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RSCAS 2019/84
Robert Schuman Centre for Advanced Studies
Global Governance Programme-373

Made in the World Revisited

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EUI Working Paper **RSCAS** 2019/84

ISSN 1028-3625

Printed in Italy, October 2019
European University Institute
Badia Fiesolana
I – 50014 San Domenico di Fiesole (FI)
Italy
www.eui.eu/RSCAS/Publications/
www.eui.eu
cadmus.eui.eu

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Abstract

In the last decade, the concept of 'global value chain' (GVC) has become popular to describe the way firms fragment production into different stages located in different economies. The 'made in the world' narrative suggests that production today is global with inputs coming from all parts of the world before being assembled into final products also shipped all over the world. The empirical basis of this story has however been questioned. On the one hand, recent evidence indicates that there is some kind of 'deglobalisation' with a trade slowdown and lower levels of fragmentation of production. On the other hand, some authors suggest that supply chains are regional rather than global. In this paper, we offer a comprehensive review of the evidence based on the 2018 update of the OECD Trade in Value-Added (TiVA) database and indicators counting the number of domestic and foreign production stages, border crossings and geographic length of supply chains. The study covers 1995 to 2016. The made in the world narrative is correct when describing the rise of GVCs in the 2000s. But globalisation has reached a peak in 2012 and since then supply chains are becoming more domestic rather than more regional. The 'erosion' in globalisation (i.e. the reduction in the average length of supply chains since 2012) is 52 kilometres per year.

Keywords

Fragmentation of production, vertical specialization, global value chain.

JEL Classification: F14, L16, L23.

1. Introduction*

In the last decade, the concept of 'global value chain' (GVC) has become popular to describe the way firms vertically fragment their production into different stages located in different economies. The concept was first introduced by Gereffi *et al.* (2001) to analyse governance structures in sectors producing for global markets and is now widely used to study structural changes in the global economy (Gereffi, 2019).

The 'made in the world' narrative suggests that production today is global with inputs coming from all parts of the world before being assembled into final products also shipped all over the world. The empirical basis of this story has however been questioned. First, even before the rise of protectionism, there was a debate about whether GVCs are truly global. For example, Baldwin and Lopez-Gonzalez (2015) argued that global production networks are "marked by regional blocs, what could be called Factory Asia, Factory North America, and Factory Europe".

Second, following the recovery from the 2008 financial crisis, rising protectionism was pointed out as a determinant of the globalisation slowdown (Bown, 2018). This protectionism was first observed among G20 economies through a more frequent use of non-tariff measures and trade remedies (Evenett, 2019) and turned into trade wars after 2018 (Crowley, 2019). Falling trade barriers after the creation of WTO and decreasing communications cost with the information technology revolution were the main drivers of the rise of GVCs in the 1990s. While new technological advances in the digital era can still lower trade costs, protectionism can offset the gains from foreign sourcing and encourage firms to source locally or from less distant countries, thus triggering a 'deglobalisation' (James, 2018).

Whether we have entered into a new era of deglobalisation and whether GVCs are becoming less global is an empirical matter. Several types of indicators based on international input-output tables are now available to shed light on these questions (Johnson and Noguera, 2012; Koopman, Wang and Wei, 2014; Timmer et al., 2014; Los, Timmer and de Vries, 2015; Johnson, 2018). In this paper, we offer a comprehensive review of the evidence based on the 2018 release of the OECD TiVA database and underlying inter-country input-output (ICIO) tables, including new indicators counting the number of domestic and foreign production stages, border crossings and geographic length of supply chains.

Moreover, in order to look at a longer time period, we add information from the previous edition of the OECD database covering 1995 to 2011. The two sets of data are not fully comparable as national accounts moved from definitions and standards of the 1993 System of National Accounts (SNA) to the new 2008 SNA. We present data separately for 1995-2011 and 2005-2016 to make sure that the interpretation of results is not affected by this change in national accounting practices.

The paper is organized as follows. Section 2 introduces the basic value chain tools and the OECD ICIO used in the empirical analysis. Section 3 explains how to measure the internationalization of supply chains in the conventional way of decomposing value-added by country and industry. It provides the first evidence of a deglobalisation in terms of lower levels of foreign value-added in exports. Section 4 then investigates whether this decline in value-added corresponds to shorter value chains in the sense of fewer production stages, building on Fally´s (2012) measure of embodied production stages. Section 5 reviews the evidence whether supply chains are regional or global and Section 6 whether we see a decrease in the geographic length of supply chains in the recent period. Section 7 concludes.

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* The views expressed in this paper are those of the authors and do not necessarily reflect the views of the organizations they work for. This paper is an updated version of Miroudot and Nordström (2015), "Made in the World?", EUI Working Papers, RSCAS 2015/60.

2. The Leontief model

We begin with a brief recapitulation of the Leontief model in a single economy setting. The model is then extended into a multi-country framework suitable to analyse international supply chains.

2.1 One country closed economy model

The input-output table of a closed economy is depicted in Table 1. The first *n×n* elements of the IO-table record intra- and inter-industry flows of intermediate goods and services, where sales from sector *i* to *j* are recorded horizontally and purchases vertically. The *n+1* column ("Final demand") records sales to final consumers and the *n+1* row ("Value added") outlays on labour and capital that process raw materials and manufactured inputs into more valuable outputs. The shaded column to the right reports total output (supply) by industry and the shaded column at the bottom total input (use) by industry, which in equilibrium are equal in monetary terms.

Table 1. Input-Output table of a closed economy

		Using sector *j = 1, 2, …, n*					
		Intermediate demand				Final Demand	Total output
		Sector 1	Sector 2	…	Sector n		
Supplying sector i =1, 2 ,… , n	Sector 1	z_{11}	z_{12}	…	z_{1n}	f_1	y_1
	Sector 2	z_{21}	z_{22}	…	z_{2n}	f_2	y_2
	…	…	…	…	…	…	…
	Sector n	z_{n1}	z_{n2}	…	z_{nn}	f_n	y_n
	Value Added	w_1	w_2	…	w_n	GDP	
	Total input	y_1	y_2	…	y_n		

To analyze interactions between sectors, Leontief (1936) proposed a linear model with fixed input coefficients and constant returns to scale (CRS). The production functions were specified as:

$$(1) \qquad y_j = \min\left(\frac{z_{1j}}{a_{1j}}, \frac{z_{2j}}{a_{2j}}, \ldots, \frac{z_{nj}}{a_{nj}}; \frac{w_j}{b_j}\right),$$

where y_j denotes the output of sector *j*, z_{ij} inputs from sector *i* and w_j inputs of primary production factors. The a_{ij} coefficients in the denominator specify the *minimum input requirements* from sector *i* to produce one unit of output in sector *j*. Since there is no substitutability between different types of inputs, firms will employ just the minimum amount of inputs to produce the output demanded by the market,

$$(2) \qquad z_{ij} = a_{ij} y_j.$$

The last term in the production function is the input of primary production factors w_j (value added) which enter with coefficient b_j (which in equilibrium equals $1-\sum a_{ij}$ under the CRS assumption). This part of the model is not well developed: it is just assumed that there is enough primary factors to supply all sectors of the economy (either because of elastic supply or flexible factor prices). The model is closed by treating final demand as an exogenous variable.

