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THE CROSS-SECTORAL TECHNOLOGICAL INTERDEPENDENCIES OF CENTRAL AND EASTERN EUROPE IN THE ERA OF INDUSTRY 4.0 AND CHINESE DIGITAL SILK ROAD

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ABSTRACT

Aim: The article aims to assess the flows of value added in the servicification of manufacturing within the two most critical value-added providers for Central and Eastern Europe (CEE): Germany and China in the era of Industry 4.0 and the Digital Silk Road (DSR). **Methods:** The input-output model for the decomposition of gross exports was applied to evaluate the cross-sectoral links between analyzed economies. **Results:** The CEE economies are increasingly dependent on high-quality services from Germany and China for their manufacturing, while analogous flows from CEE to Germany and China are decreasing or remaining stable. German manufacturing is starting to depend more on Chinese services' value-added in advanced sectors. There was no direct trade-off between pairs of economies, but a decrease in German value-added flows to China led to a significantly larger increase in Chinese value-added in German manufacturing. **Conclusions:** Bearing in mind the limitations of the study, the deepened imbalance in value-added flows between economies was proved. Moreover, the study proved the effectiveness of China's Industry 4.0 and DSR in terms of enhancing the sophistication of Chinese value-added exports and making key economies reliant on this value-added

Keywords: ICT, servicification of manufacturing, China, Germany, CEE
JEL codes: DF0, F14.

INTRODUCTION

Over the recent decades, the production process has become more geographically and vertically fragmented. It means that intermediate products are shipped across boarders many times and every exporting economy provides some value added according to its competitive advantage. As a result, global value chains (GVCs) have become one of the most important features of international trade. Following [Gereffi and Fernandez-Stark 2011], in this study, GVCs are defined as "the full range of activities that firms and workers do to bring a product from its conception to its end use". Humphrey and Schmitz [2002] pointed out four types of upgrading in GVCs: product, process, functional, and chain. The fragmentation of production has led to a rapid increase in trade in intermediate goods as companies often offshore an intermediate stage of the production process. While offshoring has been typical in manufacturing [Timmer et al. 2012], services have often been overlooked despite playing a major role in supporting GVCs [Kommerskollegium 2013].

Nowadays, the Central and Eastern European (CEE) economies are becoming more heavily involved in

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GVCs. Many empirical studies have shown these countries' close and dynamic integration with the EU market (especially the EU-15) and, to a more limited extent, with the global economy [Behar and Freund 2011]. Democratization, strengthening political and economic relations (particularly with the EU), and modernizing many sectors (including finance and more advanced industries) were common elements of long-term development policies in CEE countries. Recently, the role of an economy in GVCs has been determined more by the advancement of value added that it offers. Companies move toward services and innovations in the business model [Nenenen and Storbacka 2010] and introduce Industry 4.0 [Bundesministerium fur Bildung und Forschung 2016]. A symptom of these novelties is the concept of 'servicification' of manufacturing (sometimes called "servitization of manufacturing" in the literature) [Neely et al. 2011], which has reconstructed traditional GVCs [Naude et al. 2019] and, together with Industry 4.0, is expected to change the landscape of global manufacturing. As a result of the facilitation of manufacturing, economies placed in the downstream market (e.g., CEE economies) can improve their role in GVCs.

The Chinese answer to new tendencies in international trade was the Belt and Road Initiative and then the Digital Silk Road (DSR), introduced in 2015 as a significant part of this initiative[1]. This strategy, part of China's long-term technological plan, provides support to its exporters – including many well-known technology companies – and builds a network of cooperation with selected countries in the field of technology, including ICT infrastructure, services, 5G networks, e-commerce, etc. The DSR's mission is to increase China's presence in more advanced areas of the global economy, especially with those connected to Industry 4.0 [Nouwens 2020]. In almost all official documents and events related to the Belt and Road Initiative, the DSR has been on the agenda. The original goal of the DSR was to develop a digital infrastructure in member countries. This was emphasized in the thirteenth 'Five-Year Plan' [Xinhua 2017]. The processes of servicification of manufacturing with ICT services can be considered an important element of the initiative [Brown 2017, Sen and Bingqin 2019].

China's rapid technological changes have not gone unnoticed by its trading partners. These include European countries which are increasing their technological advancement and enhancing market protection against Chinese technology to maintain international competitiveness. Until recently, the value added from China to European countries was concentrated mainly on medium-technology industries, while value added from Europe to China focused more on advanced goods and services. However, there is now a redirection of the Chinese value added towards high-tech activities (including service activities), reflecting China's ambition to build an economy leading to innovation and Industry 4.0.

The CEE economies and their relations with China and Germany in the context of the DSR are particularly interesting subjects for the study of production networks. CEE is still in the catch-up stage with Germany [Szalavetz 2020]. It is observed that CEE is facing unfavorable effects of the transformation towards Industry 4.0. More and more advanced technologies are replacing labor-intensive production, which harms the location of greenfield investments and labor-saving technologies. Consequently, the position of CEE in GVCs is deteriorating [Pavičić 2019]. However, access to digital technologies (including ICT services) seems to be of key importance for CEE economies and entry into the Industry 4.0 phase. One of the important suppliers of such technologies is Germany, the economy with which CEE ties are the strongest [Popławski and Bajczuk 2019]. However, the strategies of "going into the world" introduced by China, which has increasingly advanced products and services, mean that the country can be considered an important non-European supplier of technologies for CEE [OECD 2022]. This process has been strengthened by the DSR (CEE belongs to the '17+1' format, which can be interpreted as indirect belonging to the DSR through the Belt and Road Initiative). Its main channel of presence in CEE countries is the development of ICT services, including the 5G network, IT services, and other advanced services enriching manufacturing. At this level, China may appear as a competitor to Germany in CEE [Le Corre 2023]., CEE has become an important destination for the Chinese DSR in Europe because this region could be a "bridgehead" of Chinese technological projects

