Position and Comparative Advantages of Sectors and Countries in Global Value Chains[1]

Tomáš Oleš

University of Economics in Bratislava, Faculty of National Economy,
Dolnozemská cesta 1, Bratislava 5, 852 35
Slovak Republic
tomas.oles@euba.sk

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Abstract. This paper contributes to the empirical evidence on the position of each industry in the world production chains in 2014. Using the World Input-Output database we have documented the longest output supply and value-added demand production chain for the sector of manufacturing and services and the shortest production chains for the construction sector and sector of public services. Based on the structural interpretation proposed by Fally (2012) we identify industries, with the most/least possible negative impact on output if a negative shock to productivity due to the upcoming fossil-fuel crisis in Europe would occur in the industry of gas and coke and refined petroleum products manufacturing. We also documented new revealed comparative advantages for each industry, and we find highly prevalent industries with comparative advantages, especially in the manufacturing and service sectors. We find, that countries with higher revealed comparative advantages tend to vertically specialize more than those without them. The same observation does not hold for most of the sectors.

Keywords: Input-Output Analysis, Fragmentation of Production, Supply and Demand Chain Length

JEL classification: *F13, F14, 024*

1 Introduction

The technological and institutional change in the world economy has fueled significant globalization and fragmentation of production processes across countries. The typical" 'Made in' labels in manufactured goods have become archaic symbols of an old era (Antràs & De Gortari, 2020), where Portuguese wine was traded for English cloth.

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Figure 1 presents the complexity of world trade by plotting all significant trade links in countries' value-added that is embodied in partner's exports (induced by partner's final foreign demand). With insights provided in Li et al. (2019) we could identify the economies that serve as the important buyer (hubs) of domestic value added in highly dense production structures and their respective hub economies in North America – the United States in Europe – Germany and in Asia – China.[2]

Fig. 1 – Trade in Domestic Value Added embodied in Foreign Final Demand as a Share of Receiving Country's Exports. Author's illustration based on the TiVA indicators database in 2011.

The sole display of trade links gives us an incomplete picture of the position of countries and their industries in the production process. Are European value chain more fragmented and thus distant from final demand or primary inputs? What are the lengths of supply and demand of sectoral production chains? Do industries with accrued comparative advantages vertically specialise more than industries with their absence? Are central hubs economies comparatively more advantageous in international trade? This paper is devoted to providing empirical pieces of evidence to answer this set of questions and associate them with some policy implications. This draw research is closely tied to core work in this field, which constructed and mapped the position of individual sectors (Antràs et al., 2012; Fally, 2012; Johnson & Noguera, 2012; Miller & Temurshoev, 2017) and reproduce the previous analysis with the emphasis on the relationship between the position of countries in supply and demand production chains and their involvement in international production sharing activities that are subsequently linked to their vertical specialisation in trade. Our work also connects an augmented traditional Balassa's revealed comparative advantage index based on the precise decomposition developed by (Koopman et al., 2014; Wang et al., 2017) to the

[2] Interactive map with bilateral labels can be found in online appendix: <https://rpubs.com/TomasOles/dva_foreigndemand_share_of_partner>

relative positions of industries/countries in production-sharing activities and their relative downstreamness and upstreamness positions in production chains. The remainder of the paper is structured as follows. In Section 2 we discuss the calculation of the main indicators used in this study. Section 3 presents the empirical result and discusses the most important finding on the position and length of sectors' and countries' production chains. Section 4 concludes.

