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The Characteristics of Regional Value Chains in the Sector of Chemicals and Pharmaceutical Products in the EU

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Abstract: The COVID-19 pandemic has impacted trade flows, causing a trade drop in 2020 that was especially sensitive for pharmaceutical and medical products necessary to ensure public health. The production of pharmaceutical products is dispersed in a framework of global value chains. This study aimed to provide a detailed analysis of the EU situation in the sector of production of chemical and pharmaceutical products, to discover the fragmentation of production chains within the EU as well as globally. International inter-country input–output tables were employed to disaggregate the value-added created in EU member states. The GVC and RVC participation indexes, backward and forward participation, length of sourcing, and selling value chains were calculated and compared with the main global hubs.

Keywords: chemical and pharmaceutical products; input–output tables; GVC and RVC participation and position; EU

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1. Introduction

The motivation for doing this research was instigated by the COVID-19 pandemic and the (un)availability of pharmaceutical products in the EU. In other words, even the internationalization of production has many positive implications, the lock-down of economies highlighted the problem of production processes if they depend on foreign inputs, or if they produce inputs that are to be exported to other countries. The COVID-19 pandemic during 2020 and early 2021 impacted on the drop in international trade and in global value-chain activities, where countries and sectors are not in an equal position. Global production chains suffer from putting different restrictions on the movement of people that disrupt the transportation process, but also, initially, some factories were closed for a period of time and employees stayed at home, so production was stopped. The interconnected producers in other countries or regions of the world were faced with an inability to obtain the production inputs on time, but they were also pushed to temporarily close their production capacities as the pandemic spread around the world. The pandemic initiated many questions about the future of international trade and, even more often, about the future development of global value chains (Baldwin and Freeman 2020). Global value chains are facing different challenges: effectiveness vs. resilience and regionalization vs. globalization.

The goal of this research was to focus on the trade of pharmaceutical and related products, to see the geographical pattern of international trade (the main producers, exporters, and importers) in the EU, but also to deepen the analysis with an insight into the global (or regional) value chains in the EU. Here, we focused on the product group chemicals and pharmaceutical products (D20T21), because there were no available data for the pharmaceutical industry alone that includes inter-sector and inter-country linkages.

We covered the data for 2005 and 2015 from the OECD database (inter-country input–output tables, ICIO, OECD 2021), and for numerical operation over matrices we used our own MATLAB code. The methodological framework was already well developed by Koopman et al. (2010), and we applied selected indicators from the disaggregation of gross export into value-added components. The focus was on EU member states and we were aiming to find out the scope and direction of mutual relationships (inter-linkages) in production in that specific sector, i.e., to find out if the value chains in the EU were regional or global. Further, we analyzed the trade in final goods and intermediate products with main competitors: China, USA, India, Japan, and the UK.

Our approach was based on the hypothesis that the trade in chemicals and pharmaceutical products in the EU is characterized by dominance of intra-EU trade, but also that EU member states, besides regional cooperation, participate in GVCs that also include countries outside of the EU, indicating the dependence on the world market (and on trade policies).

The originality of the paper arises from the fact that it deals with two hot and important issues: (1) regionalization of GVCs (as a contemporary trend) and (2) chemicals and pharmaceutical products (where COVID-19 pandemic crucial products and ingredients belong). In this analysis, we provide results about the regionalization of production processes in the EU in the sector of chemicals and pharmaceutical products, which we can define as a very sensitive sector due to the COVID-19 pandemic (i.e., during the beginning of the pandemic, many countries imposed trade restrictions on the export of medical and pharmaceutical products or ingredients).

The paper is organized into five sections, where the second comprises the theoretical background and literature review, the third section explains the methodological framework, and the fourth presents an analysis of the research results with discussion. This is followed by the conclusion and policy recommendations section.

2. Theoretical Background and Literature Review

Global value chains represent the fragmentation of production processes into many stages (phases) that take place in different countries. The precondition for GVC development and its widening lies in the liberalization of trade policies and in enabling smooth transport of goods between countries (or availability of services). The characteristics, coverage, and complexity of global value chains were presented in Gereffi and Fernandez-Stark (2011), Taglioni and Winkler (2016), and Hernández and Pedersen (2017). Baldwin and Freeman (2020) pointed out two main shocks of the pandemic on production and GVCs: through the number of cases that prevent people's ability to work, and from the expectation that it is hurting demand for manufactured goods. The drop in a nation's income will reduce consumption and imports, while production suffers from a drop in exports.

The internationalization of production has stagnated in the last twenty years with the additional counter-effect caused by the COVID-19 pandemic where the main question the GVCs are facing is the trade-off between efficiency and resilience. Gölgeci et al. (2020) highlighted that efficiency needs to be sustained to achieve long-term resilience and survival and that the pandemic is not the sole factor that determines the future of GVC structures and strategies. The pandemic has disrupted production and supply chains, causing global recession and, in the longer term, it has created the imperative to increase the resilience of supply chains and to increase national and/or regional autonomous productive capacities (UNCTAD 2020).

The possible directions for the future development of GVCs are elaborated by Kersan-Skabic (2021): reshoring, resilience in supply chains, adjustments in governance, diversification, and development of risk-management strategies.

In the approach to the issue of regionalization of global value chains (GVCs) in the EU, it is important to point out three aspects: (1) trade flows (total and pharmaceutical/medical products), (2) internationalization of production in the sector of chemicals and pharmaceu-

tical products, and (3) intra-regional relationships/flows/trends within the EU regarding the specific sector.

2.1. COVID-19 Pandemic and International Trade

The estimate is that the total trade in goods has fallen in 2020 by 8% (UNCTAD 2021). Relevant international organizations predict the recovery of foreign trade in 2021.

The WTO (2020a, 2020b, 2020c) pointed out that trade in medical products[1] had a growth of 16% (in the first half of 2020 in comparison with the same period in 2019), where the highest growth was in facemasks (84%), and China is the leading exporter of these. Regarding the value, medicines remain the largest category, accounting for more than 50 per cent of all traded medical products. That study also found that China, Germany, and the USA are the world leaders in the trade of medical products (COVID-19-critical products).

The share of pharmaceutical products in world merchandise trade was just 3.2% in 2019. In 2019, the most important exporters of pharmaceutical goods were Germany (USD 98.4 billion, or 16% of global pharmaceutical goods exports), Switzerland, Ireland, the United States and the Netherlands, while in medical instruments, appliances, and similar, the leaders were the USA (USD 46.2 billion), Germany, China, the Netherlands, and Mexico. On the import side, the USA was the leader, with about 20% of global imports (USD 122 billion), followed by Germany, the Netherlands, Belgium, and the UK.

McKinsey Global Institute (2020) found that trade is becoming more regional, and in pharmaceutical products, 40% of trade in the EU27 + UK is intra-trade. They also systematized the risks that global production is facing with differentiation across sectors (not all sectors are exposed to the same extent). The pharmaceutical sector is among the less-affected sectors. The most important producers are China, the USA, Europe, and India. The production chains are largely global, with specialization of countries in specific products, where the EU27 + UK is specialized in human vaccines and produces 84% of global production; this region also produced 44% of other APIs (active pharmaceutical ingredients) and 29% of antibiotic APIs in 2018. The shift towards more localized (home or near-home production) can be influenced by government policies to restore domestic production of some medicines to ensure public health. McKinsey Global Institute (2020) estimated that 38–60% of the pharmaceutical value chain could shift geographically in the coming years.

Due to the COVID-19 pandemic, Eurostat (2021) provided statistics about export and import of COVID-19-related products (medical equipment and pharmaceutical products) for the EU in the first half of 2020. It is evidenced by a sharp increase in import of COVID-19-related products, but also, some countries imposed protectionist measures on exports to facilitate the necessary quantity of these kind of products for the home country. China, the USA, and Switzerland are the most important trade partners for the COVID-19-related products trade[2].

2.2. Internationalization/Regionalization of Production Process of Chemicals and Pharmaceutical Products

Research of international production fragmentation in the domain of chemicals and pharmaceutical products is very scarce. Here, we have presented some articles that deal with some aspects of this particular topic. Bhakoo and Chan (2011) highlighted that pharmaceutical supply chains are very complex because they require the participation of different stakeholders such as pharmaceutical manufacturers, wholesalers, distributors, customers, information service providers, and regulatory agencies. Because of these complexities, the pharmaceutical sector is not widely researched. Sousa et al. (2011) discussed the issue of the dynamic allocation/planning problem for optimization of global supply chains of pharmaceutical companies.

Singh et al. (2016) presented the literature review covering the following topics: inventory management, new product development, process development, capacity planning,

network design, plant design, pipeline and development management, outsourcing logistics activities, reverse logistics, lean manufacturing, green supply-chain management, and implementation of e-business processes in the pharmaceutical sector. They concluded that there were many gaps identified, indicating that this sector is not widely researched in developing countries. The findings also imply that developing countries are not investing much on R&D, use of electronic media for health awareness, process and capacity building, sustainability, and quality issues. This was followed by Mendoza (2021), who presented a review of literature about the complexity and fragmentation of the drugs supply chain and discussed the shape or reshape of action and risk aversions of its actors. He connected the main participants, their interests, and potential risks in the supply chain.

According to Haakonsson (2009), the process of internationalization of the pharmaceutical industry rose in the late 1990s thanks to the internationalization of patent protection in the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs Agreement)[3]. Geymond (2020) found that top pharmaceutical TNCs are highly concentrated where the strategic decisions are highly centralized, but just some research, production, and commercial activities are fragmented and organized into global networks. Folfas and Udvari (2019) compared different GVC indicators in the chemical sector for Hungary and Poland and concluded that the level of domestic value-added in both countries is declining and is low. That indicates their high participation in production fragmentation and in GVCs, and the DVA contents should be increased so that domestic economies could have a positive implication for chemicals export.

A global approach (coverage) is present in Fróes de Borja Reis and Guedes Pinto (2021), who examined center–periphery relations in pharmaceutical value chains and came to interesting findings, which are: They proved the regionalization of pharmaceutical value chains with centers in the USA (in America), Switzerland, and Germany (in Europe); some big countries which form the global peripheries (i.e., Brazil, Russia, Saudi Arabia) have very low participation in GVCs; for some countries (Mexico, India, Hungary, Poland and even China), they found that they become "large exporters of pharmaceuticals with low prices per kilogram and a high content of imported added value, paying low salaries and maintaining deficits in intellectual property rights charges".

UNCTAD (2020) also covered GVC characteristics in the group of chemicals and pharmaceutical goods and warned that the last crisis (COVID-19 pandemic) pointed out the necessity of keeping open the supply chains for pharmaceutical products (that are needed for combating the virus). The main findings were: The export of chemicals and pharmaceutical products contain 47.8% of value-added created in that sector, while more than 50% comes from other industries, and the services account for 34% of its export; the share of foreign inputs is 25.5%, where for some countries (the USA, China) this ratio is lower and for some countries higher (Chinese Taipei and Singapore).