[1] The DSR is a part of the Belt and Road Initiative. Both initiatives include the Chinese Going Out Strategy. The DSR is also part of China's digitization strategies and programs related to the implementation of Industry 4.0 and Industry.

in Europe and a bridge for acquiring technology from Western Europe [Krpata 2023]., Chinese presence in Germany means two opposing strategies. On the one hand, Germany is also indirectly and informally involved in the DSR and has strong cooperation with China. The most visible connections can be found in the automotive and electronics industries. The country does not want to completely exclude China from the technology market in Europe as it uses these services directly in country-located factories or factories abroad (e.g., in CEE). On the other hand, Germany wants to protect its critical industries from Chinese value added and, therefore, protect the economy from too much influence from the DRS [CNN 2023, Reuters 2023].

Therefore, when analyzing changes in the role of CEE economies in GVCs, it is vital to consider their two most significant value-added suppliers: China and Germany. These three economies have established a triangle of value-added flows. Germany's regional supply chains in the CEE have allowed it to maintain a comparative advantage in important economic sectors while helping the CEE countries join GVCs, positively influencing their economic growth but also reducing them to entities operating in less advanced stages of production [Jacoby 2010, Fortwengel 2011].

In light of the above-mentioned relations, the purpose of the article is to assess the flows of value added in the servicification of manufacturing within the two most important value-added providers for CEE: Germany and China in the era of Industry 4.0 and the DSR. In this context, the question arises: How strong are these links in the servicification of manufacturing, and are there visible trends in value-added flows within this triangle in the era of Industry 4.0 and the Chinese DSR? The research question seems to be relevant; thus, in the subject literature, little is known about the mentioned relations [Roland Berger, 2021]. Moreover, in light of the possible establishment of the EU-China Comprehensive Agreement on Investment [European Commission 2021], these relations might be crucial for Europe.

A multi-regional input-output model was devised, encompassing the incorporation of value-added flows between industries. The study used Inter-Country Input-Output (ICIO) databases collected from OECD databases for the years 2005–2018 [OECD 2022].

The study covered 14 economies: China, Germany, and the CEE economies (i.e., Czech Republic, Estonia, Hungary, Poland, Slovakia, Slovenia, Bulgaria, Croatia, Lithuania, Latvia, and Romania).

The study proved the rising role of China in the analyzed triangle and the growing asymmetry in value-added flows. In most cases, the increasing dependence of manufacturing on Chinese ICT value added was proved. Unfortunately, the opposite tendency occurred relatively rarely.

This article is divided into four sections. The first section provides a justification of the topic undertaken, followed by a brief overview of the methodology used in the paper. The third section discusses the results of the estimations. Finally, the fourth section presents the conclusions drawn from the analysis.

JUSTIFICATION OF THE TOPIC

There have been limited studies to date regarding China's involvement in servicification. Virtually all studies on this subject point to similar conclusions. Du and Agbola [2022] explored the servicification of manufacturing in China, noting that FDI, capital intensity, and institutions are improving due to production links. However, they also found that the growing global market share of the Chinese manufacturing industry has led to a decrease in the role of manufacturing firms in China that use foreign servicification of manufacturing. Similar conclusions were drawn from the study conducted by Huang et al. [2022] and Chen et al. [2023].. They demonstrated that the servicification of manufacturing, whether commercial or non-commercial, positively affects the competitiveness of value-added exports and shapes the standing of Chinese enterprises in the global network. They emphasized that the servicification of China's manufacturing sector is still in its early stages of development. Guo et al. [2018] built a model for the Chinese economy from 1981–2014 and conducted counterfactual experiments, demonstrating the significant role of the servicification of investment. Similarly, Liu and Kim [2020] used an input-output model to determine that the service sector is a key driver for economic development. All

cited studies focused on the internal servicification of manufacturing and did not confront international flows. Only Pomfret [2019] offered a case study on servicification as a part of increased trade between China and Europe in the 20th century, utilizing the Eurasian Landbridge Corridor.

These studies have some limitations. Firstly, they did not provide an investigation of interdependencies in the servicification of manufacturing between strong-linked economies: China, Germany, and CEE. Moreover, all of them focused on holistic services rather than classifying them according to their level of sophistication. This study aims to address these gaps.

The second reason for taking up the topic is the growing role of Chinese services in German and CEE manufacturing [Liu and Li 2022, OECD 2022]. The expansion of China's services market has significant repercussions for the country's recent shift away from a reliance on exports and toward domestic consumption promotion [Grimes and Sun 2014]. Analyzing the years 2005–2018, it can be seen that the share of Chinese services flowing to German and CEE manufacturing is growing dynamically. It does not yet reach average annual values at a level similar to the flows of value added in manufacturing, but these increases between the period 2010–2014 and 2015–2018 (i.e., after the introduction of the DSR) are much greater on the side of servicification of manufacturing (Table 1). If this pace is maintained, services will soon overtake manufacturing.