2 Methodology

The position of sectors and countries in the value chain process, as well as vertical specialisation and revealed comparative advantage could be calculated using the harmonized input-output tables. In our paper, we are solely using the World Input-Output Tables (henceforth WIOT) rel. 2016, for the last available year 2014 was constructed by Dietzenbacher et al., (2013) and Timmer et al., (2015). The WIOT links national supply-use tables with bilateral trade data in goods and services to produce a global I-O table to represent the world economy. The database covers 27 European countries and 16 other major world economies and comprises 56 industries, corresponding to a broad the International Standard Industrial Classification Revision 4 (ISIC Rev. 4). The core of the WIOT table is a square matrix $\boldsymbol{Z}$ collecting trade in intermediate goods and services produced industries classified as sectors s ($s = 1, \dots, S$), subdivided in individual industries i ($i = 1, \dots, N$) located in country c ($c = 1, \dots, C$). Typical element $z_{i,j}$ denotes a dollar value of intermediate goods and services produced by industry *i.* and purchased in industry *j.* WIOT contains the vector of gross production $\boldsymbol{x}$, with the typical element $x_i$which stands for gross production of industry i. The gross production of an industry is either purchased as an intermediate input by other sectors, or it travels to the final demand represented by matrix $\boldsymbol{F}$ where typical element $f_{i,k}$ denotes the final demand for goods or services of industry i. by the final demand sector k (households, government, investors). The on-diagonal elements of the block $\boldsymbol{Z}$ matrix represents the domestic production process, while off-diagonal blocks represent trade in intermediate production among countries. The same can be said about the block $\boldsymbol{F}$ matrix concerning trade in final products. Thus, in our case, we can obtain 2464 value chains with the direct and indirect links in the whole production line.

2.1 Industries' Upstreamness and Downstreamness Measures

The position of a country/sector in the value chain can be calculated by applying the decomposition of production stages pioneered by Fally (2012), later extended by (Antràs et al., 2012). We can assess the position of a country's or sector's production process from the two perspectives. Firstly, we can find how many additional plats a product from a sector *s.* on average must travel to reach the final demand. Conversely, we can count an average number of stages that sequentially must have entered the product/industry production of the *s-th* sector. The preceding indicator measures the sector's *upstreamness.* If all the production is directly sent to the final demand (households, government, or investors henceforth *HGIs*). A sector has the upstreamness measure equal to one. The ascending indicator measures the sectors' *downstreamness.*

On condition that all primary inputs (capital and labor from households) enter the production of sector *s.* directly in one step, the downstreamness measure corresponds to the one.

Miller and Temurshoev (2017) using well-known relations in the I-O model derived the same measurement as Antràs et al., (2012) and Fally (2012)the for upstream and downstream position of sector/country in the value chain, and in our paper, we are using their computational strategy. Nevertheless, we are relying on theory based Fally's (2012) structural interpretation of obtained terms. We start by writing the output-side accounting identity:

$$\boldsymbol{x = Lf} \tag{1}$$

where $\boldsymbol{L = I + A + A^2 + \cdots = (I - A)^{-1}}$ is the Leontief-inverse matrix (Leontief, 1936) and $\boldsymbol{f}$ is aggregated vector across final demand sectors *k.* Further, let $\boldsymbol{B}$ denote the allocation matrix with typical entry $b_{j,i}$ that stands for the share of industry *j's* output that is used in industry *i's* production. And denote vector $\boldsymbol{v}$ as the industries' vector of primary inputs (value added) coefficients. Then the input-side accounting identity is in form of:

$$\boldsymbol{x' = v'G} \tag{2}$$

where $\boldsymbol{G = I + B + B^2 + \cdots = (I - B)^{-1}}$ is Ghosh-inverse matrix and prime stands for transposition.

Using the definition of $\boldsymbol{A = Z\,\hat{x}^{-1}}$ and $\boldsymbol{B = \hat{x}^{-1}Z}$ the link between the Leontief's and Ghosh's matrices is:

$$\boldsymbol{\hat{x}^{-1}L\hat{x} = \hat{x}^{-1}(I - Z\hat{x}^{-1})^{-1}\hat{x} = [\hat{x}^{-1}(I - Z\hat{x}^{-1})\hat{x}]^{-1} = (\mathrm{I} - \hat{x}^{-1}Z)^{-1} = G} \tag{3}$$