2.3. Regionalization of Value Chains in the EU

In this study, we were interested in providing a deep analysis of the situation in the EU. European economies are focused on developing regional value chains. On the global arena, China was the dominant supplier of inputs (raw materials) in the pharmaceutical value chain in 2019, followed by Ireland[4]. Baldwin and Freeman (2020) warned that the trade in intermediate products is more regionalized than the trade in final goods. China dominates as exporter of intermediates, so the closure of capacities in China will have a big impact on the manufacturing sector globally. Los et al. (2015) applied a new input–output model of the world economy, covering 40 countries and 14 manufacturing product groups based on the WIOD database. They compared fragmentation in production in 2008 with the initial data for 1995 and they found the foreign value-added share in gross exports is increasing, pointing to an even higher growth of FVA from the world in comparison with FVA arrived from the region. They indicate the transiting from regional production systems to "Factory World". For the EU member states, they found an increase in FVA in total exports, but the increase in FVA coming from the EU region was higher than the

increase in FVA that arrived from the rest of the world. Therefore, in the EU member states, the trend towards regional fragmentation is present.

Hanzl-Weiss et al. (2018) dealt with analysis of intra-regional and inter-regional parts of participation in global value chains. They found stagnation of GVC development in the 2011–2014 (post-crisis) period and compared the situation in the EU with the situation in North America and in Asia. The findings indicate that global value chains in Europe are 50% regional and the same goes for the inter-regional component. They calculated bilateral trade matrices for export to immediate production partners and to ultimate production partners and they highlighted that Germany, Austria, the Czech Republic, Hungary, Poland, and Slovakia together form the Central European Manufacturing Core. According to them, demand is strongly shaping the organization of production; while RVCs are predominantly producing for the EU market, GVCs are predominantly procuring for third countries.

The European Commission (2020) pointed out the domination of the higher share of intra-EU value-added in export and import of member states in comparison with value-added coming from the rest of the world (European Commission 2020, p. 20).

The specific detailed input–output analysis of trade in value-added in the sector of chemicals and pharmaceutical products in the entire EU has not been made, to the authors' knowledge, arising from the results of searching the relevant scientific database.

3. Research—Data and Methodology

The GVC framework and international production indicators are the subject of many papers, and the concept was developed by Timmer et al. (2014) and Koopman et al. (2014)[5].

Sources of data were the OECD Inter-Country Input–Output (ICIO) Tables for the years 2005 and 2015 (2018 edition): ICIO2018_2005, and ICIO2018_2015 for 64 countries (36 OECD countries and 28 non-OECD economies), plus the rest of the world, for 36 industries (sectors). The data for China and Mexico were aggregated since the data for these countries were split in the ICIO table. The structure of the OECD Inter-Country Input–Output Table with G countries and N sectors consisted of an *Intermediate use* (Intermediate demand) part, a $(GN \times GN)$ matrix **T**, which element t_{ij} describes the value of output of source sector (country) i used in the production sector (country) j, and a *Final demand* part, which in the OECD ICIO tables consisted of six different types of Final demand: Household final consumption expenditure, Non-profit institutions serving households, General government final consumption, Gross fixed capital formation, Change in inventories and valuables, and Direct purchases abroad. Since the goal of this research was not an insight into different kinds of Final demand, these six types of Final demand were aggregated as one type in a $(GN \times G)$ matrix of Final demand **Y.**

Since the *Gross output* of one sector must be used as an intermediate or final good, the sum of each row element of matrix **T** plus the sum of each row element of matrix **Y** represented the gross output of a sector of one country, defined as $(GN \times 1)$ vector **X**.

If matrix **T** and **Y** are represented as block matrix:

$$\mathbf{T} = \begin{bmatrix} \mathbf{T}_{11} & \mathbf{T}_{12} & \cdots & \mathbf{T}_{1G} \\ \mathbf{T}_{21} & \mathbf{T}_{22} & \cdots & \mathbf{T}_{2G} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{T}_{G1} & \mathbf{T}_{G2} & \cdots & \mathbf{T}_{GG} \end{bmatrix}, \mathbf{Y} = \begin{bmatrix} \mathbf{Y}_{11} & \mathbf{Y}_{12} & \cdots & \mathbf{Y}_{1G} \\ \mathbf{Y}_{21} & \mathbf{Y}_{22} & \cdots & \mathbf{Y}_{2G} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{Y}_{G1} & \mathbf{Y}_{G2} & \cdots & \mathbf{Y}_{GG} \end{bmatrix} \quad (1)$$

where $\mathbf{T}_{ij}$ denotes a $(N \times N)$ matrix, and $\mathbf{Y}_{ij}$ denotes a $(N \times 1)$ vector, the sum of each off-diagonal row element of **T** represents the *Intermediate Export*, and the sum of each off-diagonal row element of **Y** represents the *Export of Final goods*. The sum of these two elements represented the *Gross export* of a sector (industry) of a certain country. The *Import* of a sector of a certain country could be calculated as a sum of each off-diagonal column element of matrix **T**.

The matrix of *Technological coefficients* **A** could be calculated as element-wise division of columns of matrix **T** by gross output vector **X**. The matrix **A** has the same dimension as matrix T, $(GN \times GN)$. The *Leontief inverse matrix* could be defined as:

$$\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1} \tag{2}$$

where **I** is an identity matrix of dimension $(GN \times GN)$.

The *Direct value-added* coefficient vector **V** could be calculated as 1 minus the sum of each column of matrix **A**. If defining a block diagonal matrix:

$$\hat{\mathbf{V}} = \begin{bmatrix} \hat{\mathbf{V}}_1 & 0 & \cdots & 0 \\ 0 & \hat{\mathbf{V}}_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{\mathbf{V}}_\mathbf{G} \end{bmatrix} \tag{3}$$

where $\hat{\mathbf{V}}_i$ is a diagonal $(N \times N)$ matrix with direct value-added coefficient vector of country i on the main diagonal, hence, the dimension of $\hat{\mathbf{V}}$ is $(GN \times GN)$, and a block diagonal matrix:

$$\hat{\mathbf{E}} = \begin{bmatrix} \hat{\mathbf{E}}_1 & 0 & \cdots & 0 \\ 0 & \hat{\mathbf{E}}_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & \hat{\mathbf{E}}_\mathbf{G} \end{bmatrix} \tag{4}$$

where $\hat{\mathbf{E}}_i$ is a diagonal $(N \times N)$ matrix with exports vector of country i on the main diagonal $(N \times N)$, hence, the dimension of $\hat{\mathbf{E}}$ is. It is possible to calculate the *Trade in value-added matrix* $\mathbf{T_v}$ as:

$$\mathbf{T_v} = \hat{\mathbf{V}}\mathbf{B}\hat{\mathbf{E}} \tag{5}$$

where all matrices are of the same dimension $(GN \times GN)$. The matrix $\mathbf{T_v}$ shows how the value-added contained in gross exports of a country (sector) is generated by column and distributed by row across country (sector). The diagonal elements of matrix $\mathbf{T_v}$ denotes *Domestic value-added* (DVA) in gross exports, and off-diagonal elements along a column are the measure of value-added from abroad embodied in a country's gross exports, or *Foreign value-added* (FVA). The sum of off-diagonal elements along a row is the *Indirect value-added exports* via third countries (DVX).

If we summarize by country the column of matrix $\mathbf{T_v}$, we can derive the *Bilateral value-added* in production of chemicals and pharmaceutical products, or we can see how much of value-added is created by exports of the chemicals and pharmaceutical products sectors allocated in all sectors of different countries.

Based on DVA, FVA, and DVX metrics, Koopman et al. (2010) defined the following indexes:

$$\textit{Forward GVC participation} = \frac{DVX}{E} \tag{6}$$

$$\textit{Backward GVC participation} = \frac{FVA}{E} \tag{7}$$

$$\textit{GVC participation} = \frac{DVX}{E} + \frac{FVA}{E} \tag{8}$$

$$\textit{GVC position} = \ln\left(1 + \frac{DVX}{E}\right) - \ln\left(1 + \frac{FVA}{E}\right) \tag{9}$$

The GVC participation index is a sum of backward and forward linkages in GVCs. The GVC position index indicates if a country specializes in the first or the last steps of production. If a country is upstream in the production network (first stages of production), it is likely that it has a high value of forward participation relative to backward. If a country specializes in the last steps of production (downstream), it is likely that it imports a lot of

intermediate goods from abroad and therefore it has high backward participation. The GVC position index is constructed in such a way that countries with high forward relative to backward participation record a positive value.

The country's gross export to the world is the sum of DVA and FVA. Domestic value-added (DVA) can be disaggregated on six components (according to Koopman 2014, p. 481, eq. 36):

1. DVA in direct final goods exports (VAX1): $\mathbf{V_s} \sum_{\mathbf{r \neq s}}^{\mathbf{G}} \mathbf{B_{ss}} \mathbf{Y_{sr}}$;
2. DVA in intermediates exports absorbed by direct importers (VAX2); $\mathbf{V_s} \sum_{\mathbf{r \neq s}}^{\mathbf{G}} \mathbf{B_{sr}} \mathbf{Y_{rr}}$;
3. DVA in intermediates re-exported to third countries (VAX3): $\mathbf{V_s} \sum_{\mathbf{r \neq s}}^{\mathbf{G}} \sum_{\mathbf{t \neq s,r}}^{\mathbf{G}} \mathbf{B_{sr}} \mathbf{Y_{rt}}$;
4. Intermediates that return via final imports (DVA4): $\mathbf{V_s} \sum_{\mathbf{r \neq s}}^{\mathbf{G}} \mathbf{B_{sr}} \mathbf{Y_{rs}}$;
5. Intermediates that return via intermediate imports (DVA5): $\mathbf{V_s} \sum_{\mathbf{r \neq s}}^{\mathbf{G}} \mathbf{B_{sr}} \mathbf{A_{rs}} (\mathbf{I} - \mathbf{A_{ss}})^{-1} \mathbf{Y_{ss}}$;
6. Double-counted intermediate exports produced at home (DVA 6): $\mathbf{V_s} \sum_{\mathbf{r \neq s}}^{\mathbf{G}} \mathbf{B_{sr}} \mathbf{A_{rs}} (\mathbf{I} - \mathbf{A_{ss}})^{-1} \mathbf{E_{ss}}$.

The sum of the first three components defines *Value-added export*, or VAX according to Johnson and Noguera (2012), which does not account for domestic content in intermediate exports that finally return home (components DVA4, DVA5, and DVA6).

Then, we also calculated the length of the sourcing and selling chains. The *sourcing chain length* addresses the degree of interconnections of a particular country/sector with those upstream countries/sectors from which it purchases intermediate products (De Backer and Miroudot 2014), and is defined as the transposed sum of columns of Leontief inverse matrix **B:**

$$\mathbf{N} = (\mathbf{u}' \mathbf{B})' \tag{10}$$

where $\mathbf{u}'$ is a unit row vector, and the dimension of $\mathbf{N}$ is $(GN \times 1)$. Its length is equivalent to total backward linkages and provides a measure of downstreamness (Miller and Blair (2009); Wang et al. (2016)). The sourcing chain length consists of domestic and international parts. The domestic part measures the length of production processes when the intermediate products for the realization of a final product are domestically sourced. Conversely, the international part measures the length of production processes when the intermediate products for the realization of a final product are sourced from foreign countries. The minimum value of the sourcing chain length is one representing that the product is produced in a single production stage. Its value increases with the raising of intermediate production processes (stages) in its production.

