technology. The advanced in ICT have helped to offset the adverse effects of the COVID-19 pandemic on economic activities globally, facilitating in many cases production and distribution of goods and services in the environment of disrupted physical people-to-people interactions. The economic sectors involved in the production of ICT goods and services therefore have received a growing attention from policymakers in light of their strategic importance.

In this respect, an important aspect of the modern world economy is the rise of cross-border production sharing as production activities nowadays are increasingly sliced up and distributed geographically with intermediate output produced by some countries used as inputs in the production by other countries, amounting to complex networks of supply-use relationships. Recent developments in the statistical data compilation have allowed researchers to construct and analyse the extent of cross-border production sharing via global value chains (GVCs), identifying in gross export flows value added contributions by different countries and sectors. The global value chain phenomenon has been studied extensively in the literature, both theoretical and empirical—see, e.g. Miroudot et al, 2013; Koopman et al, 2014; Timmer et al, 2013, 2014; UNCTAD, 2013; Wang et al, 2013; World Bank et al., 2017.

Taking into account cross-border production sharing and in light of the growing importance of the ICT sectors in the modern world economy,[1] this policy brief focuses explicitly on the recent developments in GVCs associated with the ICT production, comprising both manufacturing and services sectors. Complementing the conventional approach measuring the extent of countries' GVC integration using such measures as forward and backward GVC participation,[2] we take a complex network analysis perspective on the structure of the GVCs in the ICT sector. In brief, under a network approach each country—or, in this case, country-sector—is viewed as a node (also called a "vertex") connected to other nodes by linkages (also known as "edges") representing trade flows in intermediate inputs. In this respect, the world economy is viewed as a network of country-sectors that are linked via value-added trade relationships. Apparently, the connectivity of individual nodes and linkages in the system have important implications for the adjacent nodes, as well as the entire network. While the network perspective seems to be a particularly well-suited application to the analysis of backward and forward linkages in global cross-border production sharing, the literature on GVC networks is still rather scarce. Among the recent studies, global input-output networks were constructed in Cerina et al. (2015), Cingolani et al., (2017), Criscuolo and Timmis (2018), Lejour et al. (2014) and Zhu et al., (2018), offering a broad characterisation of their topology and its evolution over time.

[1] See also the analysis on the importance of ICT tangible and intangible capital for GVC formation in Adarov and Stehrer (2021).

[2] Among the seminal contributions that develop the frameworks to decompose gross exports into value-added components see Hummels et al., 1998, 2001; Daudin et al., 2011; Koopman et al., 2014; Wang et al., 2013; Buelens and Tirpak, 2017. More recent contributions that further improve the framework are Los and Timmer, 2018 and Borin and Mancini, 2019

Thus policy brief takes advantage of the newly developed by wiiw multi-country input-output database (wiiw MC IOD), covering the period 2005–2018, to examine the structure and the dynamics of global value chains associated with the ICT sectors. First, the next section provides a concise review of the structure of the multi-country input-output database along with the essential technical details on the construction of the GVC networks. Then, the discussion zooms in on the ICT cluster within the GVC network and analysis its structure and properties, as well as the position of individual countries therein.

2 Constructing the GVC network for the ICT sector

Prior to the construction of the GVC network for each year in the sample period and the analysis of the ICT cluster, a few technical details should be provided concerning the overall framework, the country sample and the sectoral classification used in the analysis, as well as the main metrics used in the analysis. The sample of countries that is used for the construction of GVC networks includes 51 country and the rest-of-the-world aggregate over the period 2005–2018. Table 1 lists the countries along with their ISO3 codes.

Table 1: Sample of countries

ISO3	Country name	ISO3	Country name	ISO3	Country name	ISO3	Country name
ALB	Albania	DNK	Denmark	ITA	Italy	PRT	Portugal
AUS	Australia	ESP	Spain	JPN	Japan	ROU	Romania
AUT	Austria	EST	Estonia	KOR	South Korea	RUS	Russia
BEL	Belgium	FIN	Finland	LTU	Lithuania	SRB	Yugoslavia
BGR	Bulgaria	FRA	France	LUX	Luxembourg	SVK	Slovak Republic
BIH	Bosnia and Herzegovina	GBR	United Kingdom	LVA	Latvia	SVN	Slovenia
BRA	Brazil	GRC	Greece	MEX	Mexico	SWE	Sweden
CAN	Canada	HRV	Croatia	MKD	Macedonia	TUR	Turkey
CHE	Switzerland	HUN	Hungary	MLT	Malta	TWN	Taiwan
CHN	China	IDN	Indonesia	MNE	Montenegro	UKR	Ukraine
CYP	Cyprus	IND	India	NLD	Netherlands	USA	United States
CZE	Czech Republic	IRL	Ireland	NOR	Norway	XKX	Kosovo
DEU	Germany	ISL	Iceland	POL	Poland		