Under these assumptions, the model boils down to a linear equation system of supply and demand,

$$\underbrace{\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}}_{\boldsymbol{y}} = \underbrace{\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}}_{\boldsymbol{A}} \underbrace{\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix}}_{\boldsymbol{y}} + \underbrace{\begin{bmatrix} f_1 \\ f_2 \\ \vdots \\ f_n \end{bmatrix}}_{\boldsymbol{f}}.$$

where $\boldsymbol{y}$ denotes the production vector, $\boldsymbol{A}$ the input-output matrix per unit of output and $\boldsymbol{f}$ the final demand vector, and where the product of $\boldsymbol{A}$ and $\boldsymbol{y}$ gives the intermediate demands for inputs. The solution to this equation system (the general equilibrium of the economy) is,

(3) $$\boldsymbol{y} = [\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{f},$$

where $[\boldsymbol{I} - \boldsymbol{A}]^{-1}$ is the "Leontief inverse" that computes the total input requirements from each sector to produce the exogenous vector of final demand.[1]

2.2 One country open economy model

Let us now introduce exports and imports into the model. Let´s assume that we have data on the total export by sector ($\boldsymbol{x}$) whilst the import vector ($\boldsymbol{m}$) is further divided into intermediate and final goods. The demand from the world market is treated as an exogenous "variable" just as domestic final demand, whereas the demand for intermediate imported goods and services depends on the domestic production. The open economy model is described by two blocks of linear equations

(4a) $$\boldsymbol{y} = \boldsymbol{A^D y} + \boldsymbol{f^D} + \boldsymbol{x},$$
(4b) $$\boldsymbol{m} = \boldsymbol{A^M y} + \boldsymbol{f^M},$$

where the first block is the supply-equals-demand conditions for domestic goods (superscript $\boldsymbol{D}$) and the second block supply-equals-demand conditions for imported goods (superscript $\boldsymbol{M}$). The solution to this block-recursive equation system is:

(5a) $$\boldsymbol{y} = [\boldsymbol{I} - \boldsymbol{A^D}]^{-1}\left(\boldsymbol{f^D} + \boldsymbol{x}\right),$$
(5b) $$\boldsymbol{m} = \boldsymbol{A^M}[\boldsymbol{I} - \boldsymbol{A^D}]^{-1}\left(\boldsymbol{f^D} + \boldsymbol{x}\right) + \boldsymbol{f^M}.$$

Note that the open economy version of the Leontief model establishes a direct link between exports and imports flowing from the dual assumptions of fixed input coefficients and no substitutability between domestic and imported inputs. Specifically, if export demand rise by $\boldsymbol{dx}$ units, intermediate imports will

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[1] As shown by Miller and Blair (2009, p. 33), provided that $a_{ij} \geq 0$ for all i and j and $\sum_{i=1}^{n} a_{ij} < 1$ for all j, the Leontief inverse is the solution to an infinite geometric series of $\boldsymbol{A}$,

$$[\boldsymbol{I} - \boldsymbol{A}]^{-1} = \boldsymbol{I} + \boldsymbol{A} + \boldsymbol{A^2} + \boldsymbol{A^3} + \cdots,$$

which is the analogue to a geometric series in standard algebra: $[1 - a]^{-1} = 1 + a + a^2 + a^3 + \cdots$ for $|a| < 1$. The reason why increasingly higher powers of $\boldsymbol{A}$ enter the market clearing condition,

$$\boldsymbol{y} = [\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{f} = \boldsymbol{f} + \boldsymbol{Af} + \boldsymbol{A^2 f} + \boldsymbol{A^3 f} + \cdots = \underbrace{\boldsymbol{A}[\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{f}}_{\substack{\boldsymbol{intermediate} \\ \boldsymbol{consumption}}} + \underbrace{\boldsymbol{f}}_{\substack{\boldsymbol{final} \\ \boldsymbol{consumption}}}$$

is that the suppliers of inputs use inputs themselves, which in turn are produced with yet other inputs all the way back to the initial production stage. In equilibrium, the production of each industry must satisfy both the final demand $\boldsymbol{f}$ and the intermediate needs of all sectors in the economy $\boldsymbol{A}[\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{f}$.

have to rise by $\boldsymbol{dm = A^M[I - A^D]^{-1}dx}$ units in order to produce the additional demand for the world market.

If we apply this model on different country datasets, we can study how integrated various countries are in the world economy and the change over time if IO-tables are available for several years. The most common index used in this context is the *vertical specialization* (**VS**) index proposed by Hummels, Ishii and Yi (2001),

$$(6) \qquad \boldsymbol{VS = \frac{i' A^M [I - A^D]^{-1} x}{i' x}},$$

which measures the import content of the export vector.[2] While this is a very useful and data sparse indicator, it has some limitations that can only be resolved by linking national IO-tables into a global IO-model. For instance, the single country model can only provide an approximate assessment of the foreign content since imported inputs may contain domestic inputs that have been processed abroad ('returning value added').

2.3 Multi country input-output model

Extending the Leontief model into an ICIO model is straightforward in theory but demanding on data. The starting point is the realization that the world as a whole is a closed economy and hence can be modelled in the same way as a closed single country model. Following Koopman, Wang and Wei (2014), we formulate the ICIO-model in block matrix notation in order to distinguish as clearly as possible between domestic and international transactions. The data is organized in three matrices,

$$\boldsymbol{Y} = \underbrace{\begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1m} \\ y_{21} & y_{22} & \cdots & y_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ y_{m1} & y_{m2} & \cdots & y_{mm} \end{bmatrix}}_{mn \times m}, \quad \boldsymbol{A} = \underbrace{\begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1m} \\ A_{21} & A_{22} & \cdots & A_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & \cdots & A_{mm} \end{bmatrix}}_{mn \times mn}, \quad \boldsymbol{F} = \underbrace{\begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1m} \\ f_{21} & f_{22} & \cdots & f_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mm} \end{bmatrix}}_{mn \times m},$$

where $\boldsymbol{Y}$ is a block matrix that defines production by origin, sector and destination markets, $\boldsymbol{A}$ is the intermediate consumption matrix with domestic IO-links on the diagonal blocs and international IO-links on the off-diagonal blocks, and where $\boldsymbol{F}$ is the final demand matrix by destination markets. In general equilibrium supply must equal demand in all sectors and countries, taking into account the intermediate consumption used in all production activities:

$$(7) \qquad \begin{aligned} \boldsymbol{Y} &= \boldsymbol{AY} + \boldsymbol{F} \\ &= \boldsymbol{[I - A]^{-1} F}. \end{aligned}$$

Note that the off-diagonal blocks of $\boldsymbol{Y}$ constitute the global trade matrix. For example, $\boldsymbol{y_{12}}$ is the export of country 1 to country 2; or viewed from the other side, the import of country 2 from country 1. While it is not necessary, we shall for clarity define explicit matrices for exports $(\boldsymbol{X})$ and imports $(\boldsymbol{M = X'})$ in the subsequent analysis. Also $\boldsymbol{A}$ and $\boldsymbol{F}$ will be partitioned into domestic and foreign blocks as need arises, such as in the calculations of how many borders are crossed in a supply chain.