METHOD[2]

The input-output model for the decomposition of gross exports (Fig. 1) was used to evaluate the cross-sectoral links between the analyzed economies. For the aim of the study, the foreign value added embodied in gross exports was evaluated. The applied approach was a combination of methods developed by Koopman et al. [2014], Hummels et al. [2001], and Timmer et al. [2019]; however, it was extended to cross-sectoral links.

The chosen research method was based on analyzing data from the OECD, specifically the trade in value-added databases that contain world input-output tables for 2005-2018. The study used ICIO databases collected from OECD databases. The 2021 version of the ICIO features 45 distinct industries, classified according to the ISIC Revision 4 [OECD 2022].

The input-output model's balance equations system for a single economy was adapted to a multi-economy model based on the decomposition of gross exports. The method includes estimates of total value-added in GVCs in addition to calculations at the mezoeconomic level and cross-sectoral flows of value-added, including the servicification of manufacturing.

We have S sectors and N economies. Each sector produces a single differentiated product: SN goods:

$$\begin{bmatrix} X_{11} & \cdots & X_{1N} \\ \vdots & \ddots & \vdots \\ X_{N1} & \cdots & X_{NN} \end{bmatrix} = \begin{bmatrix} B_{11} & \cdots & B_{1N} \\ \vdots & \ddots & \vdots \\ B_{N1} & \cdots & B_{NN} \end{bmatrix} \begin{bmatrix} Y_{11} & \cdots & Y_{1N} \\ \vdots & \ddots & \vdots \\ Y_{N1} & \cdots & Y_{NN} \end{bmatrix}$$

Table 1. An average Chinese total and services' value-added share in foreign value added in German and CEE's manufacturing in 2005–2018 [%]

Specification	2005–2009	2010–2014	2015–2018
Chinese manufacturing value added directed to partner's manufacturing			
Germany	5.9	8.7	10.2
CEE	7.3	10.2	10.6
Chinese total services' value added directed to partner's manufacturing (servicification of manufacturing)			
Germany	2.9	4.3	5.9
CEE	4.0	5.8	7.1

Source: based on OECD [2022].

[2] This method was first applied in [Cieślik 2021].

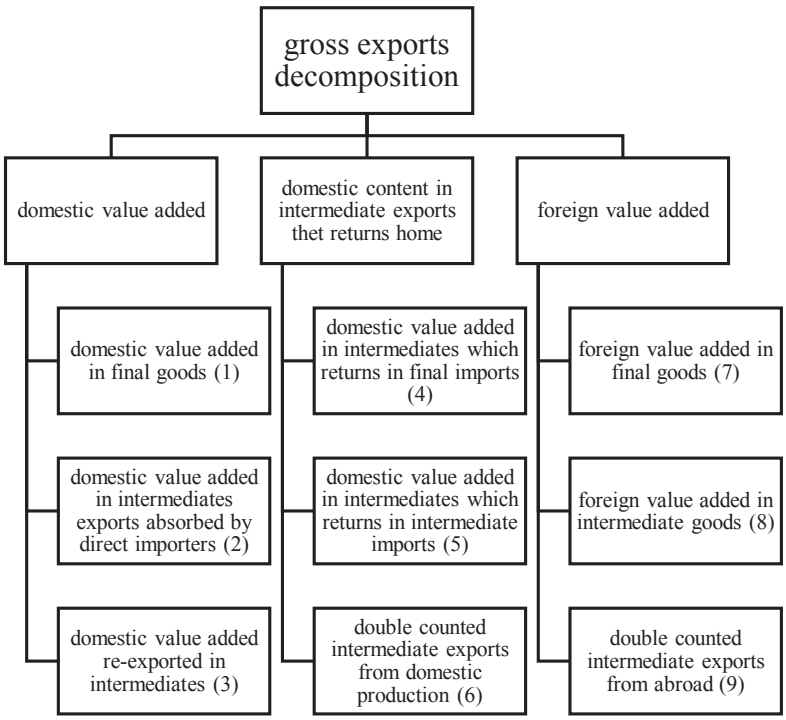


Fig. 1. Decomposition of gross exports scheme

Note: in parentheses, there are the number of equations.
Source: Koopman et al. [2012].

Where: G – Total amount of gross production in the economy (i) needed to meet the final demand in the economy (j); X – Gross output produced in the economy (i) and absorbed in the economy (j); Y – Gross output produced in the economy (i) and consumed in the economy (j).

Then, we create the value-added production matrix $\hat{V}GY$.

$$\begin{bmatrix} \hat{V}_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \hat{V}_N \end{bmatrix} \begin{bmatrix} X_{11} & \cdots & X_{1N} \\ \vdots & \ddots & \vdots \\ X_{N1} & \cdots & X_{NN} \end{bmatrix} =$$

$$= \begin{bmatrix} \hat{V}_1 \Sigma_j^N G_{1j} Y_{j1} & \cdots & \hat{V}_1 \Sigma_j^N G_{1j} Y_{jN} \\ \vdots & \ddots & \vdots \\ \hat{V}_N \Sigma_j^N G_{Nj} Y_{j1} & \cdots & \hat{V}_N \Sigma_j^N G_{Nj} Y_{jN} \end{bmatrix}$$

Elements in the diagonal matrix mean the value added absorbed at home. All elements of the diagonal matrix mean value added embodied in the partner's gross exports.

Because we focused on the foreign value added embodied in gross exports, we omitted some equitation related to domestic contents.