With equation (1) and (3) we can obtain upstreamness as (Miller & Temurshoev, 2017):

$$\boldsymbol{U = \hat{x}^{-1}(I + 2A + 3A^2 + \cdots)f = \hat{x}^{-1}Lf = \hat{x}^{-1}Lf\hat{x}\iota = G\iota} \tag{4}$$

the $\boldsymbol{\iota}$ stands for unit summation vector and $\boldsymbol{U}$ is the column vector of average industries' upstream position. Better understanding of upstreamness can be seen in an recursive representation of $\boldsymbol{U}$:

$$\boldsymbol{U = \iota + BU} \tag{5}$$

That illustrates the fact that industries that are important input suppliers to customer industries that have higher upstreamness are themselves far away from final consumption (Branger et al., 2019). The upstreamness measure are exactly industries' total forward linkages in terms of gross output (Miller & Blair, 2009b; Miller & Temurshoev, 2017), which is highlighted in recursive representation in equation (5).

Similarly using identities (2) and (3) the downstreamness of the sector is column sums of Leontief's matrix (Miller & Temurshoev, 2017):

$$\boldsymbol{D' = v'(I + 2B + 3AB^2 + \cdots)\hat{x}^{-1} = v'GG\hat{x}^{-1} = \iota'^{\hat{x}}G\hat{x}^{-1} = \iota'L} \tag{6}$$

We also can rewrite downstreamness in a recursive representation:

$$\boldsymbol{D' = \iota' + D'A}$$

Which analogously captures the fact that industries that purchase large shares of their inputs from supplier industries that have a high downstreamness are themselves far away from primary inputs (Branger et al., 2019). The downstreamness measure are exactly industries' total backward linkages in terms of gross output (Miller & Blair, 2009b; Miller & Temurshoev, 2017).

2.2 Industries' Vertical Specialization

To capture how each industry is involved in international production sharing activities we rely on the measure of *import content of exports* proposed by Hummels et al. (2001). We start with the further disaggregation of the $\boldsymbol{A}$ matrix into domestic (on-diagonal) part $\boldsymbol{A_d}$ and imported (off-diagonal) $\boldsymbol{A_m}$ to country *c*. We can find total direct and indirect import requirements by finding the import inverse matrix:

$$\boldsymbol{R} = \boldsymbol{A_m}(\boldsymbol{I} - \boldsymbol{A_d})^{-1} \tag{7}$$

the sum of each column of $\boldsymbol{R}$ gives us the import requirement ratio for the corresponding sector/industry, influenced by both domestic and foreign demand. The induced amount of imports to change in total demand $\boldsymbol{f}$ can be easily obtained:

$$\boldsymbol{M} = \boldsymbol{Rf} \tag{8}$$

we can easily find the import content of export by disaggregating the final demand into domestic demand $\boldsymbol{f_d}$ and third's country demand $\boldsymbol{f_t}$, which are in fact country's exports. The last step is to obtain the import content of exports in form:

$$\boldsymbol{vs} = \frac{\boldsymbol{\iota' R f_t}}{\boldsymbol{\iota' f_t}} \tag{9}$$

where vector $\boldsymbol{vs}$ contains the sum of import content of export for each industry and country or in other words sector's *vertical specialisation* in global value chain activities in gross terms (Hummels et al., 2001). To acquire a relative comparability across countries we construct the relative vertical specialisation measure as the share of import content of export on the value added for each industry.

2.3 Industries' New Revealed Comparative Advantages

Traditional Balassa's revealed comparative advantage (RCA) index is based on the relative export performance of an industry - i. We are saying that if the share of a country-sector's gross export in the country's total gross exports divided by the sector's gross exports from all countries as a share of world total gross exports is relatively higher (above one), a country must have a comparative advantage in the production of goods and services of that specific sector. The concept of Balassa's RCA index, however, ignores two facts: that the sector's value added could be exported via the country's exports to other sectors and should be then included in the sector of its origin. And secondly, it ignores the fact that the country's gross exports partly include foreign value added embodied in the domestic sector's export. The decomposition pioneered by Koopman et al. (2014) and further developed by Wang et al. (2017) enables us to calculate the sector's *new revealed comparative advantage* index, defined as a share of a country-sector's forward linkage based masseur of domestic value-added (henceforth DVA) in exports in the country's total domestic value added in exports divided by that sector's total forward-linkage based DVA in exports as a share of global value added in exports, in the form:

$$NRCA_i^c = \left(\frac{DVA_{F_i}^{\ c}}{\sum_i^N DVA_{F_i}^{\ c}}\right) \Bigg/ \left(\frac{\sum_{k=1}^{C} DVA_{F_i}^{\ k}}{\sum_{k=1}^{C}\sum_i^N DVA_{F_i}^{\ c}}\right) \quad (10)$$

The domestic value added embodied in total export and a lot of other calculations and decomposition in this paper was technically obtained thanks to R-package *'decompr'* written by Quast & Kummritz, (2015).

3 Results

In this section, we discuss structural patterns among industries and countries, which can be derived from the above-defined measures. We firstly plot the relative up-downstream position of each industry and add a linear smoothing curve to assess the different relationships among various industries' positions in the value chain that are aggregated to 7 typical WIOT sectors (Figure 2). What is immediately apparent is the strong positive relationship between downstreamness and upstreamness in each industry, which could be misleading because their partial labels indicate the opposite. The upstreamness (*U*) and downstreamness (*D*) measures, however, capture two different chains. While U quantifies the upstream position of the industry along the global output supply chain; *D* characterizes the relative position in the global input demand chain. Both indicators are calculated relative to the respective demand (supply) of the final (original) demand (supply) sectors of goods (primary factors). We thus observe the fact that industries that sell a large portion of gross output directly to final demand, also directly absorb a large share of value-added from their owners (households, government, investors (HGIs)). The closer the sectors are to the origin [1, 1] the weaker their intermediate input or output supply or demand links are (which implies closely interrelatedness with forward and backward industrial linkages). It moves us to the second compelling observation on the length of supply or demand chains of various sectors. The lengths of these chains vary from the shortest in the sector of *Public services* to the *Manufacturing* or sector of *Services*, which appear to be immensely fragmented and highly engaged in the trade of intermediate products.

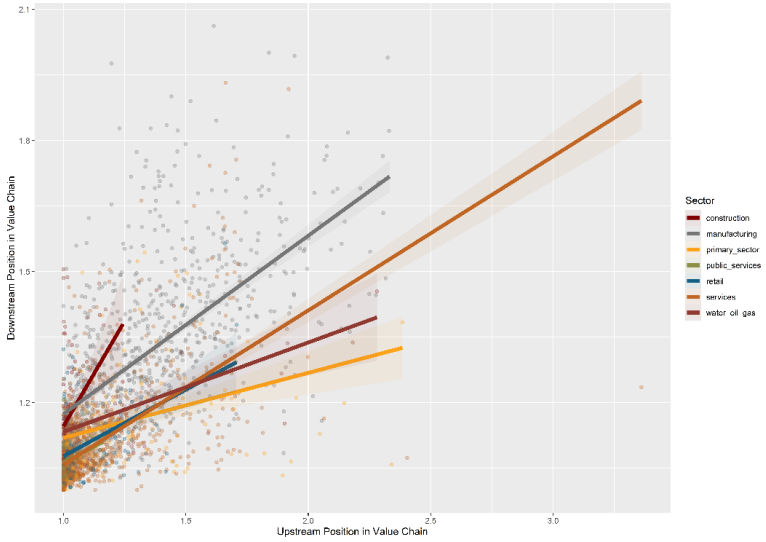

Fig. 2 Relative downstreamness and upstreamness of sectoral clustered industries in 2014. Author's calculations based on the WIOT database.