[2] Post-multiplication of a matrix by the unit vector $\boldsymbol{i}$ creates a column vector with elements equal to the *row sums* of the matrix, while pre-multiplication with $\boldsymbol{i'}$ creates a row vector with elements equal to the *column sums* of the matrix.

2.4 OECD Inter-Country Input-Output tables

The Leontief model is implemented in the 2018 edition of the OECD ICIO that contains annual IO-tables for 64 economies from 2005 to 2016, accounting for about 92 percent of world GDP. All other countries are subsumed in a 'Rest of the World' (ROW) region. These tables are the underlying data of the OECD Trade in Value-Added (TiVA) database. Countries covered are listed in Table 2 and industries in Table 3. The 2008 edition of the OECD ICIO follows definitions of the SNA 2008. We complement this dataset with the 2016 edition of the database that had data from 1995 to 2011 in SNA 1993. Industries in the 2018 edition are in the International Standard Industry Classification (ISIC) Rev. 4, while industries in the 2016 edition are in ISIC Rev. 3. There is only a 'rough' one-to-one correspondence between the two at the 2-digit level, as illustrated in Table 3. With respect to countries, only Kazakhstan was not covered in the previous edition and is excluded from the analysis.

Table. 2 Countries in the OECD ICIO (2018 edition)

ISO3	Country	Region	ISO3	Country	Region
ARG	Argentina	South and Central America	KAZ	Kazakhstan	Other regions
AUS	Australia	Other regions	KHM	Cambodia	East and South East Asia
AUT	Austria	Europe	KOR	South Korea	East and South East Asia
BEL	Belgium	Europe	LTU	Lithuania	Europe
BGR	Bulgaria	Europe	LUX	Luxembourg	Europe
BRA	Brazil	South and Central America	LVA	Latvia	Europe
BRN	Brunei Darussalam	East and South East Asia	MAR	Morocco	Other regions
CAN	Canada	North America	MEX	Mexico	North America
CHE	Switzerland	Europe	MLT	Malta	Europe
CHL	Chile	South and Central America	MYS	Malaysia	East and South East Asia
CHN	China	East and South East Asia	NLD	Netherlands	Europe
COL	Colombia	South and Central America	NOR	Norway	Europe
CRI	Costa Rica	South and Central America	NZL	New Zealand	Other regions
CYP	Cyprus	Europe	PER	Peru	South and Central America
CZE	Czech Republic	Europe	PHL	Philippines	East and South East Asia
DEU	Germany	Europe	POL	Poland	Europe
DNK	Denmark	Europe	PRT	Portugal	Europe
ESP	Spain	Europe	ROU	Romania	Europe
EST	Estonia	Europe	ROW	Rest of the World	Other regions
FIN	Finland	Europe	RUS	Russian Federation	Europe
FRA	France	Europe	SAU	Saudi Arabia	Other regions
GBR	United Kingdom	Europe	SGP	Singapore	East and South East Asia
GRC	Greece	Europe	SVK	Slovakia	Europe
HKG	Hong Kong (China)	East and South East Asia	SVN	Slovenia	Europe
HRV	Croatia	Europe	SWE	Sweden	Europe
HUN	Hungary	Europe	THA	Thailand	East and South East Asia
IDN	Indonesia	East and South East Asia	TUN	Tunisia	Other regions
IND	India	Other regions	TUR	Turkey	Other regions
IRL	Ireland	Europe	TWN	Chinese Taipei	East and South East Asia
ISL	Iceland	Europe	USA	United States	North America
ISR	Israel	Other regions	VNM	Viet Nam	East and South East Asia
ITA	Italy	Europe	ZAF	South Africa	Other regions
JPN	Japan	East and South East Asia			

Table 3. Industries in the OECD ICIO (2018 edition in ISIC 4 and 2016 edition in ISIC 3)

ISIC 4 code	Industry name	Short label	ISIC 3 code (rough correspondence)
01T03	Agriculture, hunting, forestry and fishing	Agriculture	01T05
05T06	Mining and extraction of energy producing products	Mining, energy	
07T08	Mining and quarrying of non-energy producing products	Mining, non-energy	10T14
9	Services to mining and quarrying	Mining, services	
10T12	Food products, beverages and tobacco	Food products	15T16
13T15	Textiles, textile products, leather and footwear	Textiles & apparel	17T19
16	Wood and products of wood and cork	Wood	20
17T18	Paper products and printing	Paper and printing	21T22
19	Coke and refined petroleum products	Coke, petroleum	23
20T21	Chemicals and chemical products	Chemicals	24
22	Rubber and plastics products	Rubber & plastics	25
23	Other non-metallic mineral products	Non-metal minerals	26
24	Basic metals	Basic metals	27
25	Fabricated metal products	Fabricated metals	28
26	Computer, electronic and optical equipment	ICT & electronics	30T33
27	Electrical machinery and apparatus, nec	Electrical equipment	31
28	Machinery and equipment, nec	Machinery	29
29	Motor vehicles, trailers and semi-trailers	Motor vehicles	34
30	Other transport equipment	Other transport	35
31T33	Manufacturing nec; repair of machinery and equipment	Other manufacturing	36T37
35T39	Electricity, gas, water supply, sewerage, waste and remediation services	Utilities	40T41
41T43	Construction	Construction	45
45T47	Wholesale and retail trade; repair of motor vehicles	Wholesale & retail	50T52
49T53	Transportation and storage	Transport & storage	60T63
55T56	Accomodation and food services	Hotels & restaurants	55
58T60	Publishing, audiovisual and broadcasting activities	Publishing, broadcasting	n/a
61	Telecommunications	Telecoms	64
62T63	IT and other information services	IT services	n/a
64T66	Financial and insurance activities	Finance & insurance	65T67
68	Real estate activities	Real estate	70
69T82	Other business sector services	Other business services	73T74
84	Public admin. and defence; compulsory social security	Public admin	75
85	Education	Education	80
86T88	Health and social work	Health	85
90T96	Other community, social and personal services	Other services	90T93
97T98	Private households with employed persons	Private households	95