The wiiw multi-country input-output database distinguishes 38 sectors that include primary, manufacturing and services sector groups—outlined in Table 2. The table provides the full description of each sector based on NACE Rev. 2 classification (the corresponding NACE codes are also indicated). In addition, for the purposes of this brief a more concise notation is developed with numeric and four-letter codes, which greatly aids the visualisation of networks at a fine sectoral level (the codes are listed in columns 1 and 2). Along the lines of the introduced classification, the following ICT sectors are distinguished: Computer, electronic and optical products manufacturing sector (sector 11-comp) and three services sectors: Publishing, audiovisual and broadcasting activities (22-medi), Telecommunications (23-tele), and IT and other information services (24-icts)—see also the "ICT" column.

In order to facilitate further discussion in the policy brief we next provide a concise intuitive description of essential network concepts based on Adarov (2021). As in the context of GVCs both the value of intermediate trade and the direction of trade are of utmost importance, directed weighted GVC networks are constructed. Figure 1 shows a stylized weighted directed network to illustrate some of the main features of interest along with the differences from the

Table 2: Sectoral classification

Sector No.	Code	Sector description	Sector group	ICT	NACE Rev.2 codes
1	agri	Agriculture, forestry and fishing	Primary	0	A01-A03
2	ming	Mining and quarrying	Primary	0	B05-B09
3	food	Food products, beverages, and tobacco products	Manufacturing	0	C10-C12
4	txtl	Textiles, apparel, leather and related products	Manufacturing	0	C13-C15
5	wood	Wood and paper products, and printing	Manufacturing	0	C16-C18
6	coke	Coke and refined petroleum products	Manufacturing	0	C19
7	chem	Chemicals and chemical products	Manufacturing	0	C20
8	phar	Basic pharmaceutical products and pharmaceutical preparations	Manufacturing	0	C21
9	plas	Rubber and plastic products, and other non-metallic mineral products	Manufacturing	0	C22-C23
10	metl	Basic metals	Manufacturing	0	C24-C25
11	comp	Computer, electronic and optical products	Manufacturing	1	C26
12	elec	Electrical equipment	Manufacturing	0	C27
13	mach	Machinery and equipment n.e.c.	Manufacturing	0	C28
14	motr	Motor vehicles, trailers and semi-trailers	Manufacturing	0	C29-C30
15	furn	Furniture; Repair and installation of machinery and equipment	Manufacturing	0	C31-C33
16	util	Electricity, gas, steam and air conditioning supply	Services	0	D35
17	watr	Water supply; sewerage, waste management and remediation activities	Services	0	E36-E39
18	cons	Construction	Services	0	F41-F43
19	trad	Wholesale and retail trade; repair of motor vehicles and motorcycles	Services	0	G45-G47
20	tran	Transportation and storage	Services	0	H49-H53
21	acco	Accommodation and food service activities	Services	0	I55-I56
22	medi	Publishing, audiovisual and broadcasting activities	Services	1	J58-J60
23	tele	Telecommunications	Services	1	J61
24	icts	IT and other information services	Services	1	J62-J63
25	finl	Financial and insurance activities	Services	0	K64-K66
26	real	Real estate activities	Services	0	L68
27	legl	Legal, accounting, management, architecture, engineering, etc.	Services	0	M69-M71
28	scie	Scientific research and development	Services	0	M72
29	prof	Other professional, scientific and technical activities	Services	0	M73-M75
30	admn	Administrative and support service activities	Services	0	N77-N82
31	publ	Public administration and defence; compulsory social security	Services	0	O84
32	educ	Education	Services	0	P85
33	hlth	Human health services	Services	0	Q86
34	soci	Residential care and social work activities	Services	0	Q87-Q88
35	arts	Arts, entertainment and recreation	Services	0	R90-R93
36	oser	Other service activities	Services	0	S94-S96
37	hown	Activities of households as employers; activities of households for own use	Services	0	T97-T98
38	extr	Activities of extraterritorial organisations and bodies	Services	0	U99

conventional approach (e.g. measures of backward and forward GVC participation commonly used in the GVC literature—see, e.g. Koopman et al., 2014). The figure shows nodes (denoted A–H) connected by weighted directed linkages (the weights are indicated by numbers).