The foreign value added embodied in the gross exports can be formulated as follows:

$$\text{FV} = \Sigma_{j \neq i}^N V_j G_{ji} E_{i*} = \sum_{t \neq i}^N \Sigma_{j \neq i}^N V_t G_{ti} Y_{ij} +$$
$$+ \sum_{t \neq i}^N \Sigma_{j \neq i}^N V_t G_{ti} A_{ij} (I - A_{jj})^{-1} Y_{jj} +$$
$$+ \Sigma_{j \neq i}^N V_t G_{ti} (I - A_{jj})^{-1} E_{j*}$$

Where: $\sum_{t \neq i}^N \Sigma_{j \neq i}^N V_t G_{ti} Y_{ij}$ – foreign value added embodied in final goods exports; $\sum_{t \neq i}^N \Sigma_{j \neq i}^N V_t G_{ti} A_{ij} (I - A_{jj})^{-1} Y_{jj}$ – foreign value added embodied in gross exports of intermediate products; $\Sigma_{j \neq i}^N V_t G_{ti} (I - A_{jj})^{-1} E_{j*}$ – double-counted value added of intermediate goods produced abroad.

Ultimately, the decomposition of gross exports may be formulated as follows:

$$GEX = [V_i \Sigma_{j \neq i} G_{ii} Y_{ij} + V_i \Sigma_{j \neq 1} G_{ij} Y_{jj} +$$

$$+ V_i \sum_{j \neq i} \Sigma_{t \neq ij} G_{tj} Y_{jt}] + [\sum_{t \neq i} \Sigma_{j \neq i} V_t G_{ti} Y_{ij} +$$

$$+ \sum_{t \neq i}^{N} \Sigma_{j \neq i}^{N} V_t G_{ij} A_{ij} (I - A_{jj})^{-1} Y_{jj} +$$

$$+ \Sigma_{j \neq i}^{N} V_t G_{ti} (I - A_{jj})^{-1} E_{j*}] + [V_i \sum_{t \neq ij}^{N} \Sigma_{j \neq i}^{N} G_{ij} Y_{ij} +$$

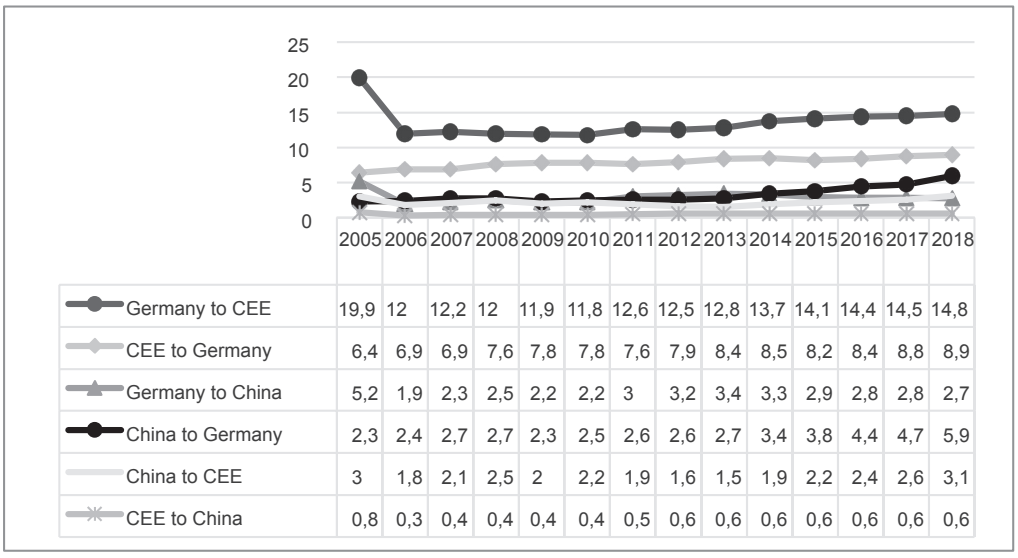
$$+ V_i \sum_{t \neq ij}^{N} \Sigma_{j \neq i}^{N} G_{ij} A_{ji} (I - A_{iix})^{-1} Y_{ii}$$

$$+ V_i \sum_{t \neq ij}^{N} G_{ij} A_{jt} (I - A_{ii})^{-1} E_{j*}$$

DISCUSSION

Germany has established a regional production network in CEE, particularly in the Visegrád Group countries (V4) – which has allowed it to maintain a comparative advantage in key economic sectors. This has also helped CEE countries to join GVCs, positively impacting their economic growth and development. However, this has also reduced them to entities operating in less advanced stages of production. Currently, Germany also has strong cooperation with China, and CEE economies are becoming increasingly dependent on the Chinese value added. This has created a linkage triangle, particularly in the automotive and electronics industries.

In general, when analyzing the production connections between CEE, China, and Germany, it is generally not surprising to find that the strongest flows occur between Germany and CEE. However, the ties between Germany and China, as well as between China and CEE, are comparatively weaker. There is an imbalance in all flows, but the situation is slightly better in the case of CEE-Germany and Germany-China connections. China has made Germany and CEE similarly dependent on its value added. In fact, 28.4% of CEE's total production is based on value added from Germany and China, the highest dependence among the analyzed economies. However, the opposite does not occur – the analyzed partners, especially China, do not rely as much on the value added generated in the CEE region [Cieślik 2022, OECD 2022].