In addition to differences in terms of industry classification and country coverage, the most important change between the 2018 edition and 2016 edition of the ICIO is the implementation of SNA 2008 definitions (instead of SNA 1993). In the new SNA, there are two important modifications affecting the measurement of GVCs. First, expenses on research and development (R&D) that were previously regarded as an intermediate consumption in SNA 1993 are now capitalized and regarded as an

investment. Since (international) R&D is now longer a foreign input and value-added is higher, the new indicators record lower levels of foreign value-added in trade. Second, the treatment of goods for processing has changed. When there is no change of ownership (i.e. the goods sent for processing abroad still belong to the firm asking for manufacturing services), exports and imports of such goods are no longer recorded in trade in goods statistics. Instead, there is an export of 'manufacturing services on physical inputs owned by others', which is an export of services from the processing country to the country of the firm asking for the processing. As inputs and processed goods are no longer recorded in trade flows, the foreign value-added is also smaller for countries involved in this type of transactions. However, it should be noted that not all processing trade is done on the basis of no change in ownership.

Finally, national accounts are regularly revised by countries and sometimes with significant changes in the level of GDP. The 2018 edition of the ICIO includes the latest available tables. Another advantage when using the OECD tables is that for China and Mexico data are split for exporting firms and non-exporting firms. Countries involved in 'processing trade', like China or Mexico, may have a different use of foreign inputs for products exported and products consumed in the domestic market. These differences are captured in the OECD tables. But as highlighted above, these economies are now exporting manufacturing services when processing trade involves no change in ownership.

3. Value added by country: signs of deglobalisation?

Having equipped ourselves with the basic input-output tools, we shall now address the question of whether there is some kind of deglobalisation in world production. We begin by picking apart the some 2340 supply chains in the OECD ICIO to check who contributed what to each supply chain and the value share of their contributions.

3.1 Supply chain decomposition

We start from the accounting identity

(8) $$\boldsymbol{i} = \boldsymbol{A'i} + \boldsymbol{v},$$

where $\boldsymbol{i}$ is a unit vector of output, $\boldsymbol{A'i}$ is the costs of non-primary inputs and $\boldsymbol{v}$ is the value-added per unit of output. If we iterate this accounting identity backward in the supply chain, we end up with an infinite series that decompose the value-added by stage of production:

(9) $$\boldsymbol{i} = \boldsymbol{v} + \boldsymbol{A'v} + \boldsymbol{A'^2v} + \cdots = [\mathbf{1} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{v}$$

$$= \underbrace{\boldsymbol{v}}_{\substack{final \\ assembly}} + \underbrace{[\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'}\,\boldsymbol{v}}_{\boldsymbol{upstream}} .$$

The contribution by an individual country can be calculated by setting all value-added coefficients to zero in the $\boldsymbol{v}$ vector apart from the country under consideration. These calculations can be done for one country at the time or in one step by redefining $\boldsymbol{v}$ as a *block-diagonal* matrix,

(10) $$\boldsymbol{V} = bdiag(\boldsymbol{v}) + [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'}bdiag(\boldsymbol{v})$$

$$= \underbrace{\begin{bmatrix} \boldsymbol{v_1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \boldsymbol{v_2} & \ldots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \boldsymbol{v_m} \end{bmatrix}}_{\substack{value\ added\ in \\ final\ assembly}} + \underbrace{\begin{bmatrix} \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_1 \boldsymbol{v_1} & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_1 \boldsymbol{v_2} & \cdots & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_1 \boldsymbol{v_m} \\ \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_2 \boldsymbol{v_1} & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_2 \boldsymbol{v_2} & \ldots & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_2 \boldsymbol{v_m} \\ \vdots & \vdots & \ddots & \vdots \\ \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_m \boldsymbol{v_1} & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_m \boldsymbol{v_2} & \cdots & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A'}\rangle_m \boldsymbol{v_m} \end{bmatrix}}_{\substack{upstream\ valued\ added \\ by\ country\ (j=1,2,\ldots,m)}}$$

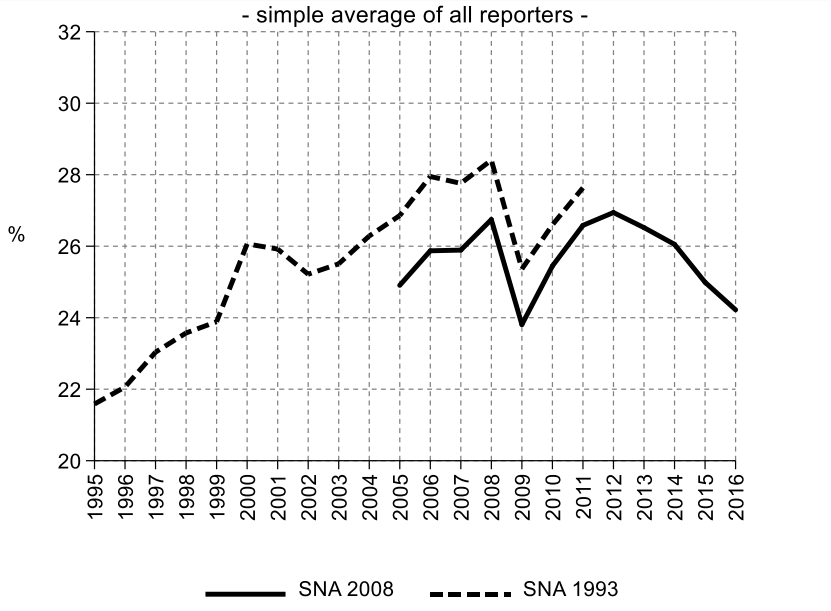
The $\boldsymbol{V}$-matrix provides a full decomposition of the value-added shares by country for each supply chain in the database, where the domestic value-added shares are recorded on the diagonal blocks and the foreign value-added shares *by country* on the off-diagonal blocks.

3.2 Foreign value-added in total exports

Figure 1 plots the foreign value-added share in total exports from 1995 to 2016. A simple average is used across reporters. Results based on the 2018 edition of the OECD ICIO (SNA 2008) and 2016 edition (SNA 1993) are reported separately. Since there is an overlap in the period covered by the two databases between 2005 and 2011, one can see the difference in results. Foreign value-added shares are lower with SNA 2008 data but the trend is similar when it comes to their change over years.

In 2016, the foreign shares range from 5 to 67 percent, with Saudi Arabia at the low end and Luxembourg at the high. The most obvious reasons for the rather large differences we observe are: (a) the sector composition of export, (b) economic size and (c) trade barriers on inputs. Other things equal, large countries with high trade barriers specializing in raw material exports will use relatively little foreign inputs. And the other way round, small countries with low trade barriers specializing in processed goods and services will tend to use relatively more foreign inputs. The reason why the size of a country matters is economies of scale in production. That is, small countries cannot cost-efficiently produce the full range of inputs and will therefore naturally import more foreign inputs than large countries.