It is immediately apparent that the relative connectivity of nodes and thus their systemic importance in the network differs notably. For instance, nodes H and G have only one linkage, while nodes D and E are highly interconnected with five linkages each. In the language of the network theory, nodes H and G have the total degree—also called degree centrality—of 1, while nodes D and E have the degree of 5 (one may also distinguish in-degree and out-degree corresponding to the number of incoming and outgoing linkages). It is common in the empirical network analysis literature to use scaled degree dividing the raw degree count by the total number of possible linkages that can be formed by a given node (we also use the scaled degree). Another important metric, the weighted degree, measures the total value of all linkages associated with the node (again, one can distinguish also weighted in-degree and out-degree).

Figure 1: Stylized weighted directed network

Note: The figure shows a stylized weighted directed network with nodes indicated by letters A–H and numbers indicating the weight of a directed link. Source: Own elaboration.

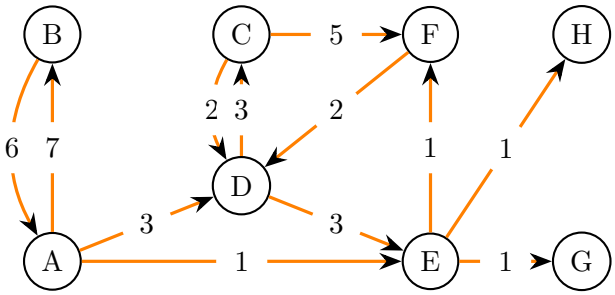


Table 3: Selected centrality measures for the stylized network in Figure 1

Node	PageRank	Degree	In-degree	Out-degree	Weighted degree	Weighted in-degree	Weighted out-degree
A	0.12	0.57	0.14	0.43	17	6	11
B	0.10	0.29	0.14	0.14	13	7	6
C	0.13	0.43	0.14	0.29	10	3	7
D	0.22	0.71	0.43	0.29	13	7	6
E	0.14	0.71	0.29	0.43	7	4	3
F	0.15	0.43	0.29	0.14	8	6	2
G	0.07	0.14	0.14	0.00	1	1	0
H	0.07	0.14	0.14	0.00	1	1	0

The advantages of the network techniques over the conventional approach could be illustrated when comparing, for instance, the connectivity of nodes B and D. While the weighted in-degree and weighted out-degree of both nodes are the same—7 and 6, respectively (the weighted degree is thus 13)—clearly, node D, bridging 4 other nodes, is much more important to the network, as opposed to node B, which is linked only to node A. The importance of node D in the network is even higher if one takes into account the fact that it is linked to another highly interconnected node E. Certain measures devised in the network theory can incorporate such second-order connectivity effects to reflect the overall multilateral connectivity of nodes. We

use PageRank centrality (Brin and Page, 1998 and Page et al., 1999),[3] which allows to take into account the weight and direction of linkages, as well as second-order effects. In brief, PageRank centrality conveys the probability that a random shock originating anywhere in the network and traveling through the network from one node to another via adjacent linkages (with the higher probability of choosing the linkage with a higher weight), will arrive at a given node in a given time. Table 3 reports the basic centrality measures, including (scaled) degree, weighted degree and PageRank. As shown in Table 3, PageRank indeed correctly describes node D as the most "central" node in the network.

3 The ICT-related segment of the GVC networks

Similarly to the stylized network described above, but at a much larger scale, spanning 51 countries and 38 sectors per each country, the GVC networks are constructed based on the wiiw multi-country input-output database yearly tables.[4] The structure of a typical inter-country input-output table for a given year is shown in Figure 2 for a world economy comprising J countries and S sectors. Each cell in the table represents the value of intermediate input flows from countries and their sectors indicated in the leftmost column to countries and sectors importing the inputs, indicated in the top rows.