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Germany to CEE	19,9	12	12,2	12	11,9	11,8	12,6	12,5	12,8	13,7	14,1	14,4	14,5	14,8
CEE to Germany	6,4	6,9	6,9	7,6	7,8	7,8	7,6	7,9	8,4	8,5	8,2	8,4	8,8	8,9
Germany to China	5,2	1,9	2,3	2,5	2,2	2,2	3	3,2	3,4	3,3	2,9	2,8	2,8	2,7
China to Germany	2,3	2,4	2,7	2,7	2,3	2,5	2,6	2,6	2,7	3,4	3,8	4,4	4,7	5,9
China to CEE	3	1,8	2,1	2,5	2	2,2	1,9	1,6	1,5	1,9	2,2	2,4	2,6	3,1
CEE to China	0,8	0,3	0,4	0,4	0,4	0,4	0,5	0,6	0,6	0,6	0,6	0,6	0,6	0,6

Fig. 2. Value added flows in total ICT services in manufacturing of the triangle in 2005–2018 (% of gross exports of the recipient country)

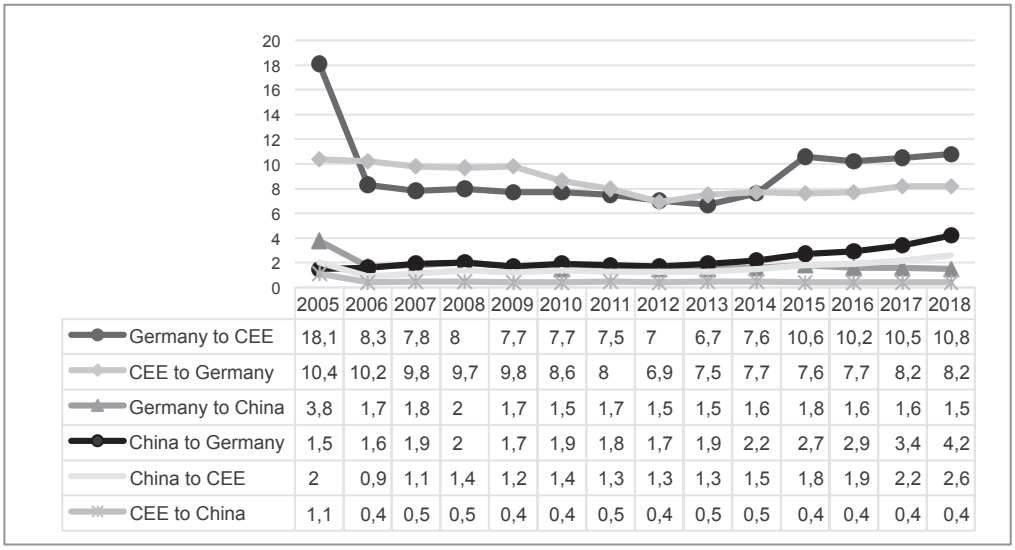
Source: author's calculations [OECD 2022].

After CEE countries joined the EU, there were high inflows of German value-added to the region, which resulted largely from these countries' favorable economic and social features. Over time, these value-added flows normalized, usually amounting to over a dozen percent. Additionally, the role of Chinese ICT services in cross-sectoral connections with both Germany and CEE was limited due to their underdevelopment, usually below 5%[3] (Fig. 2).

There is a notable imbalance between pairs of economies. The cross-sector flows from Germany to CEE are significantly greater than the value-added flows from CEE to Germany. In contrast, the value-added connections between Germany and China are much lower, indicating limited DSR impact. There is an upward trend in the flows of value-added Chinese ICT services to German industries. Still, this trend is not visible in the flows of German ICT services to Chinese industries, indicating a deeper imbalance in Chinese-German cross-sectoral relations. The largest asymmetry occurs between CEE and China, where the DSR strategy is achieving its intended results. China's ICT sectors add significant value to CEE's industries, while the opposite trend is not visible. Overall, Germany and CEE are becoming increasingly dependent on Chinese value added in their manufacturing and its subgroups (Fig. 2).

The gaps between the countries analyzed increased in the value-added flows of ICT services and their subgroups in manufacturing. The relationships between economies are becoming more imbalanced but in different ways. In terms of telecommunications in manufacturing, both CEE economies and Germany became more dependent on the Chinese value added. Moreover, the role of CEE's telecommunications services in German manufacturing grew. Therefore, in these intersectoral flows, Germany was more and more dependent on CEE and China (12.4% of foreign value added). However, the highest fluctuations of value-added flows occurred between German telecommunications and CEE manufacturing (the standard deviation amounted to 2.9%), (Fig. 3).

CEE manufacturing has become more dependent on both German and Chinese computer programming, consultancy, and information services activities. However, in the relationship between Germany and China, there was