Identified length of supply and demand chains are in line with the traditional finding of I-O literature that uses the hypothetical extraction method (chapter 12 in (Miller & Blair, 2009a)), and we do observe the lower overall intensity of both upstream and downstream activities in *Primary sector*, *Oil, Gas and Water sector*, *Construction sector* and surprisingly *Retail sector*, while the high intensity of *Manufacturing* and *Services.* As one may notice in the above Figure, we see observe different steepness of each sector's average curve. All sectors (except the *Construction*), have their aggregate sector's curves slopes lower than 1, which means that on average they are positioned closer to the supplier of primary inputs than to the buyers of their gross outputs. The supply chains are then much longer from the perspective of households than the respective demand chains of their primary inputs. It indirectly implies that the sectors with the very low steepness of sectoral curves are much more prone to outsourcing of inputs (even our measures cannot differentiate between the domestic outsourcing and foreign outsourcing enriching discussion in Antràs & Chor (2018)), and it is reasonable to assume that much of these inputs are outsourced from foreign markets if the sector is labor-intensive and oppositely if the sector is R&D oriented (Tomiura, (2009) demonstrates the firm-level empirical evidence).

We explore a relationship between the position in demand and supply chain fragmentation (defines as their average length) by plotting in Figure 3 the position of each industry and their respective vertical specialisation defined in Equation (9). To capture possible non-linearities in the relationship, we add the sector-specific polynomial smoothing curve.

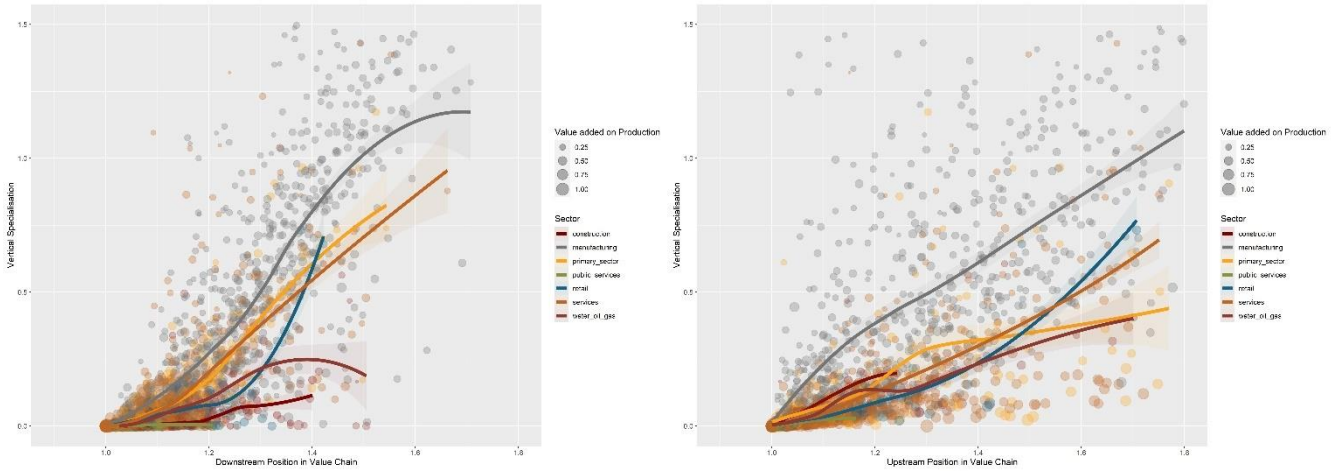

Fig. 3 Relative downstreamness (left panel) and upstreamness (right panel) of countries' industries to their vertical specialisation in 2014. The polynomial smoothing curve and the size of the bubbles are weighted by the sector's value added on production. Author's calculations based on the WIOT database.