The *length of the selling* chain (or distance to final demand) shows the scope of interconnections of a country/sector with those downstream countries/sectors to which it sells its output (Miller and Blair (2009)). Its length measures how many stages of production are left before the goods and services produced by an industry or by a country reach final consumers (Antràs and Staiger 2012). It represents forward linkages, and it is an indicator of upstreamness. To be able to calculate the length of the selling chain, we must firstly calculate the *Total linkages matrix* **M** as:

$$\mathbf{M} = \hat{\mathbf{X}}^{-1} \mathbf{A} \tag{11}$$

where $\hat{\mathbf{X}}$ is a $(GN \times GN)$ diagonal matrix with gross output vector $\mathbf{X}$ on the main diagonal, and secondly the *Total forward linkages* matrix **G** is:

$$\mathbf{G} = (\mathbf{I} - \mathbf{M})^{-1} \tag{12}$$

known as the Ghosh inverse matrix of dimension $(GN \times GN)$. The row sum of the elements of the Ghosh inverse matrix represents the $(GN \times 1)$ **D** vector, i.e., the length of the selling chain vector:

$$\mathbf{D} = \mathbf{Gu} \tag{13}$$

where **u** is a unit column vector.

4. Results of Empirical Research

4.1. Characteristics of Regional and Global Value Chains for EU Member States

The initial starting point in our analysis was an insight into export and import of chemicals and pharmaceutical products in the EU.

Figure 1 refers to the importance of intra-EU export and import in trade of chemicals and pharmaceutical products. The highest share of intra-EU export (above 70%) appeared in Slovakia, Luxembourg, and the Czech Republic, while the huge orientation to the EU market on the import side was visible in Luxembourg, the Czech Republic, and Romania. On the other hand, Ireland had the lowest orientation to the intra-EU market.

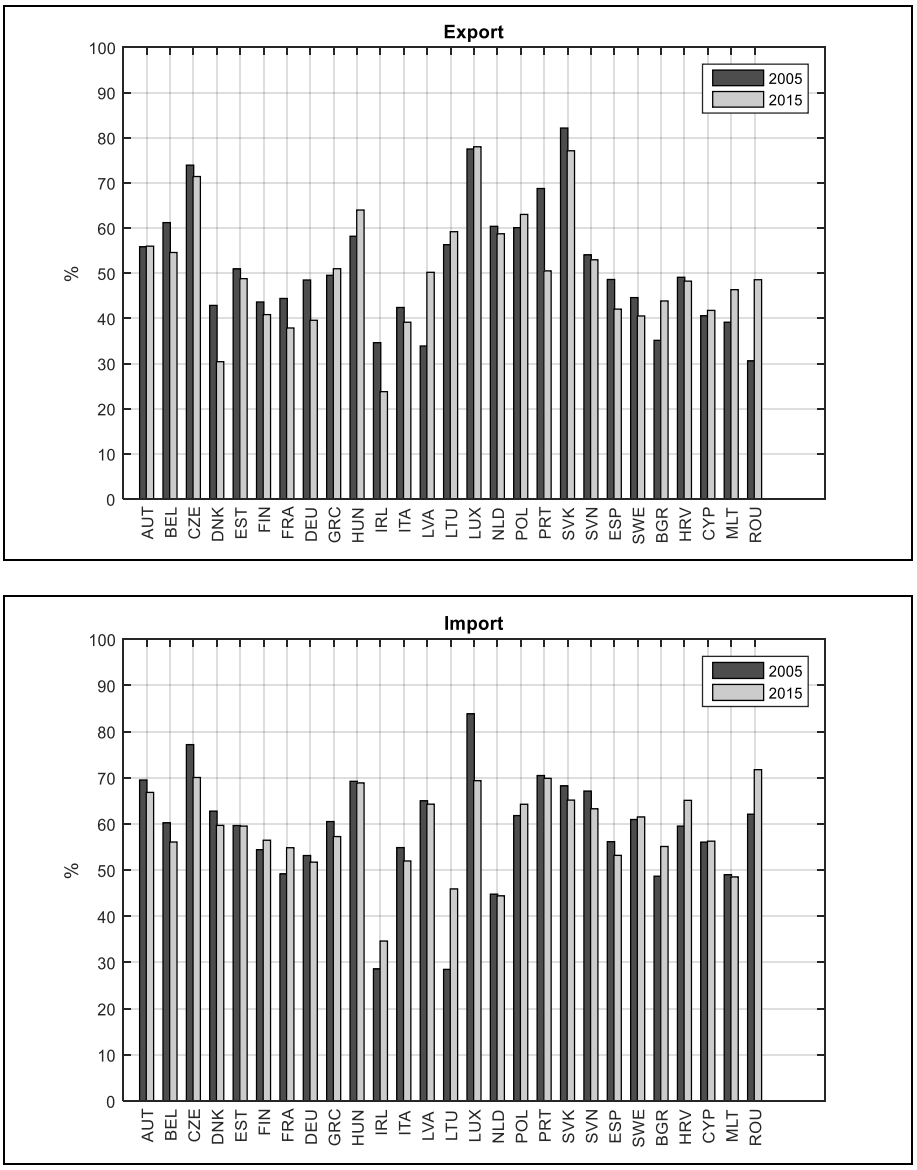

Figure 1. Intra-EU export and import of chemicals and pharmaceutical products in 2005 and in 2015 (in %). Source: ICIO tables, OECD, own calculations.

Figure 1 indicates the importance of the common market (Single market) for the sales of pharmaceutical and chemical products. The data include the sales on the domestic market and on the foreign market of EU member states. Half of the EU member states sell more than 50% of their export on the common EU market. During the ten-year period, the share of the EU market for exports slightly decreased in the majority of countries. It is obvious that EU member states import chemicals and pharmaceutical products more from the intra-market then they export to the common market. This share of intra-EU import was decreasing over the ten-year analysis period in many EU member states. It indicates the focusing on imports from outside the EU, especially from China.

For a detailed analysis of the GVC or RVC network in the EU, the share of intermediates in gross exports and gross imports is important. Higher presence of intermediates indicates higher involvement in the international (global or regional) production chains.

Figure 2 shows higher values (big differences) of intermediate exports in comparison with imports in Germany and France, where both countries exported intermediate products twice as much as they import them. Additionally, Ireland, Italy, the Netherlands, Belgium, and Spain also stand out and all of them exported more intermediate products than they imported. In comparison with the values of gross export and import (TiVA database), we found that the share of intermediates varied from just above 20% in Malta to above 75% in Luxembourg, Finland, the Netherlands, and Slovakia.

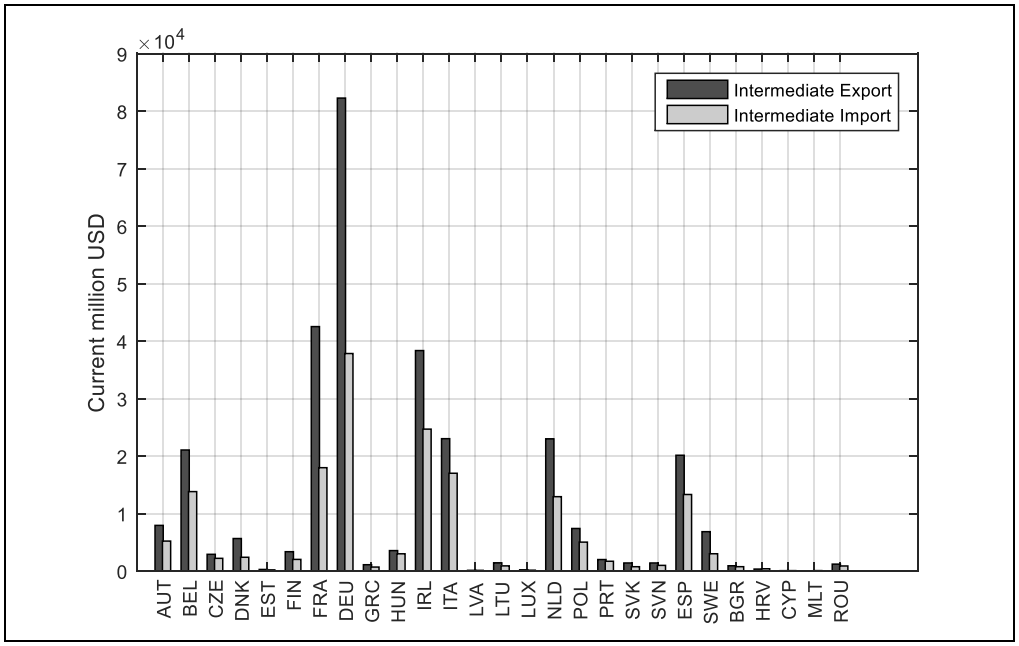

Figure 2. Export and import of intermediate products of chemicals and pharmaceutical products in the EU in 2015. Source: ICIO tables, OECD, own calculations.

According to Koopman et al. (2014), we calculated the forward and backward participation in GVCs for intra-EU trade.

Figure 3 contains the data about regional backward and forward participation in 2005 and in 2015. There is a predominance of backward linkages, which is expected due to the fact that EU countries import more ingredients (intermediate production inputs) than they export. The biggest difference in backward/forward participation in 2015, in comparison with 2005, was found in Estonia, Ireland, Bulgaria, and Malta.

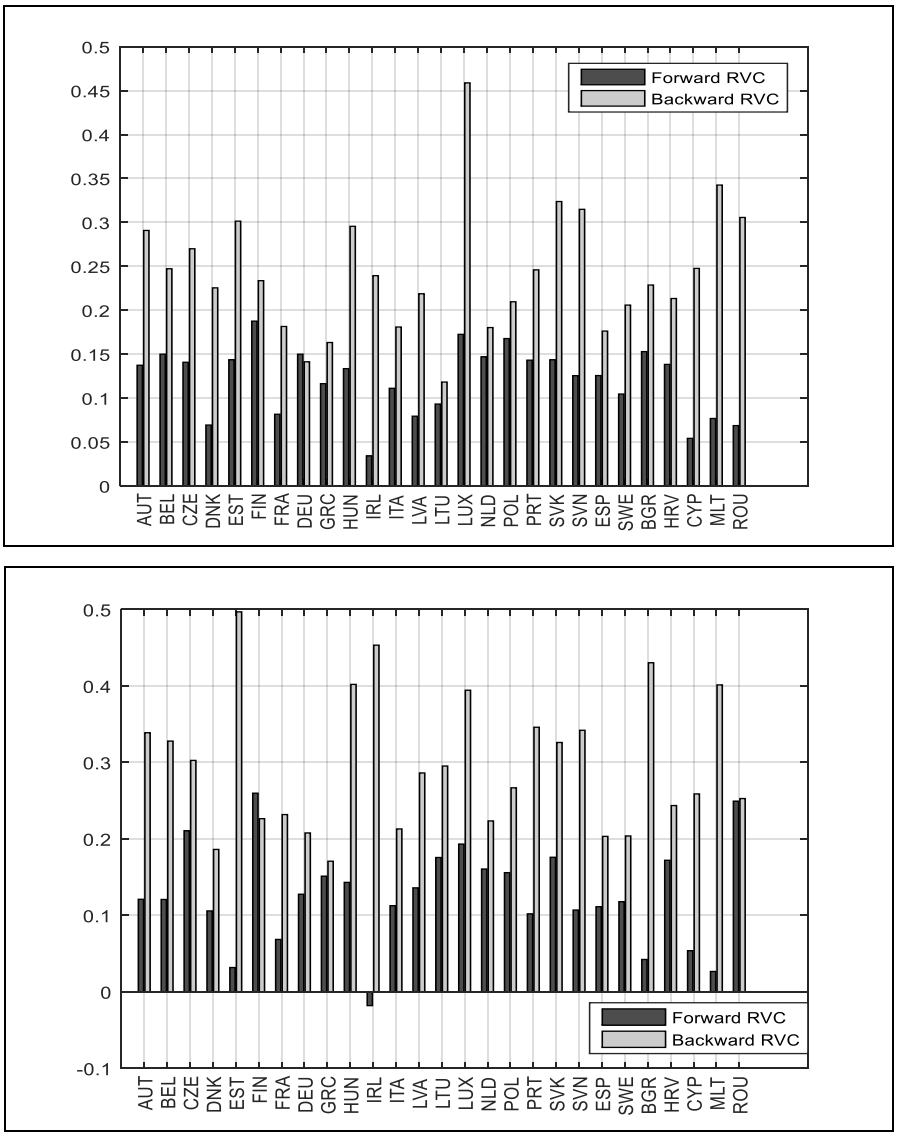

Figure 3. Forward and backward participation of EU member states in intra-trade of chemicals and pharmaceutical products in 2005 and in 2015. Source: ICIO, OECD, own calculations.