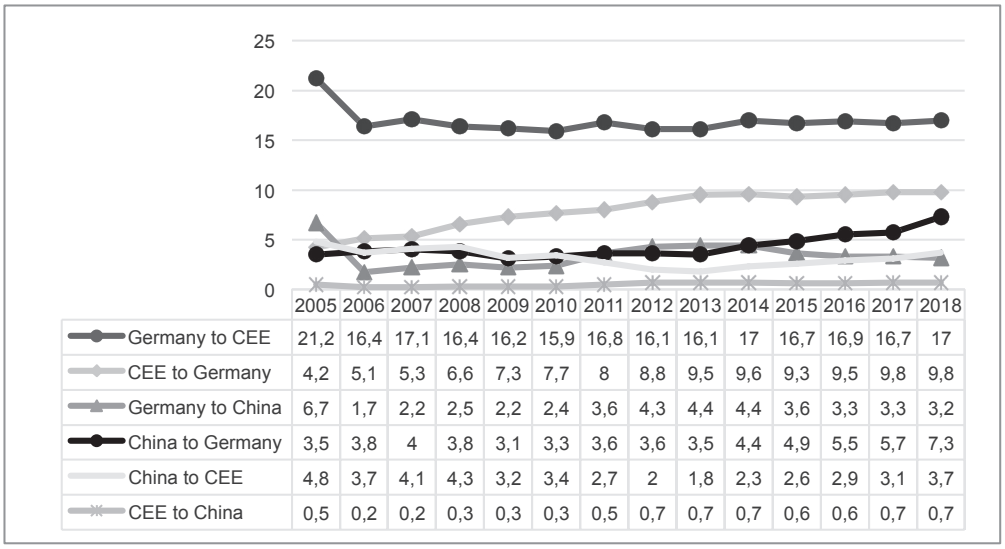
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Germany to CEE	18,1	8,3	7,8	8	7,7	7,7	7,5	7	6,7	7,6	10,6	10,2	10,5	10,8
CEE to Germany	10,4	10,2	9,8	9,7	9,8	8,6	8	6,9	7,5	7,7	7,6	7,7	8,2	8,2
Germany to China	3,8	1,7	1,8	2	1,7	1,5	1,7	1,5	1,5	1,6	1,8	1,6	1,6	1,5
China to Germany	1,5	1,6	1,9	2	1,7	1,9	1,8	1,7	1,9	2,2	2,7	2,9	3,4	4,2
China to CEE	2	0,9	1,1	1,4	1,2	1,4	1,3	1,3	1,3	1,5	1,8	1,9	2,2	2,6
CEE to China	1,1	0,4	0,5	0,5	0,4	0,4	0,5	0,4	0,5	0,5	0,4	0,4	0,4	0,4

Fig. 3. Value-added flows in telecommunications in manufacturing of the triangle in 2005–2018 (% of gross exports of the recipient country)

Source: author's calculations [OECD 2022].

[4] It is important to note that China has recently implemented several programs and strategies aimed at developing Industry 4.0, such as Made in China 2025 and the DSR. These initiatives are focused on advancing China's technological capabilities and competitiveness on the global market.

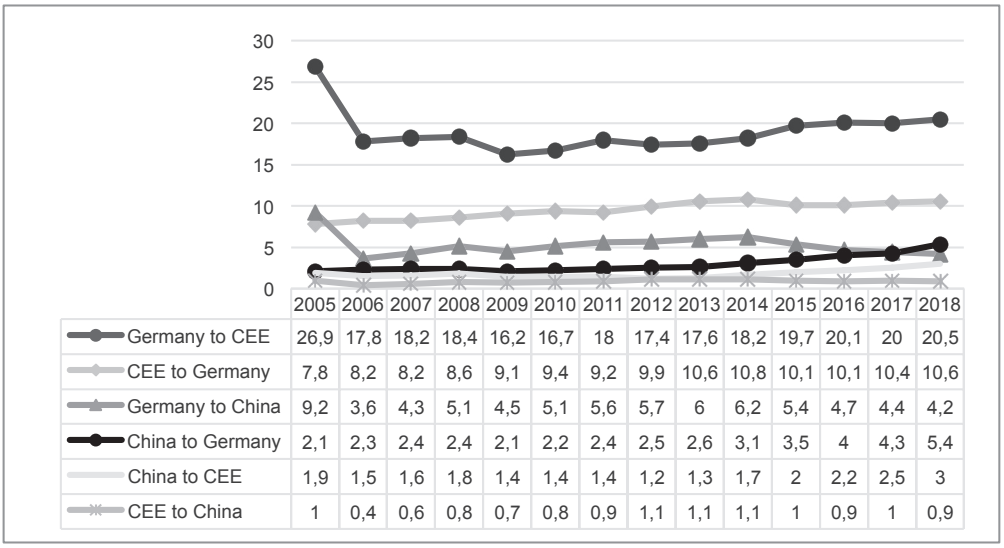
a reverse trend in computer programming, consultancy, and information services activities in manufacturing. Previously, Germany provided more services to Chinese manufacturing but, over time, China has become a larger source of advanced services for German manufacturing. While CEE has become more dependent on the Chinese value added in this case, they also increase the interdependence of the German market (Fig. 4).



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Germany to CEE	21,2	16,4	17,1	16,4	16,2	15,9	16,8	16,1	16,1	17	16,7	16,9	16,7	17
CEE to Germany	4,2	5,1	5,3	6,6	7,3	7,7	8	8,8	9,5	9,6	9,3	9,5	9,8	9,8
Germany to China	6,7	1,7	2,2	2,5	2,2	2,4	3,6	4,3	4,4	4,4	3,6	3,3	3,3	3,2
China to Germany	3,5	3,8	4	3,8	3,1	3,3	3,6	3,6	3,5	4,4	4,9	5,5	5,7	7,3
China to CEE	4,8	3,7	4,1	4,3	3,2	3,4	2,7	2	1,8	2,3	2,6	2,9	3,1	3,7
CEE to China	0,5	0,2	0,2	0,3	0,3	0,3	0,5	0,7	0,7	0,7	0,6	0,6	0,7	0,7

Fig. 4. Value-added flows in computer programming, consultancy, and information services activities in manufacturing of the triangle in 2005–2018 (% of gross exports of the recipient country)

Source: author's calculations [OECD 2022].