Figure 1. Foreign value-added in total exports (1995-2016)



The average foreign value-added share in total exports peaked in 2012 (27%) but it was already close to this level in 2008 before the Great Financial Crisis. There was an important trade slowdown during the crisis between 2008 and 2009 that affected imports of foreign inputs. But the recovery was quick with

foreign value-added shares back to their 2008 level in 2011. It is a different story after 2012 where a slow decline is first observed and then more pronounced between 2014 and 2016. From Figure 1, we can see that there is some deglobalisation based on the share of foreign value-added in exports (or in production since within the ICIO framework, this share is not different for exports and for domestic sales, with the exception of China and Mexico for which data are different).

One important caveat when looking at Figure 1 is that data are in constant prices and, despite the use of value-added shares, are impacted by changes in relative prices across years. For example, the acceleration in the decline of the foreign value-added share after 2014 may be partially explained by the drop in the cost of imports of oil, which account for a significant share of imports of inputs for some countries. Removing the coke and petroleum industry from the analysis does not change the fact that there is a downward trend but the decrease is smaller. One needs to be aware that the charts we present are not in constant prices. Some input-output tables are in previous year's prices, but tracking prices in global input-output matrices is challenging in the absence of detailed price information on imported inputs. Empirical work on GVCs is usually in current prices.

Across industries (results not reported), the foreign input content is generally higher in manufacturing sectors than in service sectors. The most 'globalised' industries measured from the inputs side are 'ICT & electronics', 'coke and refined petroleum products' and 'motor vehicles'.

4. International production stages and border crossings: are GVCs shrinking?

In this section, we provide additional evidence on the deglobalisation by, firstly, calculating the number of production stages that take place outside the country-of-completion, and, secondly, the number of borders being crossed. The latter indicator is new to the GVC literature. Lower shares of foreign value-added in exports could be explained by lower prices for imported inputs (e.g. oil) or fewer inputs sourced from abroad but with the same level of fragmentation of production. The foreign value-added share of exports does not provide information on the fragmentation of production. For example, a country sourcing a single foreign input from a single supplier with a value of 20 and producing 100 would have the same share of foreign value-added (20%) as a country producing 100 and sourcing an input from country A produced with inputs from country B and country C using further inputs from country D, etc., where total foreign value-added could be 20 but split among a broader set of countries upstream in different production stages.

4.1 Fally´s (2012) measure of embodied production stages

How many production stages are embodied in a supply chain? The answer proposed by Fally (2012) is to weigh the value added created at each production stage with the number of stages that these inputs will be processed downstream, plus one for the production of the inputs themselves:

$$(11) \quad \boldsymbol{i} = \underbrace{\underbrace{\underbrace{\boldsymbol{v}}_{\leftarrow 1} + \boldsymbol{A'v}}_{\leftarrow 2} + \boldsymbol{A'^2 v}}_{\leftarrow 3} + \boldsymbol{A'^3 v} + \cdots \; .$$

Thus, the first-tier supplies are weighted by two: one for the production of the inputs and one for the downstream assembly into the final product. The second-tier supplies are weighted by three: one for the production they supply, one for the assembly into the first-tier supplies, and one for the final assembly. Summing this chain using the value shares of the final product results in Fally´s measure of embodied production stages:

$$
\begin{aligned}
(12) \quad \boldsymbol{n} &= \boldsymbol{v} + \mathbf{2}\boldsymbol{A'v} + \mathbf{3}\boldsymbol{A'^2v} + \cdots \\
&= (\boldsymbol{i} - \boldsymbol{A'i}) + \mathbf{2}\boldsymbol{A'}(\boldsymbol{i} - \boldsymbol{A'i}) + \mathbf{3}\boldsymbol{A'^2}(\boldsymbol{i} - \boldsymbol{A'i}) + \cdots \\
&= \boldsymbol{i} + \boldsymbol{A'i} + \boldsymbol{A'^2i} + \boldsymbol{A'^3i} + \cdots \\
&= [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\,\boldsymbol{i}
\end{aligned}
$$

The index ranges from one to infinity, where the lower limit is attained if no *external* inputs are used in the production process. This is easiest seen if we divided the index into final assembly and upstream production stages (if any):

$$
(13) \quad \boldsymbol{n} = \underbrace{\boldsymbol{i}}_{\substack{\boldsymbol{final} \\ \boldsymbol{assembly}}} + \underbrace{[\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'i}}_{\substack{\boldsymbol{upstream} \\ \boldsymbol{stages}}}
$$

Fally´s index is thus a measure of the *external* fragmentation of a production process, which is as much an economic as a technical decision limited by the costs of writing and enforcing contracts relative to the economic gains of outsourcing.

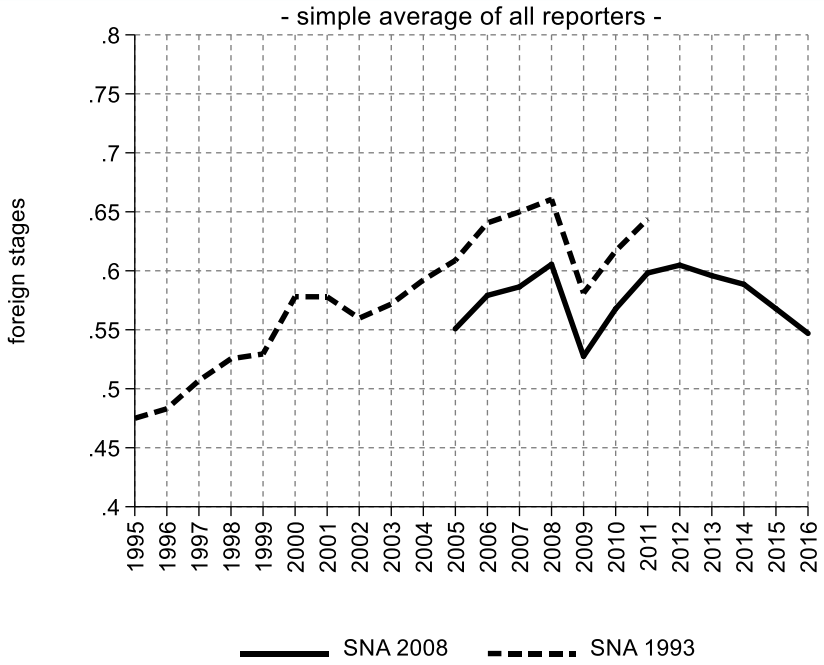
4.2 Production stages by country

Now, using the same logic as for the value-added decomposition in section 3, we can decompose Fally´s measure into production stages by country,