On the basis of backward and forward participation, we were able to calculate the GVC participation index and GVC position (Figure 4). The data here differ from the European Commission (2020) due to the focusing here just on intra-EU trade. Here, all EU member states could be grouped into the third group—higher backward participation.

The GVC participation index varied from below 0.3 in Denmark to above 0.7 in Luxembourg. For the majority of member states, the GVC participation index was above 0.5. GVC position indexes had a negative sign, indicating the dominance of backward participation and higher dependence on import of intermediates in comparison with exports. The biggest negative values were in Malta, Estonia, Bulgaria, and Luxembourg.

Luxembourg, Hungary, Estonia, and the Czech Republic had the highest RVC participation index (above 0.5) while, on the other hand, there were Denmark and France with the participation level of just 0.3 (Figure 5). The negative value of the RVC position indicates that the backward participation dominated vs. forward participation, and it coincides with the results of Figure 3, i.e., the highest negative values are in Ireland, Estonia, Bulgaria, and Malta.

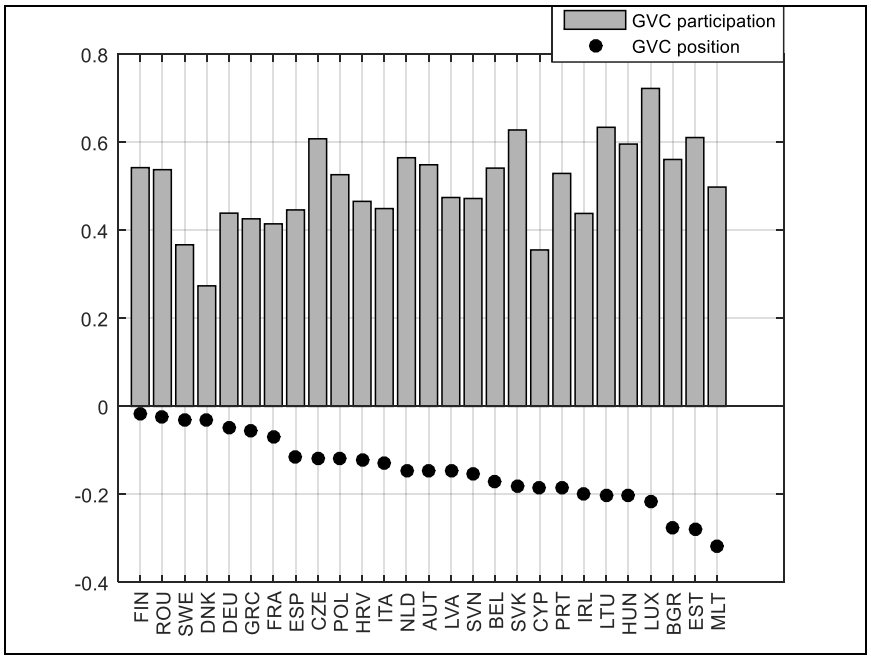

Figure 4. GVC participation and GVC position of EU member states in trade of chemicals and pharmaceutical products. Source: ICIO, OECD, own calculations.

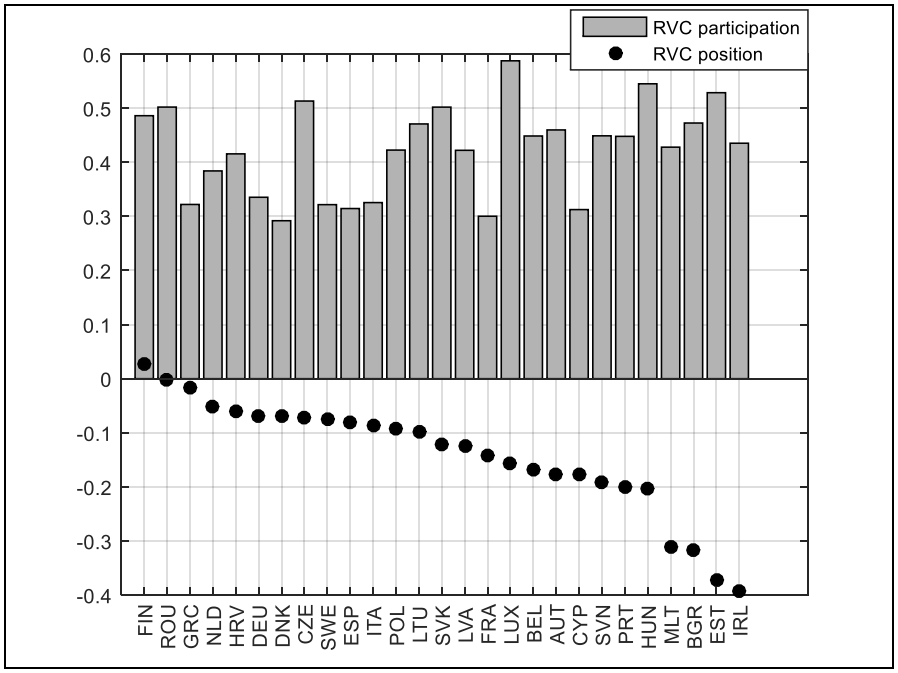

Figure 5. RVC participation and RVC position of EU member states in trade of chemicals and pharmaceutical products. Source: ICIO, OECD, own calculations.

Figure 6 gives the comparison between the GVC and RVC position indexes. The light circles refer to the RVC position index of EU member states regarding just intra-EU trade and there we can point out the highest negative values for Ireland and Estonia, meaning a prevalence of backward participation in relation to forward participation within the EU. If we look at the GVC position, these values were for the majority of EU member states more negative than for the RVC position. This indicates that in global trade, the backward orientation was even more present than in intra-EU trade. Regarding RVC, the positive value was present just in Finland and, for Romania, was around zero, meaning that in

Finland the forward linkages dominated and that Romania participated in backward and forward chains to the same extent.

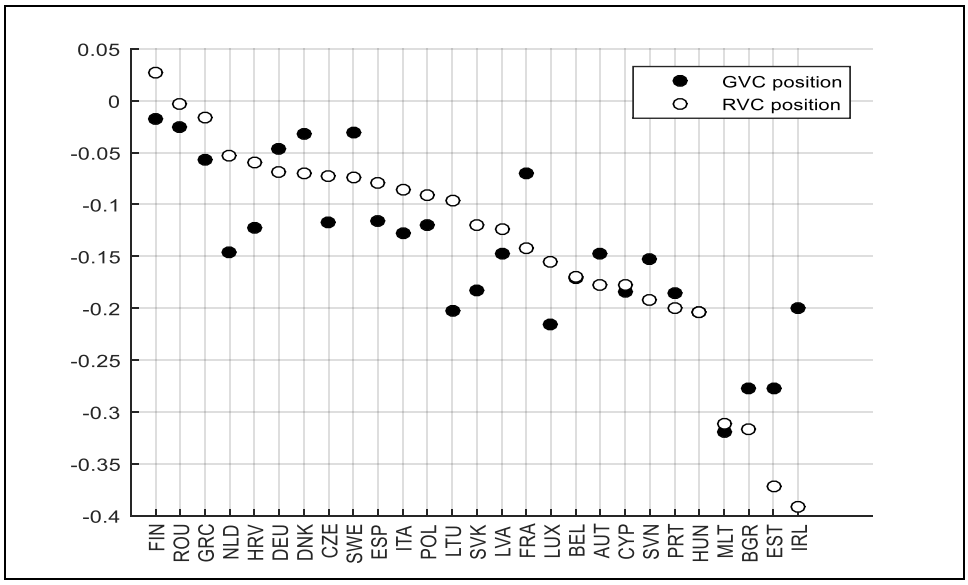

Figure 6. GVC and RVC position indexes for EU member states in 2015. Source: ICIO, OECD, own calculations.

In the EU, 48% of DVA represented the share of DVA in exports of final good, there was a 20.6% share of DVA in intermediate exports, and other categories had smaller shares (Table 1).

Table 1. The decomposition of domestic value-added in the intra-EU trade in the sector of chemicals and pharmaceutical products in 2015.

	Export (m EUR)	VAX1	VAX2	VAX3	DVA4	DVA5	DVA6	FVA	Total EU
EU	108,725.23	48.31	20.62	9.45	1.36	0.67	0.58	19.01	100.00

Source: ICIO, OECD, own calculations.

The importance of the EU for trade of every member state is further developed through the bilateral matrix of value-added (tables in Appendix A). Table A1 in the Appendix A represents the bilateral matrix of value-added. We can see the share of DVA and distribution of EU-FVA across EU member states. The main diagonal shows the disaggregated DVA through the rest of the world. For example, if we take a look at Austria then we can see that the share of DVA was 66.12%, which was absorbed in the home country (domestic sectors), and the remaining 33.88% was distributed to other EU member states (1.31% to Belgium, 1.03% to the Czech Republic., etc., and 16.21% to Germany). Germany had a dominant role as a destination of value-added, and its shares varied from 3.17% in Cyprus and 4.13% in Greece to 16.21% in Austria and 14.66% in Luxembourg. The domestic value-added spent in the home countries was in the range from 50.3% in Estonia to 81.4% in Denmark and 82.9% in Greece, and the rest went to other EU members states. Table A2 (Appendix A) shows the disaggregated DVA for intra-EU trade in the sector of chemicals and pharmaceutical products. Among all components, VAX1 had the highest shares, followed by VAX2, meaning the DVA was mostly present as a part of final or intermediate goods export. The other components were less presented, and especially very small shares went to the DVA4 and DVA5. EU member states differed among themselves, so the highest VAX1 was in Malta (83%) and Cyprus (81%), while the lowest was in Portugal (23%) and Estonia (31%). The highest shares of VAX2 (export of intermediates) were in Luxembourg (31%) and the Netherlands (26.7%) and the lowest in Cyprus (5.7%) and Malta (6.2%). This

means that the fewest countries were more oriented towards the export of final goods and less involved in GVCs, particularly in forward linkages.