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Germany to CEE	26,9	17,8	18,2	18,4	16,2	16,7	18	17,4	17,6	18,2	19,7	20,1	20	20,5
CEE to Germany	7,8	8,2	8,2	8,6	9,1	9,4	9,2	9,9	10,6	10,8	10,1	10,1	10,4	10,6
Germany to China	9,2	3,6	4,3	5,1	4,5	5,1	5,6	5,7	6	6,2	5,4	4,7	4,4	4,2
China to Germany	2,1	2,3	2,4	2,4	2,1	2,2	2,4	2,5	2,6	3,1	3,5	4	4,3	5,4
China to CEE	1,9	1,5	1,6	1,8	1,4	1,4	1,4	1,2	1,3	1,7	2	2,2	2,5	3
CEE to China	1	0,4	0,6	0,8	0,7	0,8	0,9	1,1	1,1	1,1	1	0,9	1	0,9

Fig. 5. Value-added flows in ICT services in transport equipment of the triangle in 2005–2018 (% of gross exports of the recipient country)

Source: author's calculations [OECD 2022].

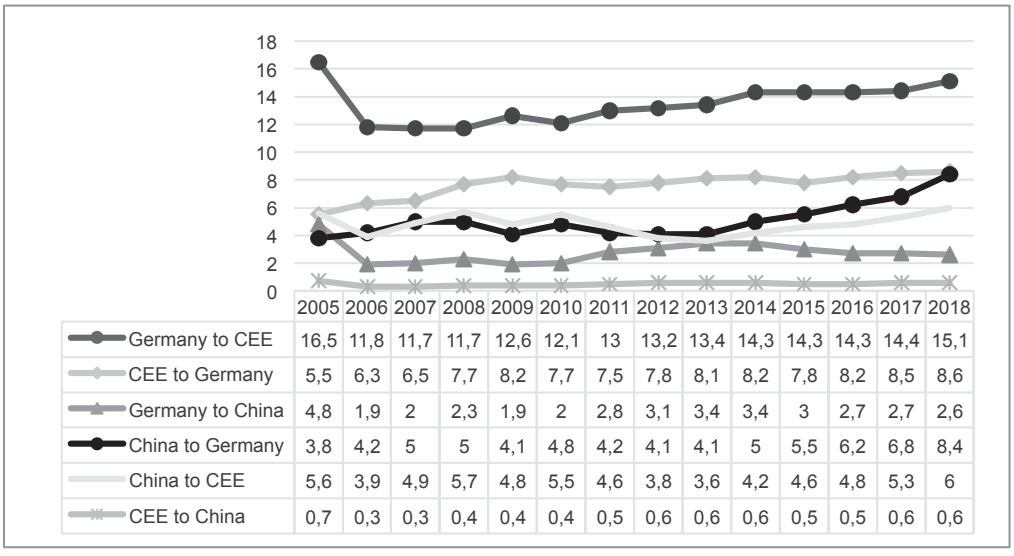
In the transport equipment industry, there was a significant decrease in the share of value-added inflows from Germany's ICT services to CEE – by 6.4% between 2005 and 2018 – and a notable increase in the share of Chinese value added to Germany – by 3.3%. However, the role of CEE in providing value-added to Germany and China did not increase significantly. China slightly increased its value-added inflows to German transport equipment, but the reverse was not observed. Additionally, there was no compensation for the decrease in flows between Germany and CEE by flows between Germany and China (Fig. 5).

In the value added of ICT services in transport equipment, the gaps between China and CEE increased and are heading toward a deeper imbalance, while between Germany and China, a reverse trend and a smaller gap occurred (perhaps it will increase) (Fig. 5).

In ICT services in computers, electronic, and electrical equipment, all pairs of economies noted growth in imbalance. The largest one occurred between CEE and Germany. In both Germany and CEE, significant growth in Chinese value added was observed. Also, both CEE and Germany have become more dependent on Chinese value added, while Chinese dependence on German and CEE stayed at a very low level (Fig. 6).

In 2018, the most considerable differences in the value-added flows of ICT services were between Germany and CEE in the value-added flows of ICT services to transport equipment (Fig 5) and the value-added flows of computer programming, consultancy, and information services activities to manufacturing (Fig. 4) – with gaps of 9.9% and 7.2%, respectively. On the other hand, the most balanced flows were between China and CEE in the value-added flows of ICT services to transport equipment, with a difference of only 2.1% (Fig. 5).

The value-added flows between CEE and Germany are much more intense than those between Germany and China. In most cases, the flows from Germany to CEE are greater than the others, except flows from German telecommunications to CEE's manufacturing in certain years (Fig. 3) and Chinese ICT services flows to German computers, electronic, and electrical equipment – which are almost equal to those from CEE (Fig. 6). The highest average share of value-added was between German ICT services and CEE transport equipment (19% on average dur-



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Germany to CEE	16,5	11,8	11,7	11,7	12,6	12,1	13	13,2	13,4	14,3	14,3	14,3	14,4	15,1
CEE to Germany	5,5	6,3	6,5	7,7	8,2	7,7	7,5	7,8	8,1	8,2	7,8	8,2	8,5	8,6
Germany to China	4,8	1,9	2	2,3	1,9	2	2,8	3,1	3,4	3,4	3	2,7	2,7	2,6
China to Germany	3,8	4,2	5	5	4,1	4,8	4,2	4,1	4,1	5	5,5	6,2	6,8	8,4
China to CEE	5,6	3,9	4,9	5,7	4,8	5,5	4,6	3,8	3,6	4,2	4,6	4,8	5,3	6
CEE to China	0,7	0,3	0,3	0,4	0,4	0,4	0,5	0,6	0,6	0,6	0,5	0,5	0,6	0,6

FFig. 6. Value-added flows in ICT services in computers, electronic and electrical equipment of the triangle in 2005–2018 (% of gross exports of the recipient country)

Source: author's calculations [OECD 2022].

ing the analyzed period) (Fig. 5), while the lowest average flows were between CEE's ICT services and German computers, electronic, and electrical equipment (7.6%), (Fig. 6).