$$
\begin{aligned}
(14) \quad \boldsymbol{N} &= bdiag(\boldsymbol{i}) + [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'}\; bdiag(\boldsymbol{i}) \\
&= \begin{bmatrix} \boldsymbol{i_1} & \mathbf{0} & \cdots & \mathbf{0} \\ \mathbf{0} & \boldsymbol{i_2} & \ldots & \mathbf{0} \\ \vdots & \vdots & \ddots & \vdots \\ \mathbf{0} & \mathbf{0} & \cdots & \boldsymbol{i_m} \end{bmatrix} + \begin{bmatrix} \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\mathbf{1}} \boldsymbol{i_1} & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\mathbf{1}} \boldsymbol{i_2} & \cdots & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\mathbf{1}} \boldsymbol{i_m} \\ \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\mathbf{2}} \boldsymbol{i_1} & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\mathbf{2}} \boldsymbol{i_2} & \ldots & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\mathbf{2}} \boldsymbol{i_m} \\ \vdots & \vdots & \ddots & \vdots \\ \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\boldsymbol{m}} \boldsymbol{i_1} & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\boldsymbol{m}} \boldsymbol{i_2} & \cdots & \langle [\boldsymbol{I} - \boldsymbol{A'}]^{-\mathbf{1}}\boldsymbol{A'} \rangle_{\boldsymbol{m}} \boldsymbol{i_m} \end{bmatrix},
\end{aligned}
$$

where domestic production stages are recorded on the diagonal blocks (divided into final assembly and upstream stages) and foreign stages *by country* on the off-diagonal blocks.

Figure 2. Foreign production stages (1995-2016)



The average development for ICIO countries is plotted in Figure 2. As with the foreign value-added, the number of foreign stages has steadily increased from 1995 to 2008. The peak is observed in 2008 but the value for 2012 is almost the same. Since 2012, GVCs are shrinking with fewer foreign production stages. Among countries found to have the highest decrease in the number of foreign production stages since 2012 are Korea, Chinese Taipei, Hong Kong and China. Asian GVCs seem to be the most affected by rising protectionism and by the re-centring of the Chinese economy on its domestic market. With wages increasing in China and domestic suppliers of inputs becoming more competitive, there was already a trend towards less vertical specialization in China before the recent trade tensions (Duan et al., 2018).

4.3 Foreign production stages by sector

Figure 3a-b plots the trend for individual sectors. As a general rule there are more foreign production stages in manufactures than in services, with 'ICT and electronics' and 'motor vehicles' at the top. The general trend is a steady increase in the international fragmentation of production until 2008 followed by a drop with the 2008-2009 financial crisis and a structural decrease since 2012. However, not all industries follow this pattern. In particular, service industries tend to be less affected, with the production of services such as 'IT services' and 'finance and insurance' becoming more fragmented until 2016. The Great Financial Crisis also had a smaller impact on services GVCs, confirming the resilience of services trade to macroeconomic shocks (Borchert and Mattoo, 2010).

Sectors where the decline in the number of foreign production stages is the highest after 2012 are first raw material industries, such as 'coke and petroleum' or 'basic metal'. But while the evolution of prices can explain a decline in the share of foreign value-added, the indicator based on production stages is less affected by prices since it is weighted by the number of stages. Therefore, the results suggest that there is a structural change in these industries and for basic metal at least, one can think that it is related to protectionism on steel or aluminium. 'Mining' is an industry where we do not see a decline in the foreign production stages, while 'basic metals' and 'fabricated metals' record such decline, suggesting that the transformation of metals is the industry where value chains are becoming less international.

Figure 3a. Foreign production stages by sector (1995-2016)