Table A3 (in Appendix A) shows the bilateral matrix for the EU member states when we include the rest of the world (ROW) in the calculation, so it covers the total trade in chemical and pharmaceutical products. The main diagonal shows the consumed DVA at home-country sectors and the off-diagonal elements show the FVAs. For example, if we take a look at Austria, we can see that the share of DVA spent in the Austrian economy was 63.2%, and the remaining 36.8% was distributed to other EU member states and to the rest of the world (ROW). What is important is that the majority of value-added went to other EU member states and also that the ROW represented between 7.59% in Denmark and 27% in Lithuania. Even when we included the ROW, Germany still had a dominant role as a destination of value-added, and its shares varied from 2.53% in Denmark to 11.8% in Luxembourg and 10.46% in Austria. Therefore, we can confirm that the European (regional) value chain was formed around Germany as a hub.

Further, we also calculated the value-chain length in both directions: source and destination length for participation in GVC and RVC, separately (Table 2). The usual length for GVCs was between 2 and 2.5 and the length was very similar in both directions: source and destination. The shortest length of value chains was in Cyprus and Malta in the destination direction and in Denmark in both directions. If we considered just intra-EU trade, then we could almost see the overlapping of chain lengths (source and destination) in Austria, Belgium, Malta, Germany, Hungary, and Luxembourg. The length of source destination went from 2.17 (Greece) to 3.28 (Ireland), and the length of destination chains went from 1.41 (Malta) to 2.92 (the Netherlands).

Table 2. Source and destination length of global value chains in the EU member states in 2015.

	GVC		RVC	
	Source Length	**Destination (Selling) Length**	**Source Length**	**Destination (Selling) Length**
AUT	2.45	2.68	2.80	2.74
BEL	2.41	2.55	2.74	2.69
CZE	2.47	2.68	2.51	2.75
DNK	1.69	1.79	2.19	1.77
EST	2.59	2.78	3.11	2.69
FIN	2.18	2.78	2.42	2.84
FRA	2.24	2.45	2.90	2.45
DEU	2.20	2.58	2.67	2.63
GRC	2.06	2.14	2.17	2.08
HUN	2.33	2.46	2.53	2.57
IRL	2.01	1.90	3.28	2.11
ITA	2.52	2.48	2.86	2.54
LVA	2.31	2.15	2.53	2.14
LTU	2.36	2.72	2.34	2.70
LUX	2.50	2.51	2.47	2.51
NLD	2.46	2.83	2.58	2.92
POL	2.47	2.67	2.62	2.73
PRT	2.54	2.57	2.90	2.71
SVK	2.57	2.80	2.57	2.91
SVN	2.17	2.15	2.53	2.23
ESP	2.54	2.66	2.87	2.79
SWE	1.90	2.09	2.33	2.03
BGR	2.49	2.33	2.96	2.32
HRV	2.30	2.22	2.39	2.22
CYP	2.12	1.66	2.45	1.64
MLT	2.41	1.50	2.71	1.41
ROU	2.28	2.68	2.48	2.68

Source: ICIO, OECD, own calculations.

4.2. Characteristics of Global Value Chains in the EU Competition

For a better understanding of the characteristics of EU member state participation in GVCs in chemicals and pharmaceutical products, it is necessary to look at the situation in the main competitors on the world market (Table 3).

Table 3. Distribution of value-added trade of chemicals and pharmaceutical products in the EU, North America, Asia, and Switzerland.

		Source of VA				
Destination of VA	Country	EU	North America	Asia	Switzerland	ROW
	EU	82.68	1.99	2.03	17.64	5.68
	North America	4.27	91.29	2.12	5.73	3.91
	Asia	1.99	1.93	85.01	1.93	5.65
	Switzerland	0.84	0.19	0.13	68.51	0.48
	ROW	10.22	4.60	10.71	6.19	84.29
	Total	100.00	100.00	100.00	100.00	100.00

Source: ICIO, OECD, own calculations. EU = 27 EU member states; North America = USA and Canada; Asia = China, India, and Japan.

The majority of value-added was absorbed in the particular region, i.e., the EU absorbed 82.7% of created value-added, North America 91.2%, etc., and the rest was exported to other regions. Switzerland had the highest connection with the EU, where the EU absorbed 17.6% of value-added produced in Switzerland. The share of the rest of the world was 4.6% in North America to 10.7% in Asia. The results are in line with Klochko and Manuylov (2019) who used the WIOD database and found that pharmaceutical GVCs in North America were de facto regional for most countries.

Figure 7 indicates that the EU had a dominant role in gross trade in chemicals and pharmaceutical products, with a huge trade surplus in performing trade with the mentioned countries. It was followed by the USA and China.

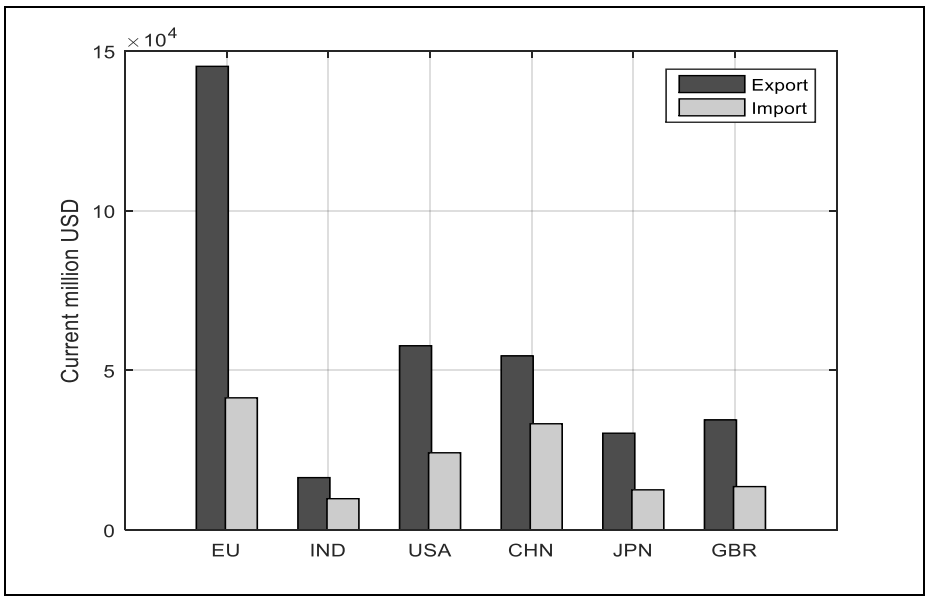

Figure 7. Mutual trade (export and import) of EU, India, the USA, China, the UK, and Japan 2015. Source: ICIO, OECD, own calculations.

In the export structure, it is obvious that the EU exports quite similar value of final products and intermediate products while other countries export more intermediate products (Figure 8).

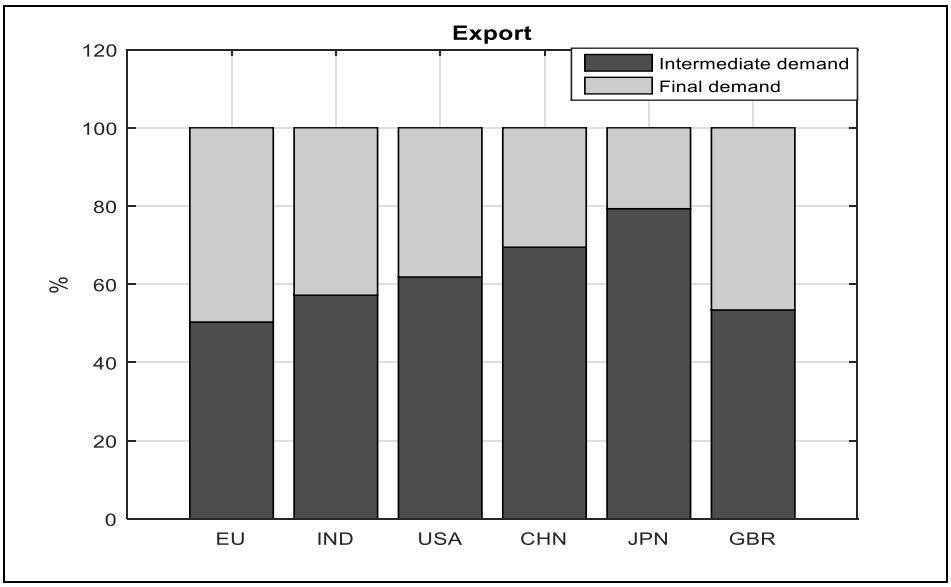

Figure 8. Export of final and intermediate products of chemical and pharmaceutical products in the EU, India, the USA, China, the UK, and Japan. Source: ICIO, OECD, own calculations.

Figure 9 shows the intermediate export and import of the observed countries which they perform with the appointed partners. In all the observed countries and the EU, export of intermediates overcame their imports, except India where the values for export and import were quite similar.

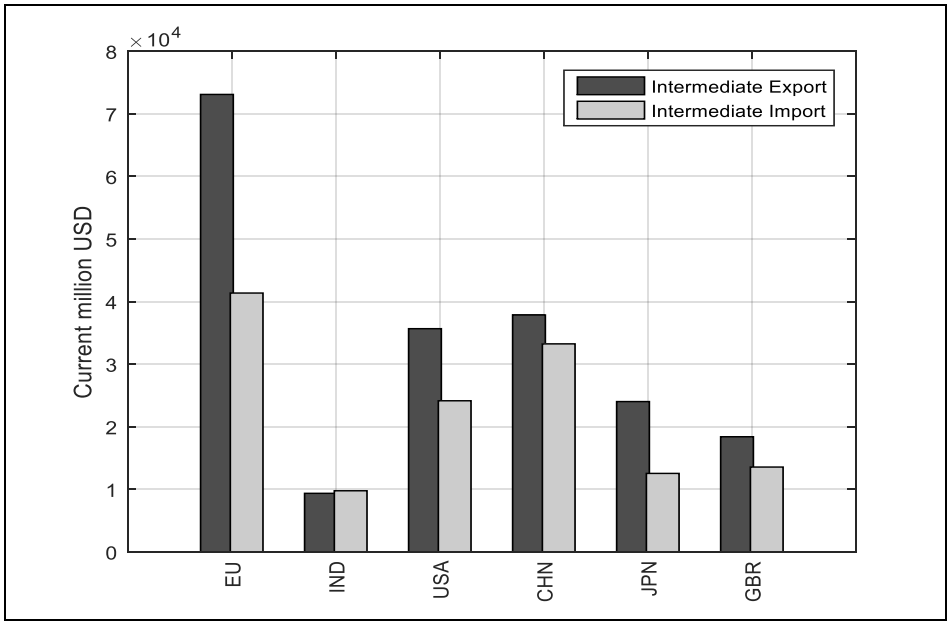

Figure 9. Export and import of intermediate products in the EU, India, USA, China, UK, and Japan. Source: ICIO, OECD, own calculations.

All the analyzed countries participated in GVCs, but not in the same way; some of them based their production on domestic sources, but also on inputs produced abroad, and some of them had a significant export of intermediates to their selected partner countries (Figure 10). Backward participation dominated in the EU, India, Japan, and the UK, while forward participation dominated in the USA and China. This means that the USA and China were providers of ingredients (intermediate products) for producers located in the EU, India, Japan, or the UK (Figure 11).