The increase in Chinese value-added flows into Germany is not directly interchangeable with the decline in flows from CEE. However, as relations between Germany and China strengthen – including through visits by German politicians and China's expansion under the DSR – the inflows of value-added from advanced Chinese services are catching up to those from CEE directed to Germany (Fig. 2–6).

CONCLUSIONS

Referring directly to the research question, the following phenomena can be observed. The study found that the imbalance in value-added flows between economies continued to deepen, especially between CEE and China and, to some extent, between Germany and China. CEE economies increasingly rely on advanced services from China for the analyzed sectors, while the share of CEE services to Chinese manufacturing usually remains steady. Most of the analyzed German sectors relied more on Chinese value-added. Only two of the analyzed sectors did not experience this tendency. Previously, the inequality between Germany and China was not so obvious because Germany provided more services to China. Between CEE and Germany, we observed a larger dependence of CEE exports on the German market and vice versa in most of the analyzed industries. However, there was no direct compensation between pairs of economies (e.g., the decrease in German value-added flows to China did not result in a similar increase in value-added from German to CEE manufacturing).

If the presented changes in flows were to reflect the effectiveness of Chinese Industry 4.0 and the DSR, it should be recognized that it fulfills its role and increases not only the advancement of Chinese value-added exports, but also makes important economies dependent on this value added. However, the DSR should be considered only as a strategy supporting current trends and not as a factor that caused sudden changes in the relationships in the studied triad. Moreover, one expects that China will change the DSR strategy to adjust to international markets [Cook et al. 2018]. On the contrary, the Industry 4.0 strategy in CEE has not improved its position. Germany still has a strong position as a provider of value added, but its dependence on foreign value added is high, which derives from the links with CEE. However, it is not only the DSR and Industry 4.0 that influence relationships between the triad. Political relations between countries are also of great (possibly the greatest) importance. From the CEE perspective, the interconnections in analyzed sectors would depend on Germany's position toward Chinese technology and China's capability of aligning with European requirements. However, the exclusion of Chinese advanced services from the European technology market will not fundamentally change the role of CEE as a recipient of ICT services. It will not improve the process of transition to the Industry 4.0 phase. Moreover, it does not transform CEE into a supplier of ICT services to former Chinese trade recipients. CEE economies will still rely largely on foreign ICT services, but their diversification will decrease as they will mainly be European suppliers. In addition, the cost of obtaining services used in manufacturing may increase because the presence of China on the market may have influenced prices [Bloom et al. 2010, European Parliament 2020].

In the end, we should be aware of some limitations of the study. First, the analyzed period is relatively short and, in a long-term analysis, there could be some significant changes in interdependencies among the three economies. Second, the COVID-19 pandemic, war in Ukraine, and technological decoupling between China and the U.S. have changed the landscape of production networks; the only question is whether the changes are short-term or long-term. Another important limitation results from the deteriorating technological relations between the European Union and China and the difficulty in predicting the direction in which restrictions on the flow of technology will take. There is a danger that Europe, including CEE, will follow the U.S. and decouple from Chinese technology.

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MIĘDZYSEKTOROWE WSPÓŁZALEŻNOŚCI TECHNOLOGICZNE EUROPY ŚRODKOWEJ I WSCHODNIEJ W DOBIE PRZEMYSŁU 4.0 I CHIŃSKIEGO CYFROWEGO JEDWABNEGO SZLAKU

STRESZCZENIE

Cel: Celem artykułu jest ocena przepływów wartości dodanej w zakresie serwicyzacji produkcji przemysłowej w obrębie dwóch najważniejszych dostawców wartości dodanej dla Europy Środkowej i Wschodniej (EŚW): Niemiec i Chin w dobie przemysłu 4.0 oraz chińskiego Cyfrowego Jedwabnego Szlaku. **Metody:**

Do oceny powiązań międzysektorowych pomiędzy analizowanymi gospodarkami zastosowano model rozkładu przepływów międzysektorowych. **Wyniki:** Gospodarki EŚW coraz silniej uzależniają swój przemysł przetwórczy od wysokiej jakości usług z Niemiec i Chin, podczas gdy analogiczne przepływy z EŚW do Niemiec i Chin maleją lub utrzymują się na stałym poziomie. Niemiecka produkcja zaczyna w większym stopniu zależeć od wartości dodanej chińskich usług w zaawansowanych sektorach. Nie było bezpośredniego trade-off między parami gospodarek, ale spadek niemieckich przepływów wartości dodanej do Chin doprowadził do znacznie większego wzrostu chińskiej wartości dodanej w niemieckiej produkcji przemysłowej. **Wnioski:** Mając na uwadze ograniczenia badania, wykazano pogłębioną nierównowagę w przepływach wartości dodanej pomiędzy gospodarkami. Co więcej, badanie wykazało efektywność chińskiego Przemysłu 4.0 i Cyfrowego Jedwabnego Szlaku pod względem udoskonalenia chińskiego eksportu o wartości dodanej i uzależniania kluczowych gospodarek od tej wartości dodanej.

Słowa kluczowe: ICT, serwicyzacja produkcji przemysłowej, Chiny, Niemcy, EŚW