As apparent in Figure 3, the longest and most fragmented production chain across the borders is in the *Manufacturing sector*. On average we can observe that in all sectors a positive tendency of the industry's average distance relative to final demand or source of primary inputs tends to be positively related to the import content of the industry on value-added. While from both perspectives we observe diminishing returns of vertical specialisation in play, with an exemption of the *Retail sector.* As was foreseeable by the character of the production of the retail sector, our result only underlines the fact that if the retail sector is more distant from the final demand or source of primary inputs, the volume the intermediate production that must come from imports increases in a higher proportion to distance. Unsurprisingly, the *Construction* and *Public services* sectors report a low vertical specialisation combined with previously discussed small average distances from the HGIs. The findings here suggest a well-established fact of a very high downstream position to a value-added source (and thus low backward industrial linkages) of the *Oil, Gas, and Water sector* and a fairly low upstream position (high forward industrial linkages) in the production chain to a final demand, which lies in a fact that the primary energy products are one of the most important intermediate products entering to the production in the world economy.

According to the structural interpretation of different magnitudes for upstreamness and downstreamness of different sectors (in detail discussed in (Fally, 2012)), we can make a couple of conclusions from obtained measures. Firstly, higher values of

downstreamness measure, imply higher transportation costs within the input demand-supply chain that are accumulating across the further value-added must travel along the production chain. In a Cobb-Douglas production and preference economy, the output multipliers to positive productivity shock (or error shock with opposite sign) is positively dependent on the higher the measure of downstreamness of an industry is. In a Leontief production and preference economy, a positive productivity shock has a higher effect on output the further the industry lies from the final demand. The price effects of the productivity shocks in a specific industry tend to negatively depend on the size of a measure of downstreamness of a specific industry (Fally, 2012). Regarding the possible implications of highly probable negative productive shocks, to especially exposed industry in Europe D35 - *Electricity, gas, steam and air conditioning supply* the very low measure of upstreamness are in Cyprus, Austria, Spain, Italy, Greece, Portugal on the other side of the spectrum stand Belgium, Slovenia, Denmark, Hungary, and Estonia. Instead, if we assume a Leontief type of production function and preferences, a relatively higher negative impact could be assumed if the negative productivity shock would occur in the especially second group of countries. On the other hand, with the assumption of the Cobb-Douglas economy, for a sector C19 - *Manufacture of coke and refined petroleum products* the highest negative output multipliers, if a negative productivity shock would occur (e.g. in an expected scale of -30% to refinery Slovnaft a.s. in Slovakia), we could (*ceteris paribus*) assume the most severe output impacts along the production chains from Malta, Belgium, Austria, Bulgaria, Slovakia, and Germany.

To better understand the fragmentation of the production chain and the above-discussed position of industries in the world economy, we rather loosely indicated some bi-directional causal relationship between the position of industries along the value chain to the vertical specialisation of industries. It could be interesting to see, whether industries with previously accrued relative comparative advantages, that we can precisely measure on the level of every industry, tend to be also more deeply involved in the production sharing activities. Thus, in the following exercise, in Figure 4 we show the accrued relative comparative advantages (RCA > 1) of 2464 industries, and we have found that almost 40% of industries have some level of revealed comparative advantage. For the *Manufacturing sector,* the level of cross-border production sharing activities tends to trend (on average) higher than in the sector of *Services*, while others with a lower limit of *Public services* sector tend to be o average less vertically specialised.

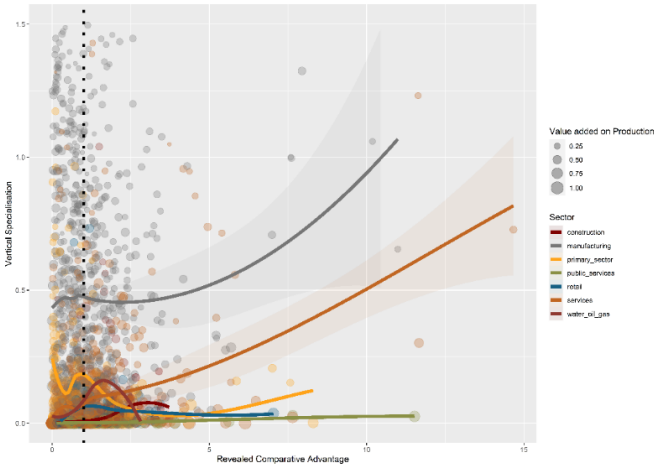

Fig. 4 New revealed comparative advantages of countries' industries to their vertical specialisation in 2014. The polynomial smoothing curve and the size of the bubbles are weighted by the sector's value added on production. Author's calculations based on the WIOT database.