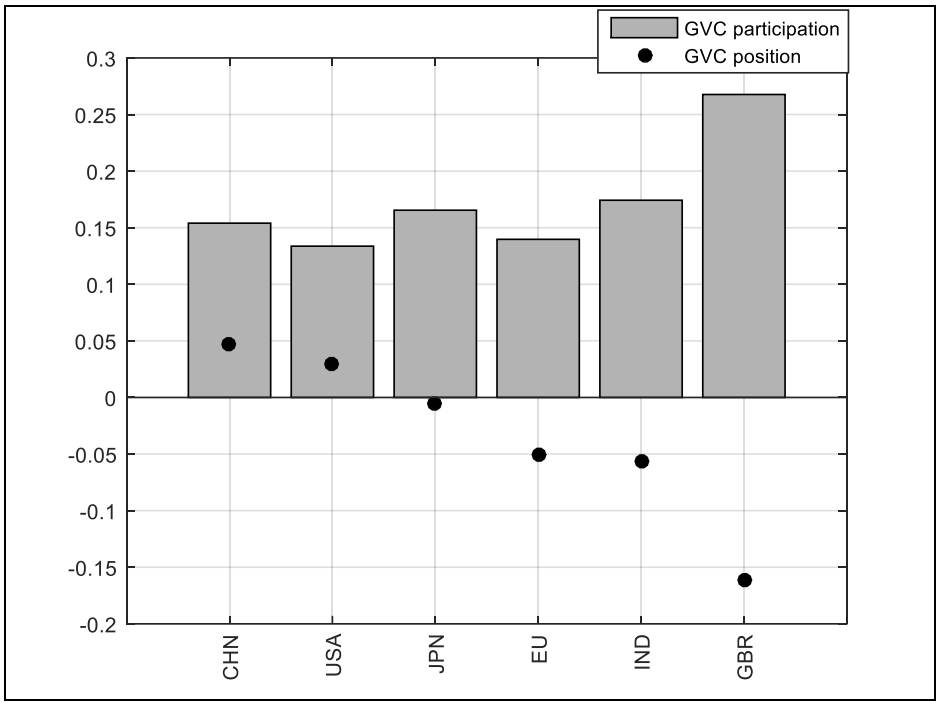

Figure 10. GVC participation and GVC position in the EU, India, the USA, China, the UK, and Japan. Source: ICIO, OECD, own calculations.

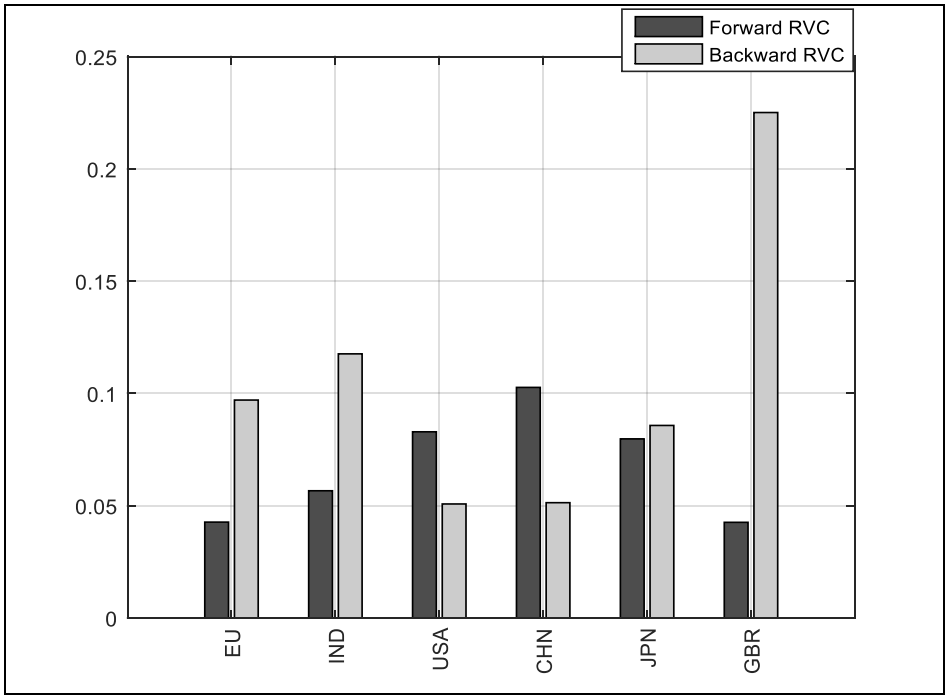

Figure 11. Forward and backward participation in GVCs of the EU, India, the USA, China, UK, and Japan. Source: ICIO, OECD, own calculations.

Based on mutual trade, the UK had the highest GVC participation in trade (above 0.25); India, Japan, and China reached a level above 0.15, while the USA and the EU lay below 0.15 (Figure 11).

Figure 12 indicates the length of value chains with the upstream partners/sectors in obtaining the necessary inputs for the production (sourcing chain) and in finalizing production until the final shape—to consumers (selling shape). Both chains were the

shortest in the US, meaning these processes included just under 2 stages (production processes until the finalization and consumers), followed by UK with the sourcing chain length of 2.32 and destination chain length of 2.11. The longest was in China, where the source chain reached about 2.9 and the selling chain above 3.47. This indicates a more-fragmented production process in China in comparison with the EU and with the USA, including both the domestic production stages and the production stages in the observed countries. India also had longer value chains in both directions in comparison with the EU and with the USA.

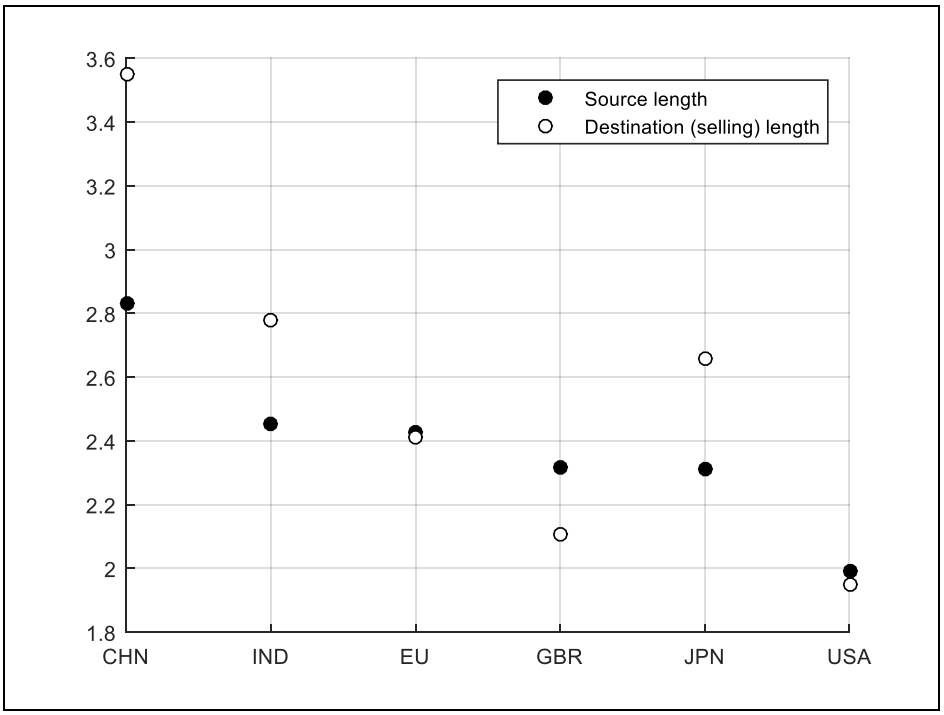

Figure 12. Length of sourcing and selling chains in the EU(average), India, the USA, China, the UK, and Japan. Source: ICIO, OECD, own calculations.

5. Discussion and Concluding Remarks

GVCs are facing many challenges in their further development, where the reorientation towards the regional framework is one of the most important. This paper provides an in-depth analysis of value-added chains within EU member states, but also shed some light on the global scene in the trade of chemicals and pharmaceutical products.

The analysis was based on the calculation and presentation of numerous indicators that show the inter-linkages between countries, i.e., the share of intermediate products in the export, participation in global and regional value chains, the bilateral matrix of value-added created in the sector of chemicals and pharmaceutical products, and the length of the value chain.

The main findings can be summarized in that we confirmed a high level of interconnected production chains in the EU, where intra-trade represented around half of the trade of the EU member states. Intermediate products trade represented above 75% of the total trade in Luxembourg, Finland, the Netherlands, and Slovakia. In EU member states, the backward linkages dominated towards the forward, meaning EU member states are more dependent on the import of intermediates products in comparison with export. The biggest difference was in Estonia, Ireland, Bulgaria, and Malta. All countries showed participation in global and regional value chains; there were differences between them, where the lowest GVC participation was marked in Denmark and the highest in Luxembourg, Lithuania, Slovakia, the Czech Republic, and Estonia (above 0.6). Focusing on regional value chains, the situation was very similar, with the highest involvement of

Luxembourg, Hungary, Estonia, and the Czech Republic, and the lowest in Denmark. The GVC and RVC position indexes were in a negative area due to the prevalence of backward participation.

By analyzing the bilateral matrix, we found very big shares of created domestic value-added in the sector of chemicals and pharmaceutical products that were absorbed at home, while the rest of value-added was directed mainly to other EU member states. The domestic sectors spent between 50% and 83% of produced value-added. The rest of the world took between 7.6% and 27% of value-added. The detailed disaggregation of DVA also indicated that the major part of DVA was incorporated in the export of final and intermediate goods, while the other components represented significantly smaller shares. Germany had arisen as the hub, i.e., the most important country, and the other EU member states were oriented to sell a big part of domestic value-added in Germany. The length of value chains was usually between 2 and 2.5 in both directions, meaning that there are two or slightly more stages (producers at home or abroad that create and export ingredients/intermediates) before the production (creating value-added) in the home country, and also there are two or slightly more stages in the production in a particular country to the finalizing of products and putting them on the market.

In widening the analysis by including EU member states together and observing the EU as one partner with the most important producers of chemical and pharmaceutical products in the world, we found the EU absorbed above 80% of domestic created value-added at the home market, while North America absorbed even more (91%). For the EU, the most important locations for export of value-added were North America and Asia (together they absorbed 6.3% of the EU's value-added). North America and Asia exported about 2% of value-added to the EU, while Switzerland was the most connected country with the EU and exported as much as 17% of created value-added to the EU market. There was also a difference in the way the observed countries participated in GVCs: backward participation dominated in the EU, India, Japan, and the UK, while for China and the USA, forward participation was more important. This results in the fact that the EU, India, Japan, and the UK had negative values of the GVC position index, and the USA and China had positive values. The length of value chain was the largest in China, meaning that the highest level of fragmentation of production processes appeared there.

Due to the pandemic, the real expectation is of the strengthening of regional value chains in the EU. This research, in a lot of detail, shows the interconnection between EU member states and, even in 2015, there were very strong mutual relationships within the EU, but new challenges will force countries to cooperate with each other even more. The pandemic indicates the problem in the free circulation of goods and services due to the partial lock-down of economies, and restrictions on traveling and transport, but also the big problem lies in the trade policy domain, where countries are becoming oriented to fulfill domestic needs, public health and, in a way, they were/are "selfish". Such behavior harms global value chains, and the production process that depends on foreign inputs suffers and faces the situation of inability to finalize production without the necessary intermediates or ingredients. Due to of all of these facts and new circumstances, the solution can be in a huge reorientation of the common EU market.