- simple average of all reporters -

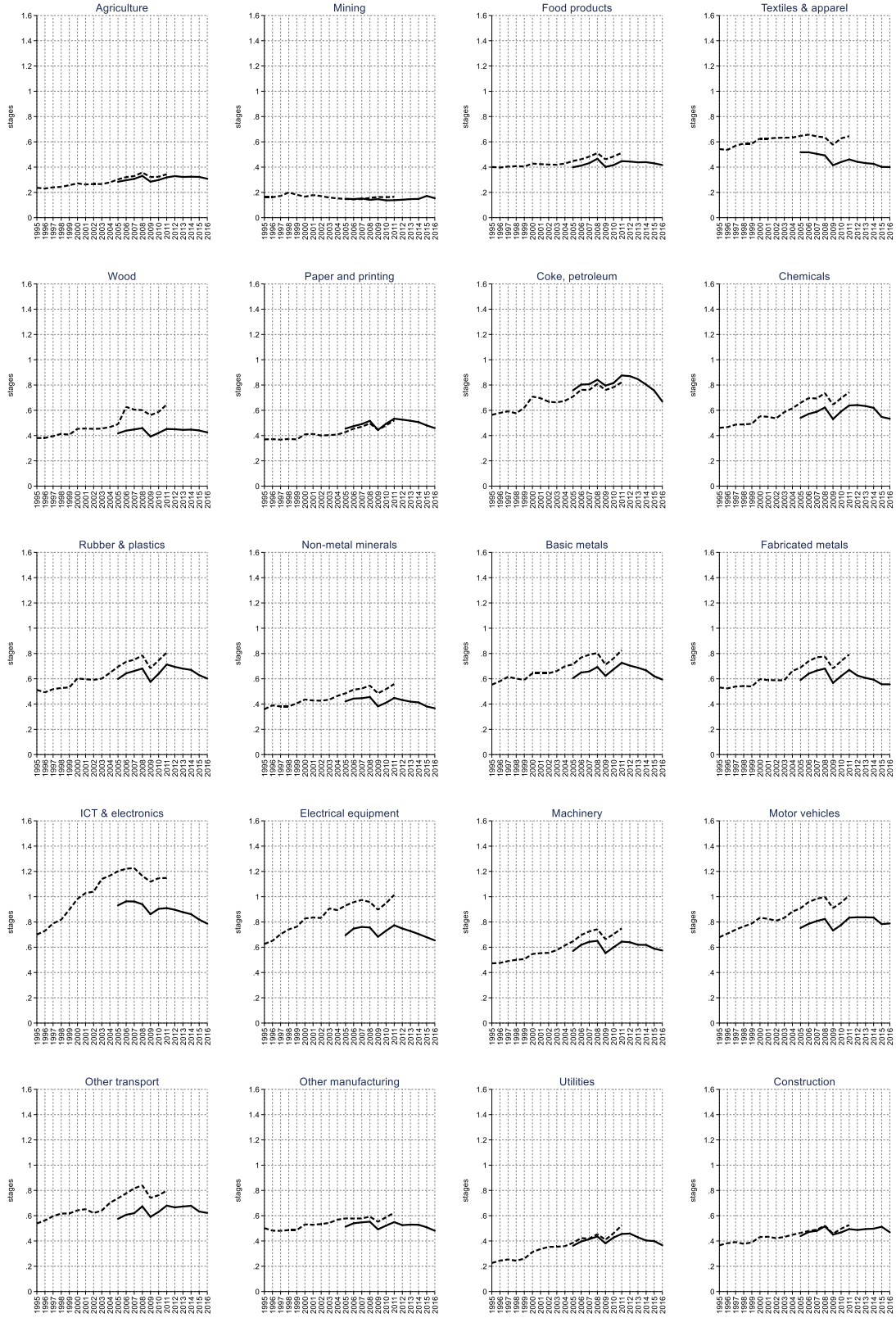
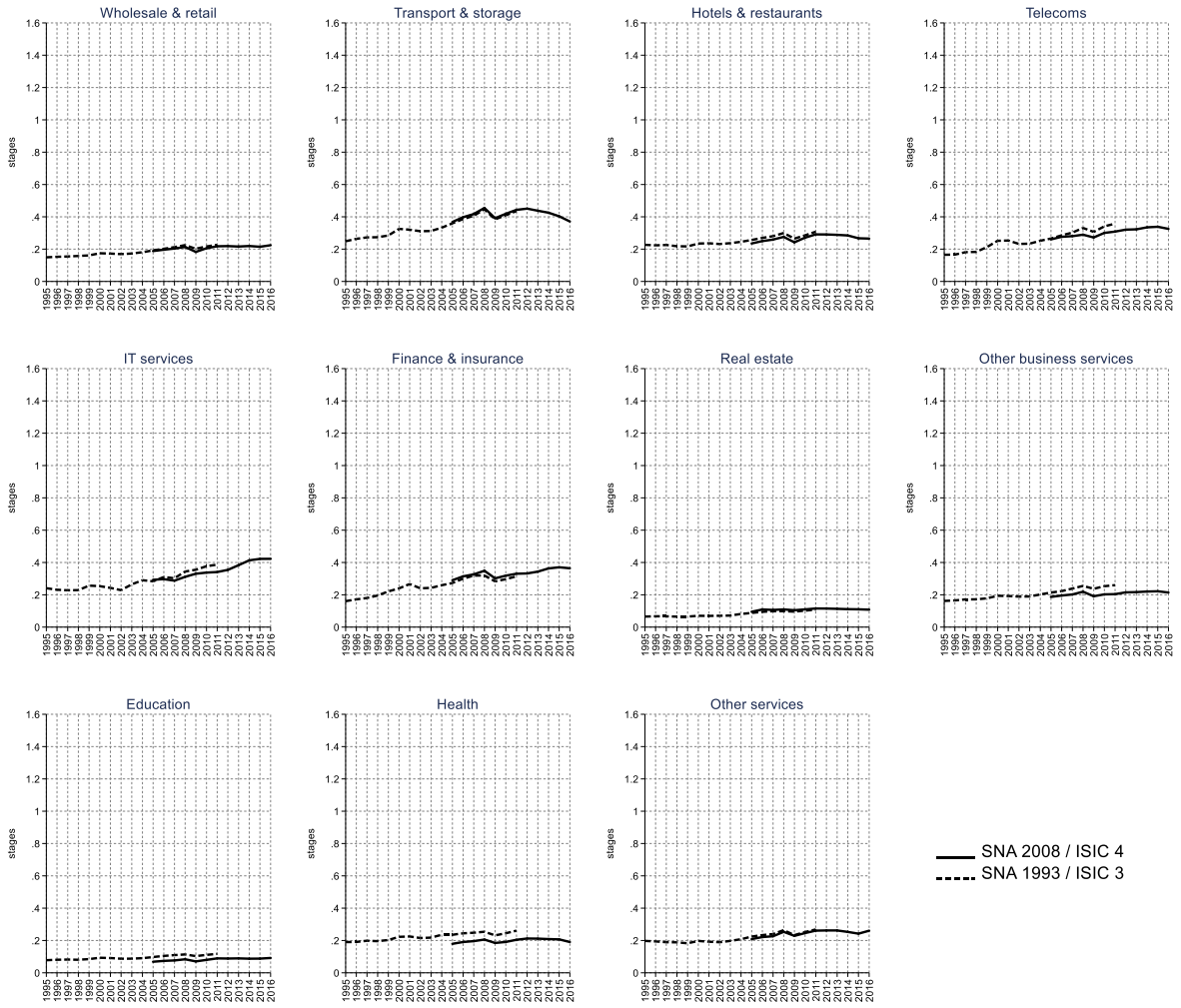


Figure 3b. Foreign production stages by sector (1995-2016)

- simple average of all reporters -



The second type of industries where we see a decline in the number of foreign production stages after 2012 are consumer goods such as 'textiles and apparel' and 'ICT and electronics'. Here it is also interesting to look at the difference between SNA 2008 and SNA 1993 figures. These industries are those where processing trade and contract manufacturing take place and the fact that these transactions are no longer recorded in trade in goods in SNA 2008 (when there is no change in ownership) seems to have an important impact on the measurement of foreign production, with possibly some information lost and an underestimation of the number of foreign production stages. But if we believe the trend observed after 2012, these industries are the ones that are also more affected by recent protectionist measures, as they are the ones involving China and Asian GVCs. But our figures cannot disentangle the impact of protectionism from structural trends related to rising wages and shifts in productivity and competitiveness in Asia that would also lead to a consolidation of value chains in the absence of protectionist measures.

4.4 The border effect on supply chains

While our data cannot tell us the reason why GVCs are shrinking, we can nonetheless try to infer more from structural changes in production by trying to assess whether fewer foreign production stages are related to a national clustering of activities. If it is more costly to write and enforce contracts with foreign

suppliers than with domestic suppliers, or if distance and border costs are important parameters in sourcing decisions, supply chains may display national clusters in different branches of the supply chain. For example, if a Swedish producer of cars outsources the gearbox to Germany and the suspension system to France, the gearbox branch may display a German cluster of sub-suppliers and the suspension branch a French cluster, because of the preponderance of using local suppliers. Rising costs of doing business with other countries as a consequence of protectionism should for example be manifested not only in a decrease in the international fragmentation but also more national clusters in the supply chain. To investigate this hypothesis, we begin by dividing $\boldsymbol{A}$' into two parts,

$$\boldsymbol{A^{D\prime}} = \begin{bmatrix} \boldsymbol{A'_{11}} & \boldsymbol{0} & \cdots & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{A'_{22}} & \ldots & \boldsymbol{0} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{A'_{mm}} \end{bmatrix}, \quad \boldsymbol{A^{M}} = \begin{bmatrix} \boldsymbol{0} & \boldsymbol{A'_{21}} & \cdots & \boldsymbol{A'_{m1}} \\ \boldsymbol{A'_{12}} & \boldsymbol{0} & \ldots & \boldsymbol{A'_{m2}} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{A'_{1m}} & \boldsymbol{A'_{2m}} & \cdots & \boldsymbol{0} \end{bmatrix},$$

where $\boldsymbol{A^{D\prime}}$ contains the domestic IO-links and $\boldsymbol{A^{M}}(= \boldsymbol{A^{X\prime}})$ the international IO-links, where the latter means that a border is being crossed in the supply chain. Using this decomposition we can decompose $\boldsymbol{n}$ into nationally clustered production stages $\boldsymbol{n^{C}}$ and cross-border production stages $\boldsymbol{n^{B}}$:

$$(15a) \quad \boldsymbol{n^{C}} = \boldsymbol{i} + [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A^{D\prime}}\boldsymbol{i},$$

$$(15b) \quad \boldsymbol{n^{B}} = [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\,\boldsymbol{A^{M}}\boldsymbol{i}.$$