Figure 2: The structure of an inter-country input-output database

Note: The figure shows a stylized inter-country input-ouput database for J countries and S sectors. Source: own elaboration.

			Use of inputs and value added by countries and sectors									Final use (households, government, GFCF)			Total use
			Country 1			...			Country J			Country 1	...	Country J	
			Sector 1	...	Sector S	...			Sector 1	...	Sector S				
Intermediate inputs supplied by countries and sectors	Country 1	Sector 1													
		...													
		Sector S													
	...	...													
	Country J	Sector 1													
		...													
		Sector S													
Total value added															
Gross output															

Based on the entire GVC network that includes all countries, as well as the rest-of-the-world aggregate, the key centrality measures, including PageRank centrality, are computed and analysed. In addition, to aid visual assessment of the structure of the ICT-related segment of the network, we construct the sub-network involving only the ICT sectors (as described above) and all other sectors to which the ICT sectors have incoming or outgoing linkages. Figure 3 shows the ICT GVC network for the most recent year for which the database was constructed (2018), indicating country-sectors in line with the classification described in Tables 1 and 2.[5] Owing to the complexity of the network, only the strongest linkages are shown for clarity. The thickness and the colour intensity of the linkages are proportional to their weight. The size of

[3] Python NetworkX package was used to compute weighted directed PageRank centrality.
[4] More precisely, the partition of the input-output table that outlines the intermediate supply and use by country-sectors is used—indicated in the Figure 2 by the blue color.
[5] Python software was used to process and analyse the networks, and Gephi software was used for final rendering of the network images.

each node is proportional to its weighted degree—the total value of value-added exports and imports. For the ease of visual navigation, the countries are listed counter-clockwise by ISO3 code, and each country "branch" includes the ICT-related sectors of a given country sorted by their weighted degree with high-valued nodes positioned closer to the center. The labels denote country-sectors as described in the previous section (nodes are also colour-coded by sector, however it is best to refer to the node labels). ICT sectors are labelled with the black font, other sectors—with the brown font.

In addition, Figure 4 shows only the "core" of the ICT GVC network, comprising only the country-sectors with the highest aggregate value of all inward and outward value-added trade linkages (weighted degree) and the strongest linkages. In this figure, the layout algorithm ("ForceAtlas") tends to position the nodes with the highest centrality in the center of the network, which helps understanding the overall structure of the GVC network.

As can be seen from both Figures, the ICT cluster is strongly dominated by China's Computer, electronic and optical products manufacturing sector (sector labelled as CHN_comp), while the backbone of the network is formed by its linkages with the South Korean and the Taiwanese Computer, electronic and optical products manufacturing sectors. In 2018, the value-added exports of this sector is estimated to be 40.6 billion USD for exports from South Korea to China and 29.6 billion USD for exports from Taiwan to China.[6]

This triad is not only closely mutually interconnected by the strongest value-added trade linkages in the ICT network, but also bridges a large number of other countries and their sectors around the world via inward and outward linkages—both ICT and non-ICT sectors that are directly related upstream or downstream to ICT production along vertical value chains. In addition, the Computer and electronics manufacturing sectors of the USA, Japan, Mexico, Germany and the Netherlands are also centrally located in the ICT network serving as important hubs. Among the ICT services sectors, the most important ones are the ICT services sector of Ireland, China and the USA (IRL_icts, CHN_icts, USA_icts)