Although this research faced some limitations, i.e., it refers to 2015 because the last available ICIO refers to 2015 and the situation in the last five years could be slightly different, it represents an additional value-added and provides a detailed insight into intra-EU trade in a very important sector—chemical and pharmaceutical products. More useful and applicable results would arise if we could analyze just pharmaceutical products or COVID-19-related products, but there are no ICIO tables on that level of disaggregation. The obtained results also open new room for further research that can be conducted on firm-level data (to elaborate on the differences among EU member states, and also to investigate the potential for increasing of mutual cooperation), but also at the EU level, considering the EU common trade policy and specific measures taken in relation to the COVID-19 pandemic.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Bilateral value-added in production of chemicals and pharmaceutical products (intra-EU, in %).

		Source of Value-Added (Chemicals and Pharmaceutical Products Sector)														
		AUT	**BEL**	**CZE**	**DNK**	**EST**	**FIN**	**FRA**	**DEU**	**GRC**	**HUN**	**IRL**	**ITA**	**LVA**	**LTU**	**LUX**
Destination of value-added (All sectors)	AUT	66.12	0.45	1.59	0.32	0.88	0.50	0.50	1.31	0.40	3.53	0.46	0.79	0.61	0.45	0.54
	BEL	1.31	67.21	1.19	1.05	1.86	1.21	2.51	2.12	1.03	1.65	3.41	1.97	0.72	1.81	5.70
	CZE	1.03	0.40	69.74	0.24	0.83	0.23	0.27	0.70	0.17	1.92	0.36	0.29	0.44	0.67	0.29
	DNK	0.33	0.47	0.30	81.38	1.37	1.52	0.35	0.49	0.25	0.57	0.80	0.27	1.09	1.16	0.35
	EST	0.03	0.03	0.02	0.08	50.31	0.45	0.02	0.03	0.01	0.03	0.03	0.01	2.11	0.89	0.02
	FIN	0.25	0.35	0.20	0.41	6.28	77.36	0.23	0.33	0.11	0.26	0.81	0.15	1.67	1.20	0.26
	FRA	2.67	6.38	2.62	1.64	2.90	2.15	76.82	3.65	2.17	3.75	9.79	4.10	1.42	2.28	7.30
	DEU	16.21	7.68	11.62	5.84	10.65	6.09	7.35	79.22	4.13	11.80	9.55	5.68	4.80	5.43	14.66
	GRC	0.12	0.10	0.09	0.20	0.18	0.06	0.10	0.11	82.92	0.11	0.09	0.23	0.10	0.36	0.09
	HUN	0.84	0.20	0.62	0.16	0.51	0.13	0.20	0.32	0.18	59.80	0.24	0.28	0.25	0.31	0.22
	IRL	0.53	2.54	0.49	0.74	0.57	0.56	1.14	0.98	0.47	0.92	54.67	1.17	0.44	0.45	1.62
	ITA	2.53	1.70	2.12	0.92	2.20	0.99	2.60	2.13	2.87	3.01	3.73	78.70	1.29	1.76	2.38
	LVA	0.03	0.03	0.03	0.09	2.16	0.08	0.02	0.02	0.01	0.03	0.03	0.01	71.38	1.38	0.03
	LTU	0.11	0.12	0.17	0.19	4.51	0.15	0.13	0.11	0.03	0.19	0.08	0.05	5.31	70.47	0.06
	LUX	0.34	1.17	0.20	0.19	0.37	0.19	0.41	0.48	0.18	0.31	5.96	0.59	0.21	0.18	60.56
	NLD	2.14	6.93	1.73	1.74	2.80	2.51	2.38	3.58	1.20	2.92	5.33	1.83	1.22	1.73	2.19
	POL	1.50	0.91	3.07	0.91	4.59	0.95	0.76	1.54	0.51	2.80	1.02	0.65	4.28	6.08	0.92
	PRT	0.11	0.26	0.11	0.09	0.14	0.12	0.30	0.18	0.13	0.14	0.28	0.14	0.09	0.13	0.12
	SVK	0.74	0.14	2.04	0.08	0.27	0.10	0.14	0.27	0.10	2.19	0.07	0.16	0.22	0.25	0.15
	SVN	0.44	0.05	0.14	0.03	0.15	0.03	0.06	0.10	0.06	0.54	0.05	0.15	0.08	0.09	0.08
	ESP	1.02	1.68	0.97	0.67	1.21	0.66	2.63	1.30	1.39	1.26	1.89	1.91	0.70	0.94	1.25
	SWE	0.80	0.77	0.53	2.84	4.56	3.84	0.77	0.68	0.34	0.77	1.00	0.41	1.23	1.58	0.92
	BGR	0.14	0.10	0.08	0.06	0.07	0.04	0.05	0.07	0.68	0.22	0.06	0.11	0.07	0.07	0.04
	HRV	0.15	0.03	0.04	0.02	0.03	0.02	0.02	0.03	0.04	0.14	0.04	0.08	0.02	0.02	0.03
	CYP	0.02	0.02	0.03	0.01	0.34	0.01	0.01	0.02	0.18	0.03	0.03	0.01	0.14	0.10	0.05
	MLT	0.03	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.02	0.01	0.04	0.01	0.01	0.01	0.02
	ROU	0.50	0.25	0.26	0.08	0.25	0.08	0.21	0.21	0.43	1.12	0.17	0.23	0.10	0.20	0.14
	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: own calculation based on ICIO tables (OECD).

Table A1. *Cont.*

	Source of Value-Added											
	NLD	**POL**	**PRT**	**SVK**	**SVN**	**ESP**	**SWE**	**BGR**	**HRV**	**CYP**	**MLT**	**ROU**
AUT	0.43	0.97	0.39	2.02	3.97	0.38	0.46	2.18	3.14	0.89	2.00	1.55
BEL	3.51	1.41	1.41	1.10	1.15	1.24	1.35	1.74	0.74	1.16	2.42	1.06
CZE	0.24	1.32	0.17	4.49	0.81	0.22	0.24	0.79	0.67	0.46	0.18	0.61
DNK	0.62	0.54	0.26	0.28	0.38	0.26	2.40	0.61	0.33	0.28	0.31	0.19
EST	0.03	0.04	0.02	0.02	0.03	0.03	0.12	0.03	0.01	0.12	0.07	0.02
FIN	0.35	0.43	0.24	0.21	0.21	0.19	1.65	0.20	0.14	0.12	0.16	0.12
FRA	3.33	3.05	4.20	2.45	2.88	4.67	2.78	3.59	1.73	1.72	3.55	3.17
DEU	7.44	9.37	5.97	8.80	8.52	5.19	5.06	8.56	5.06	3.17	8.45	6.01
GRC	0.06	0.12	0.13	0.30	0.54	0.12	0.08	4.14	0.18	8.60	0.27	0.58
HUN	0.16	0.65	0.17	2.27	0.95	0.17	0.12	1.76	1.46	0.18	0.13	1.63
IRL	0.93	0.83	0.74	0.47	0.72	0.76	0.52	0.70	0.34	0.68	1.19	0.52
ITA	1.21	2.15	2.19	2.32	5.89	2.56	0.94	3.87	3.77	2.15	6.14	3.29
LVA	0.02	0.05	0.02	0.03	0.04	0.01	0.07	0.03	0.01	0.08	0.04	0.01
LTU	0.11	0.29	0.17	0.20	0.12	0.09	0.20	0.12	0.07	0.11	0.04	0.07
LUX	0.45	0.25	0.26	0.25	0.37	0.32	0.28	0.39	0.16	0.99	5.23	0.16
NLD	77.65	1.91	2.39	1.60	1.31	1.71	1.91	2.01	1.10	1.29	4.37	1.42
POL	0.77	73.32	0.54	3.18	1.80	0.58	1.02	2.93	0.92	0.71	0.98	1.67
PRT	0.30	0.13	65.40	0.20	0.12	1.08	0.11	0.14	0.07	0.16	0.16	0.15
SVK	0.10	0.56	0.10	67.39	0.54	0.10	0.08	0.68	0.37	0.07	0.06	0.45
SVN	0.04	0.18	0.04	0.21	65.80	0.04	0.03	0.50	2.63	0.08	0.05	0.15
ESP	1.34	1.19	14.47	0.97	1.19	79.67	0.76	2.67	0.74	1.42	2.13	1.09
SWE	0.68	0.86	0.48	0.53	0.52	0.40	79.61	0.49	0.31	0.36	1.39	0.29
BGR	0.06	0.09	0.06	0.10	0.19	0.05	0.03	56.97	0.13	0.50	0.25	0.91
HRV	0.02	0.04	0.02	0.08	1.47	0.02	0.03	0.25	75.64	0.03	0.06	0.10
CYP	0.01	0.03	0.01	0.05	0.02	0.01	0.02	0.08	0.02	74.12	0.40	0.04
MLT	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.04	0.01	0.07	59.86	0.01
ROU	0.14	0.23	0.13	0.45	0.48	0.13	0.10	4.52	0.26	0.47	0.12	74.73
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Dark grey= diagonal, DVA absorbed in home country; Light grey= shares above 2%. Source: own calculation based on ICIO tables (OECD).

Table A2. DVA in intra-EU trade in chemicals and pharmaceutical products in 2015.

	Export in Mil USD	**VAX1**	**VAX2**	**VAX3**	**DVA4**	**DVA5**	**DVA6**	**FVA**	**Total**
AUT	3192.35	34.45	19.06	9.25	0.42	0.21	0.27	36.34	100.00
BEL	10,380.34	45.85	20.35	9.44	0.23	0.25	0.45	23.42	100.00
CZE	1362.60	36.47	21.72	12.14	0.55	0.20	0.17	28.75	100.00
DNK	2914.15	71.56	12.51	6.17	0.22	0.06	0.04	9.45	100.00
EST	92.22	30.96	13.97	7.24	0.16	0.02	0.04	47.61	100.00
FIN	849.69	36.34	25.16	13.43	0.35	0.17	0.08	24.48	100.00
FRA	13,460.94	42.48	24.62	9.63	2.81	0.78	0.65	19.03	100.00
DEU	24,730.29	44.89	22.10	9.26	2.88	1.69	1.37	17.80	100.00
GRC	546.49	60.36	16.44	8.44	0.45	0.05	0.03	14.24	100.00
HUN	2208.15	46.46	12.75	6.26	0.16	0.07	0.18	34.12	100.00
IRL	14,610.03	71.89	16.14	8.54	0.10	0.03	0.08	3.21	100.00
ITA	7732.48	45.41	20.65	9.69	1.52	0.82	0.35	21.57	100.00
LVA	73.23	59.73	13.35	8.11	0.66	0.07	0.04	18.04	100.00
LTU	528.70	35.37	22.48	12.15	0.35	0.05	0.10	29.51	100.00

Table A2. *Cont.*

	Export in Mil USD	VAX1	VAX2	VAX3	DVA4	DVA5	DVA6	FVA	Total
LUX	96.79	34.29	31.27	17.07	0.09	0.01	0.01	17.26	100.00
NLD	9159.11	37.33	26.71	13.41	0.51	0.34	0.60	21.09	100.00
POL	3513.19	40.73	19.08	9.47	0.88	0.23	0.26	29.36	100.00
PRT	831.99	27.23	21.24	9.65	0.60	0.19	0.16	40.92	100.00
SVK	642.17	33.87	20.74	11.85	0.60	0.04	0.15	32.75	100.00
SVN	891.50	59.43	12.24	6.26	0.08	0.03	0.05	21.92	100.00
ESP	6840.97	45.83	19.44	8.23	1.21	0.74	0.46	24.09	100.00
SWE	3005.49	60.39	18.04	8.68	0.56	0.14	0.09	12.09	100.00
BGR	414.69	47.07	10.65	4.69	0.13	0.03	0.06	37.36	100.00
HRV	155.07	52.94	14.25	8.89	0.17	0.08	0.03	23.65	100.00
CYP	66.06	81.75	5.69	3.19	0.06	0.01	0.00	9.30	100.00
MLT	64.65	83.81	6.19	3.09	0.00	0.00	0.00	6.91	100.00
ROU	361.89	36.59	19.29	11.22	1.14	0.19	0.08	31.50	100.00

Table A3. Bilateral value-added matrix in production of chemicals and pharmaceutical products (total trade, %).