It must be stated that even we do observe not an impaired tendency of industries that have a comparative advantage in the production to be more interconnected to trade in global value chains. However, the preceding observation strongly holds for the industries with the highest comparative advantages in manufacturing and services.

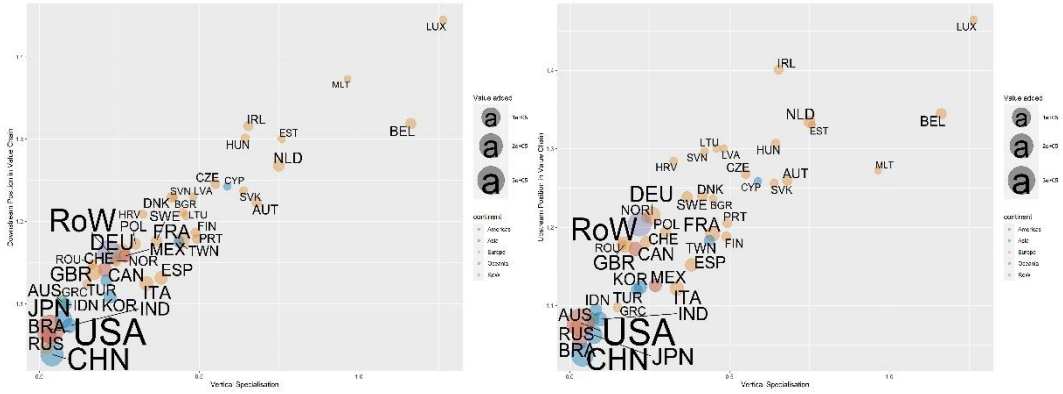

Fig. 5 Relative downstreamness (left panel) and upstreamness (right panel) of countries to their vertical specialisation in 2014. The size of the bubbles is weighted by the countries' total value-added. Author's calculations based on the WIOT database.

To uncover the countries' aggregate participation in production sharing activities and their averaged position in the supply and demand chain, we show the relative size of vertical specialisation of countries concerning their aggregated down, up- streamness along with all sectors. What is apparent at the first sight is the high degree of vertical specialisation (small countries naturally tend to trade more) and the longest supply and demand chain of countries that belong to the European cluster of value chains (top right quadrant of Figure 5). A quite surprising fact is the low position of China, one would

expect a much higher upstream position in the value chain, but in our analysis, it turns out that China's industries tend to be centered much directly around the final demand with an exemption of *air and water transport and manufacturing of computer, electronics optical product, electrical equipment, fabricated metal product except the production of machinery and legal and accounting services* has an average distance from final demand higher than 1.1, and only the industries that produce *computer, electronics optical product, basic metals or coke and refined petroleum product* tend to be rather distant from the source of primary inputs. Even a strong imperative presented in (Antràs, 2020) tells us that the individual firms and plants (nor industries or countries) decide to outsource or offshore their activities to multiple stages of production, it may be interesting to map the position and intensity of international fragmentation of individual countries in production chains because ultimately policymakers in countries set policies to adjust market equilibrium. The position of the country in the production chain relative to the degree of international sharing activities creates the policy framework with imperatives of higher efficiency of industrial (positively productivity augmenting) policies in countries positioned in the top-right quadrant of Figure 5. Based on a well-elaborated treatment of exogenous shock transmission in the value chain network in Boehm et al. (2019) on the 2011 Tōkuhu earthquake example, we can expect an enormous effect, especially to hubs economies (Figure 1 – Germany, the United States, and China) proportional to their relative position to country's difference in *y-axis* distance from hub where the shock occurs.