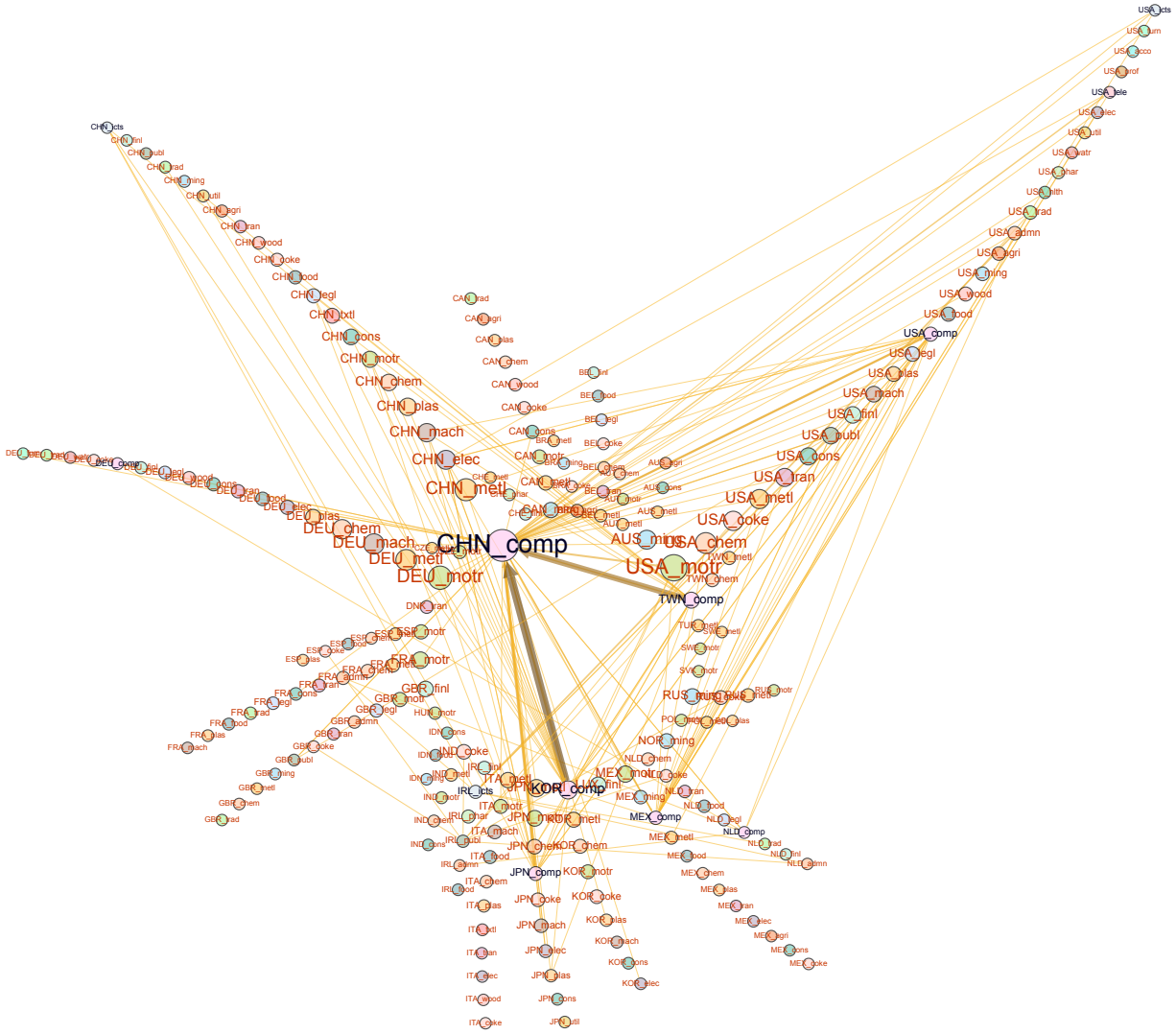
Most of the sectors that are reliant on the ICT sectors upstream or downstream in value chains are located in the USA, China and, to a smaller extent, in Germany—this is particularly evident when examining the number of related sectors in each country branch in Figure 3, i.e. the "length" of the "branches". Among the most sizable sectors (in terms of total value-added trade across the entire GVC network) that are highly reliant on the outputs produced by the ICT sectors are German. American and Chinese Motor vehicles, trailers and semi-trailers manufacturing and Machinery and equipment manufacturing sectors (DEU_motr, USA_motr, CHN_motr, DEU_mach, USA_mach, CHN_mach). However, while these are the most sizable sectors in the GVC network, it should be noted that a large number of other industries are also heavily dependent on the ICT cluster as a supplier of intermediate inputs, which is in line with the idea that ICT constitutes a general-purpose technology that is increasingly utilised across a wide range of economic applications.

Table 4 provides further details on the most important countries and sectors in the ICT GVC network, listing the key network centrality measures, based on the averages over the

[6] It is also worthwhile to note that in 2018 the highest value across all country-sector value added linkages in the GVC network is also attributed to the exports in Computer and electronic manufacturing sector (as both source and destination sectors)—from the rest-of-the-world aggregate to China, amounting to 140.6 billion USD.