		Sources of Value-Added (Chemicals and Pharmaceutical Products Sector)														
	Country	AUT	BEL	CZE	DNK	EST	FIN	FRA	DEU	GRC	HUN	IRL	ITA	LVA	LTU	LUX
Destination of value-added (All sectors)	AUT	63.20	0.25	1.17	0.14	0.45	0.30	0.24	0.70	0.26	2.28	0.12	0.49	0.39	0.27	0.39
	BEL	0.73	62.08	0.80	0.43	0.89	0.69	1.18	1.06	0.64	0.97	0.83	1.16	0.41	1.04	4.14
	CZE	0.61	0.22	61.99	0.10	0.41	0.12	0.12	0.34	0.10	1.18	0.09	0.16	0.26	0.39	0.20
	DNK	0.20	0.27	0.22	84.51	0.74	0.97	0.18	0.27	0.18	0.38	0.20	0.17	0.75	0.75	0.25
	EST	0.02	0.02	0.02	0.03	51.43	0.28	0.01	0.02	0.01	0.02	0.01	0.01	1.38	0.55	0.02
	FIN	0.15	0.19	0.14	0.17	3.30	71.78	0.11	0.17	0.07	0.16	0.21	0.09	0.98	0.69	0.19
	FRA	1.65	3.60	1.94	0.70	1.52	1.33	75.03	1.96	1.47	2.43	2.50	2.56	0.91	1.42	5.50
	DEU	10.46	4.40	8.62	2.53	5.72	3.78	3.69	75.18	2.79	7.65	2.41	3.53	3.10	3.28	11.18
	GRC	0.07	0.06	0.06	0.07	0.08	0.03	0.05	0.06	75.27	0.06	0.02	0.11	0.05	0.20	0.06
	HUN	0.53	0.12	0.47	0.07	0.27	0.07	0.10	0.17	0.12	57.03	0.06	0.17	0.16	0.19	0.16
	IRL	0.36	1.84	0.37	0.39	0.30	0.33	0.67	0.62	0.38	0.58	65.94	0.85	0.28	0.30	1.03
	ITA	1.52	0.90	1.51	0.38	1.12	0.57	1.24	1.10	1.88	1.86	0.92	69.75	0.81	1.05	1.71
	LVA	0.02	0.01	0.02	0.04	1.15	0.04	0.01	0.01	0.01	0.02	0.01	0.01	67.16	0.85	0.02
	LTU	0.06	0.06	0.11	0.07	1.79	0.08	0.05	0.06	0.02	0.11	0.02	0.03	2.75	54.99	0.04
	LUX	0.09	0.30	0.06	0.03	0.08	0.05	0.09	0.11	0.05	0.10	0.60	0.13	0.05	0.04	49.26
	NLD	1.11	3.58	1.09	0.65	1.26	1.33	1.01	1.62	0.68	1.66	1.30	0.97	0.68	0.92	1.40
	POL	0.87	0.48	2.18	0.38	2.33	0.54	0.34	0.77	0.31	1.72	0.26	0.36	2.71	3.59	0.65
	PRT	0.06	0.14	0.08	0.04	0.07	0.07	0.14	0.09	0.09	0.08	0.07	0.08	0.06	0.08	0.09
	SVK	0.39	0.07	1.28	0.03	0.12	0.05	0.06	0.12	0.05	1.16	0.02	0.08	0.12	0.13	0.10
	SVN	0.29	0.03	0.11	0.01	0.09	0.02	0.03	0.05	0.04	0.37	0.01	0.10	0.05	0.05	0.06
	ESP	0.59	0.91	0.65	0.28	0.59	0.37	1.24	0.65	0.86	0.74	0.47	1.11	0.42	0.54	0.88
	SWE	0.50	0.43	0.39	1.28	2.46	2.35	0.40	0.36	0.23	0.49	0.27	0.25	0.79	0.98	0.70
	BGR	0.08	0.05	0.05	0.02	0.03	0.02	0.02	0.03	0.42	0.13	0.01	0.06	0.04	0.04	0.03
	HRV	0.09	0.02	0.03	0.01	0.01	0.01	0.01	0.02	0.03	0.09	0.01	0.05	0.01	0.01	0.02
	CYP	0.01	0.01	0.02	0.01	0.19	0.01	0.01	0.01	0.12	0.03	0.01	0.01	0.09	0.07	0.03
	MLT	0.03	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
	ROU	0.31	0.14	0.19	0.03	0.12	0.05	0.10	0.11	0.28	0.73	0.04	0.14	0.06	0.12	0.10
	ROW	16.00	19.80	16.41	7.59	23.46	14.75	13.86	14.33	13.67	17.97	23.59	17.59	15.50	27.47	21.79
	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: own calculation based on ICIO tables (OECD).

Table A3. *Cont.*

	Source of Value-Added												
Country	**NLD**	**POL**	**PRT**	**SVK**	**SVN**	**ESP**	**SWE**	**BGR**	**HRV**	**CYP**	**MLT**	**ROU**	**ROW**
AUT	0.26	0.66	0.23	1.39	2.30	0.22	0.24	1.11	2.33	0.49	1.06	1.09	0.14
BEL	2.08	0.89	0.81	0.71	0.58	0.71	0.67	0.82	0.48	0.57	1.18	0.66	0.25
CZE	0.13	0.87	0.09	3.12	0.43	0.12	0.11	0.37	0.45	0.23	0.09	0.39	0.04
DNK	0.40	0.39	0.16	0.21	0.22	0.17	1.33	0.34	0.25	0.17	0.17	0.13	0.12
EST	0.02	0.03	0.01	0.02	0.02	0.02	0.06	0.02	0.01	0.06	0.03	0.01	0.01
FIN	0.21	0.29	0.15	0.15	0.11	0.11	0.84	0.11	0.10	0.07	0.08	0.07	0.07
FRA	2.05	2.13	2.66	1.72	1.61	2.99	1.49	1.85	1.24	0.94	1.86	2.21	0.74
DEU	4.64	6.58	3.80	6.28	4.85	3.27	2.63	4.33	3.59	1.74	4.31	4.13	1.45
GRC	0.04	0.08	0.08	0.19	0.28	0.06	0.04	1.74	0.11	4.09	0.13	0.39	0.04
HUN	0.10	0.46	0.11	1.67	0.53	0.11	0.06	0.90	1.06	0.09	0.07	1.13	0.04
IRL	0.59	0.66	0.52	0.37	0.50	0.54	0.28	0.42	0.26	0.34	0.60	0.42	0.49
ITA	0.71	1.43	1.31	1.60	3.14	1.52	0.45	1.89	2.64	1.15	3.12	2.22	0.51
LVA	0.01	0.03	0.01	0.02	0.02	0.01	0.04	0.02	0.01	0.04	0.02	0.01	0.01
LTU	0.05	0.18	0.10	0.13	0.06	0.05	0.10	0.06	0.05	0.05	0.02	0.04	0.02
LUX	0.15	0.08	0.07	0.08	0.08	0.08	0.06	0.07	0.05	0.19	0.89	0.04	0.03
NLD	62.39	1.12	1.32	0.98	0.60	0.91	0.89	0.87	0.67	0.65	2.11	0.82	0.34
POL	0.43	66.12	0.30	2.19	0.96	0.33	0.49	1.42	0.61	0.36	0.51	1.08	0.12
PRT	0.18	0.08	61.82	0.14	0.07	0.65	0.06	0.07	0.05	0.09	0.08	0.10	0.04
SVK	0.05	0.33	0.05	56.62	0.26	0.05	0.03	0.27	0.22	0.03	0.03	0.26	0.02
SVN	0.02	0.13	0.02	0.15	66.98	0.02	0.02	0.28	2.02	0.04	0.02	0.10	0.02
ESP	0.77	0.77	8.81	0.63	0.63	70.62	0.37	1.27	0.49	0.78	1.10	0.70	0.35
SWE	0.43	0.60	0.30	0.38	0.29	0.24	79.79	0.24	0.22	0.20	0.74	0.19	0.16
BGR	0.03	0.06	0.04	0.06	0.10	0.03	0.01	54.31	0.09	0.23	0.13	0.61	0.01
HRV	0.01	0.02	0.01	0.06	0.85	0.01	0.02	0.13	69.13	0.01	0.03	0.07	0.01
CYP	0.01	0.02	0.00	0.04	0.01	0.00	0.01	0.04	0.01	71.37	0.22	0.03	0.01
MLT	0.00	0.01	0.01	0.00	0.01	0.00	0.00	0.02	0.01	0.04	55.30	0.00	0.00
ROU	0.08	0.15	0.08	0.32	0.27	0.07	0.05	2.33	0.18	0.23	0.06	71.51	0.03
ROW	24.16	15.81	17.14	20.77	14.23	17.07	9.85	24.72	13.71	15.75	26.03	11.55	94.95
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Notes

[1] Medical goods comprise: medical equipment, medicine, medical supplies, and personal protective products, i.e., it is a wider term than just pharmaceutical products.

[2] The dominant products are: medical consumables for imports originating from Switzerland, protective gear for imports from China, and diagnostic testing equipment for imports from the United States.

[3] Haakonsson (2009) emphasized the importance of the World Trade Organization (WTO) establishment and especially implementation of the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs Agreement) for higher involvement of this industry in international value chains. He focused his research on the governance of GVCs and made an analysis on the case studies of Uganda, India, and Denmark. Three tendencies characterize the pharmaceutical GVC: branded products, quality generics, and low-value generics, and he explained the way the governance of GVC are changing over time.

[4] China is a dominant global supplier of active pharmaceutical ingredients for many important medications. In 2018, it accounted for 95% of the US imports of ibuprofen, 91% of hydrocortisone, 40–45% of penicillin, and 40% of heparin (D Palmer and F Bermingham, "U.S. Policymakers Worry about China 'Weaponizing' Drug Exports", Politico, https://politi.co/2QXHidx).

[5] Timmer et al. (2014) employed a methodology to the WIOD database that we found not appropriate for our research due to the data limitation, i.e., time coverage was up to 2014 and also the dataset did not include all EU member states. Due to this, we chose to apply the Koopman et al. (2014) framework on the OECD TiVA database.

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