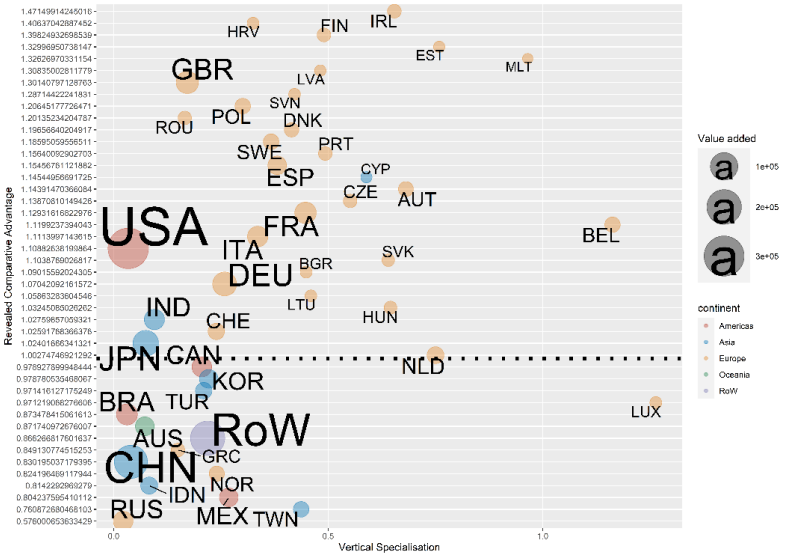

Fig. 6 Countries' new revealed comparative advantages to their vertical specialisation in 2014. The size of the bubbles is weighted by the country's total value added. Author's calculations are based on the WIOT database.

In the upper panel (Figure 6) we graph country's new accrued comparative advantage relative to the vertical specialisation in trade. On average, we observe many of the European countries to be located above the horizontal dashed line that indicates

the comparative advantage of the country in the production. The countries' position ranging from the lowest comparative advantages in Russia to the highest in Ireland. What is interesting to observe is the position of GVC hubs economies, while the United States indicates to have the highest comparative advantage followed by Germany. China's comparative advantage, if we have removed traditional biases of RCA index tends to no longer have an aggregate comparative advantage in trade.

4 Conclusions

In this paper we analyzed the position of industries/countries from the households, government or investors in the twofold role industry are to these NGIs. We have found that the position of all sectors is quite diverse. While the sector of Public services, Construction and retail tend to be positioned very close to the final demand as well as the source of primary inputs, a many industries within the sector of Manufacturing and Services are positioned quite distant from households, government and investors (NGIs) in their two-fold role. We have pointed out that labor-intensive industries that are mostly distant from final demand and primary inputs are prone to outsourcing of inputs and offshoring of outputs. To this respect, we interlinked the position of each industry to production-sharing sharing activities across the border (measured by import content of exports on value added) and found out that especially in the Manufacturing and Service sectors tend to have embodied a larger part of import content in their export. Unsurprisingly, the Construction and Public services sectors report a low vertical specialisation combined with previously discussed small average distances from the HGIs. The findings here suggest a well-established fact of a very high downstream position to a value-added source (and thus low backward industrial linkages) of the Oil, Gas, and Water sector and a fairly low upstream position (high forward industrial linkages) in the production chain to a final demand, which lies in a fact that the primary energy products are one of the most important intermediate products entering to the production in the world economy. With the exact supply and demand position of each industry in hands, we assumed that the possible negative productivity shock to whole sector of Manufacturing coke and refined petroleum products, could result in the highest negative output multipliers in Malta, Belgium, Austria, Bulgaria, Slovakia, and Germany. We also documented new revealed comparative advantages for each industry, and we found their highly prevalent presence in Manufacturing and Service sector. We have established a fact that countries with higher revealed comparative advantages tend to vertically specialize more than those without them, and the China as a whole, even serving as the GVC hub economy do not exhibit a new revealed comparative advantages on an aggregate level.

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