Figure 3: GVC network for the ICT sectoral cluster, 2018

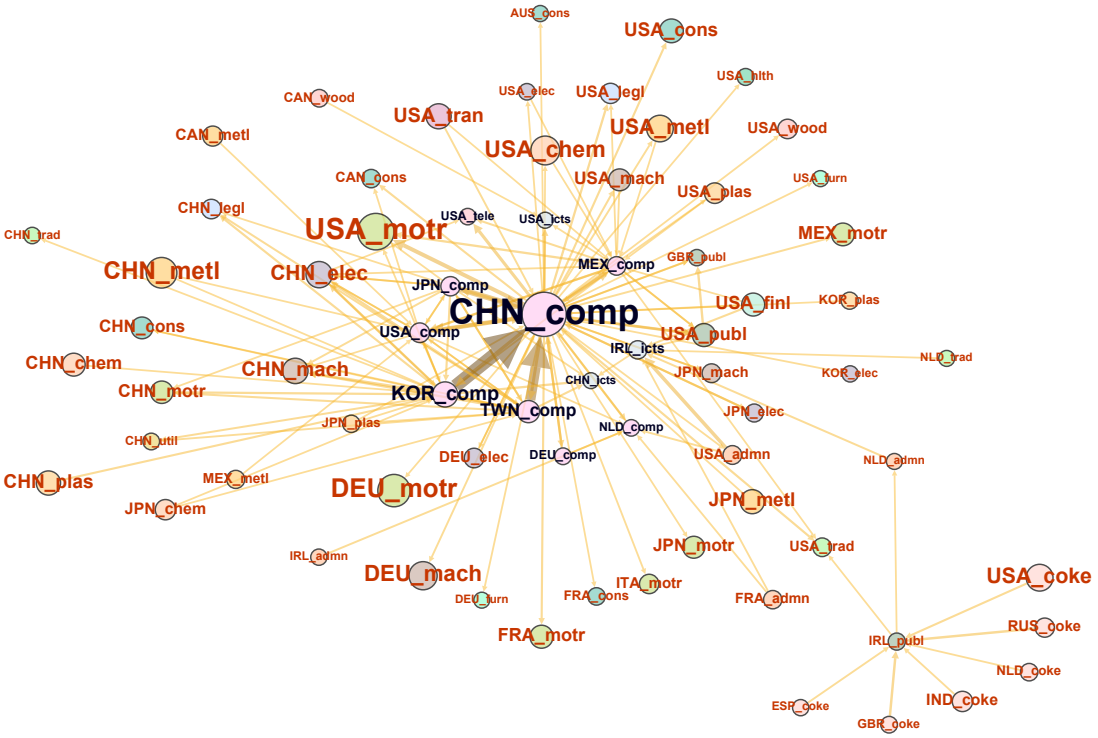
Note: The figure shows the GVC network for ICT sectoral cluster. The size of each node is proportional to its weighted degree (the total value of value-added exports and imports). The thickness and the colour intensity of linkages are proportional to their weight. The countries are listed counter-clockwise by ISO3 and each "branch" includes the ICT-related sectors of a given country sorted by their weighted degree (high-valued nodes closer towards the center). The labels denote country-sectors as described in the previous section (sectors are also colour-coded). ICT sectors are labelled with the black font, other sectors—with the brown font. Only linkages with the value added above 500 million USD are shown for clarity. Source: own elaboration.



period 2016–2018 (averaging allows to address possible biases on account of transitory shocks that may have occurred in individual years). The global ICT hub, China's Computer and electronics manufacturing sector, again, dominates the network as measured by all network metrics, signifying its importance in terms of multilateral connectivity, the strength of linkages and the number of value-added linkages to both downstream and upstream sectors globally. The 2016-2018 average total value of its cross-border production linkages exceeds 464 billion USD, relatively balanced regards the incoming and outgoing linkages (247.7 and 216.8 billion USD, respectively). When looking at the connectivity of country-sectors as conveyed by the

Figure 4: ICT GVC network–core, 2018

Note: The figure shows the subset of the GVC network for the ICT sectoral cluster with the largest nodes and linkages. The size of each node is proportional to its weighted degree (the total value of value-added exports and imports). The thickness and the color intensity of linkages are proportional to their weight. The labels denote country-sectors as described in the previous section (sectors are also colour-coded). ICT sectors are labelled with the black font, other sectors—with the brown font. Only countries with the weighted degree above 10 billion USD and the linkages with the weight above 500 million USD are shown for clarity. Source: own elaboration.



PageRank centrality measure that accounts for both the number of linkages and their weight, as well as those of the adjacent nodes, notably, a number of services sectors have also emerged as systemically important in the ICT GVC network, including Ireland's ICT services sector and the Telecommunications services sectors of the UK and the USA. As already emphasized previously, these sectors not only are linked to other ICT sectors, but are also integrated in a large number of non-ICT sectors, largely manufacturing, which highlights the ever-increasing role of digitalisation in modern production processes. Examining the nominal values, more than 94 billion USD is attributed to the value-added trade associated directly with the Irish ICT services sector.

While the relative position of countries and their sectors in the GVC network in general is rather stable over short spans of time, the ICT sector is among those that have transitioned quite

Table 4: Top 20 country-sectors by connectivity in the ICT GVC network

Note: The table shows top 20 country-sectors by connectivity in the ICT GVC network based on the averages over 2016–2018. The country-sectors are sorted in descending order by their PageRank, weighted degree, weighted in- and out-degree in corresponding columns. For reference: the weighted degree values are in millions USD. Source: own calculations.

	PageRank centrality		Weighted degree		Weighted in-degree		Weighted out-degree	
	code	value	code	value	code	value	code	value
1	CHN_comp	0.0058	CHN_comp	464461.4	CHN_comp	247677.3	CHN_comp	216784.03
2	IRL_icts	0.0057	KOR_comp	116528.7	IRL_icts	47531.78	KOR_comp	80976.248
3	NLD_comp	0.0024	TWN_comp	104851.6	TWN_comp	36249.24	TWN_comp	68602.343
4	GBR_tele	0.0019	IRL_icts	94355.52	KOR_comp	35552.43	IND_icts	61438.383
5	USA_tele	0.0016	IND_icts	66315.5	NLD_comp	32768.38	IRL_icts	46823.742
6	DEU_icts	0.0014	USA_comp	61985.73	MEX_comp	32332.54	USA_medi	42647.34
7	USA_icts	0.0014	JPN_comp	59667.7	USA_tele	29628.43	JPN_comp	42277.913
8	USA_medi	0.0014	USA_medi	59365.71	USA_comp	27884.93	USA_comp	34100.797
9	KOR_comp	0.0013	MEX_comp	51849.11	USA_icts	19088.06	USA_icts	24479.616
10	MEX_comp	0.0011	NLD_comp	46062.51	CHN_icts	18994.56	DEU_comp	22190.474
11	GBR_icts	0.0011	USA_tele	45549.14	JPN_comp	17389.79	MEX_comp	19516.564
12	CHN_icts	0.0011	USA_icts	43567.67	DEU_comp	17286.87	IRL_medi	19358.093
13	TWN_comp	0.0010	DEU_comp	39477.34	USA_medi	16718.37	USA_tele	15920.709
14	GBR_medi	0.0010	CHN_icts	32362.51	IRL_medi	12058.59	GBR_icts	15199.087
15	DEU_comp	0.0010	IRL_medi	31416.68	CHN_tele	10571.3	DEU_icts	14462.29
16	USA_comp	0.0010	DEU_icts	24646.11	CHE_comp	10343.93	CHN_icts	13367.958
17	CHE_icts	0.0010	GBR_icts	23517.19	DEU_icts	10183.82	NLD_comp	13294.122
18	SWE_icts	0.0009	CHE_comp	21964.15	IDN_comp	9980.63	CHE_comp	11620.216
19	IRL_comp	0.0009	GBR_tele	18632.59	IRL_comp	9908.869	FRA_icts	10737.511
20	NLD_icts	0.0009	NLD_icts	18486.89	GBR_medi	9063.127	NLD_icts	10626.938

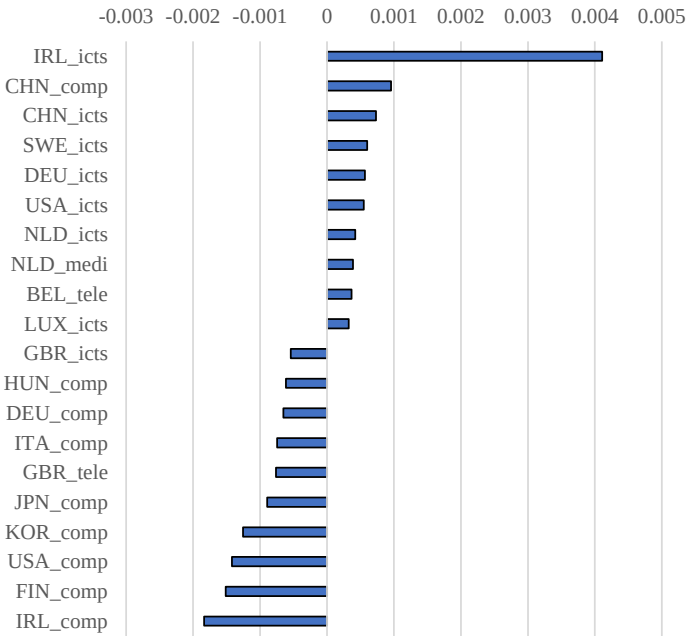
noticeably over the period 2005–2018. Figure 5 shows the change in the PageRank centrality from the 2005–2007 average to the 2016–2018 average[7]. Notably, as can be seen in the figure, since the early 2000s there has been a major shift towards a greater importance of ICT services in global value chains–as already noted, this reflects both the growth of the economic value generated by the sectors and the number of incoming and outgoing value-added linkages to other countries and sectors. At the same time, the relative centrality of Computer and electronics manufacturing sectors has declined. The most significant shift away from ICT manufacturing to ICT services is observed for Ireland, which, as already noted previously, has gained global dominance in terms of its integration in value chains. The systemic importance of the ICT services sectors and the countries specialising in them, however, has increased dramatically only relatively recently.

Another structural transition has occurred in the relative importance of countries in the ICT manufacturing, resulting in greater concentration of activity in China and the ICT core around its ICT industry. More specifically, as can be seen, the diminishing centrality (in the GVC network context) of the computer and electronics manufacturing sectors in a range of countries (IRL, FIN, USA, KOR, JPN and others) has been accompanied by a growing concentration of this sector in China, which by the end of 2000s has become dominant in terms of both the global span of its value-added linkages and their value, as shown in Table 4.

[7] Again, smoothing allows to remove the possible distortions associated with business cycles and miscellaneous transitory segment-specific shocks

Figure 5: Change in the ICT GVC connectivity, 2005–2018

Note: The figure shows the change in the PageRank centrality of ICT country-sectors from the 2005–2007 average to the 2016–2018 average. The top 10 gainers and top 10 losers in terms of centrality are shown. Source: own calculations.



4 Concluding remarks

In this policy brief, we have examined the current structure of the global ICT cluster in the GVC network taking a novel network perspective to characterise the topology of the network, its dynamics and the key countries and sectors forming the core of the network. The analysis shows that the ICT GVC network is dominated by the mutual value-added trade linkages between China, South Korea and Taiwan in the Computers and electronics manufacturing sector. These sectors are heavily interlinked via backward and forward GVC linkages with a large number of ICT and non-ICT sectors, many of which are located in the USA, China and Germany. In the recent decade, there has been a major shift in terms of importance to the GVC network from ICT manufacturing towards ICT services, especially prominent for the ICT services sector in Ireland, which has become among the most interconnected sectors in the global ICT cluster.

It is clear that ICT sectors will continue to play an increasingly important role in cross-border production sharing, as well as, more generally, the world economy. In light of this, for countries that are currently on the periphery of the ICT GVC network it is of strategically important to boost efforts to effectively integrate in the ICT sector, which calls for additional policy efforts to foster broad-based digitalisation and stimulate ICT investments (see also Adarov and Stehrer, 2020). From the standpoint of policy considerations, our results also reiterate the importance

of better understanding the risk exposures stemming from the ICT sector in light of the key features that the analysis reveals: (i) the high interconnectedness of the ICT sector to a range of other sectors and (ii) the high concentration of the ICT cluster around a rather small number of economies. Among others, the concerns about reliance on foreign ICT sectors and the need for "technological sovereignty" have been voiced in the EU, which has been lagging behind its global peers in a number of dimension in the ICT cluster.[8]

[8] In relation to this, see also the strategies and policy proposals associated with the Europe's Digital Decade, including the official communication released in March 2021—European Commission (2021).

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