Just to be clear, whether a border is crossed is *not* defined from the perspective of the ultimate user of the supplies (the country-of-completion) but from the perspective of the next producer in the supply chain. Note also that a border passage is weighted by the value of the inputs that crosses the border relative to the value of the final product (normalized to one). Thus, if supplies worth 10 percent of the value of the final product cross a border it adds 0.1 to the index. The theoretical range of $\boldsymbol{n^{B}}$ is $\boldsymbol{0}$ to $\boldsymbol{n} - \boldsymbol{i}$, where the upper limit is reached if every production stage is undertaken in a different country (possibly involving only two countries if the production goes back and forth). The decomposition *by country* is done by replacing $\boldsymbol{i}$ with $bdiag(\boldsymbol{i})$**:**

$$(16a) \quad \boldsymbol{N^{C}} = bdiag(\boldsymbol{i}) + [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A^{D\prime}}\,bdiag(\boldsymbol{i})$$
$$(16b) \quad \boldsymbol{N^{B}} = [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\,\boldsymbol{A^{M}}\,bdiag(\boldsymbol{i})\,.$$

As with the $\boldsymbol{N}$-matrix, diagonal blocks correspond to 'domestic' production stages. We put 'domestic' into quotation marks here since a domestic upstream stage can be cross-border when domestic value-added returns home after one or several production stages abroad. The $\boldsymbol{N^{B}}$-matrix will therefore have values different from zero in its block diagonal elements. [3]

The decomposition of equation 16 is presented in Figure 4, with the nationally clustered stages at the bottom and the cross-border stages on top (adding up to the total number of embodied production stages). As shown in the plot, the majority of all production stages are nationally clustered. Only *one-sixth* of production stages are cross-border.

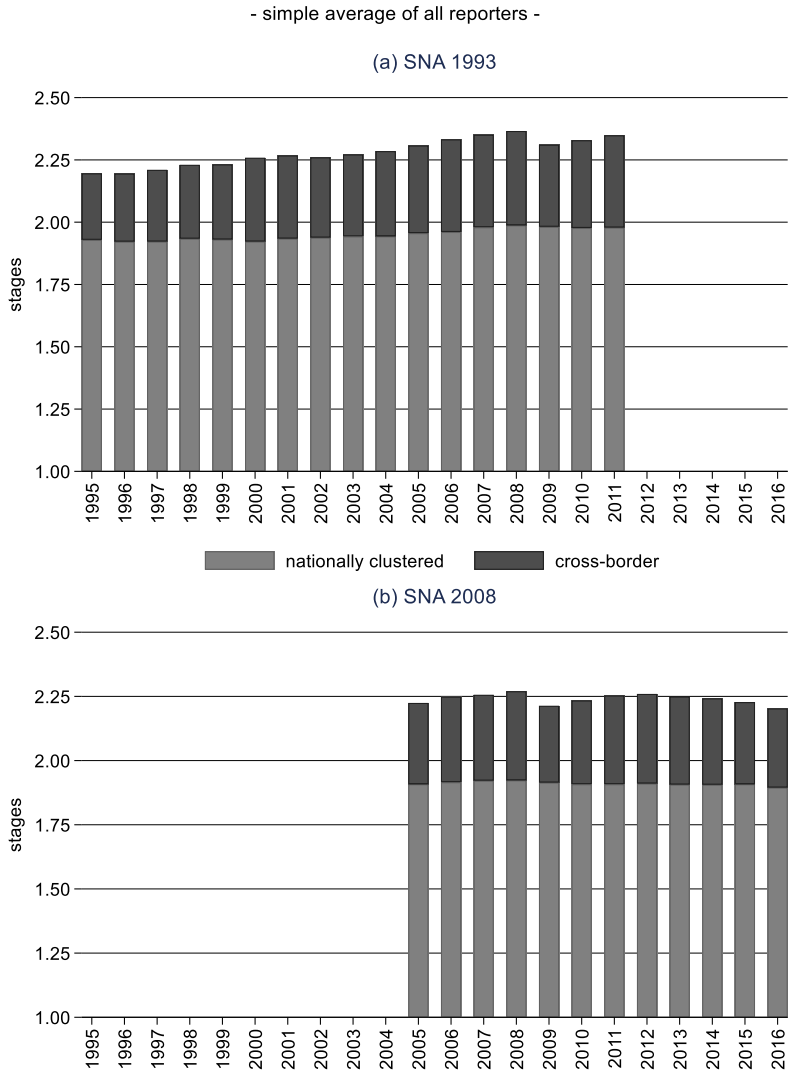
[3] In the same way, we can decomposed the value-added by country into nationally clustered and cross-border value-added**,**

$$\boldsymbol{V^{C}} = bdiag(\boldsymbol{v}) + [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\boldsymbol{A^{D\prime}}\,bdiag(\boldsymbol{v})$$
$$\boldsymbol{V^{B}} = [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\,\boldsymbol{A^{M}}\,bdiag(\boldsymbol{v}),$$

where returning value added are recorded on the diagonal blocks of $\boldsymbol{V^{B}}$.

Until 2008, most of the increase in embodied production stages was coming from cross-border stages. It is only around 2007-2008 and during the financial crisis that we see a slight increase in nationally clustered stages. Post-crisis, the evolution in the number of production stages is still driven by changes in cross-border stages. Therefore, we cannot explain the recent change in GVCs by value chains becoming more fragmented within countries instead of internationally. If there was a substitution between domestic and foreign suppliers, we should see the overall number of production stages remaining the same but the share of nationally clustered stages increasing. The evidence does not point to this type of substitution. There are fewer cross-border stages (which can still be the consequence of protectionism) and shorter GVCs. This result suggests that there are also structural shifts reducing the rationale for fragmenting production (across or within countries), which could be related to the digital transformation or the servitisation of manufacturing with production becoming closer to consumers.

Figure 4. Nationally clustered and cross-border production stages in total exports (1995-2016)

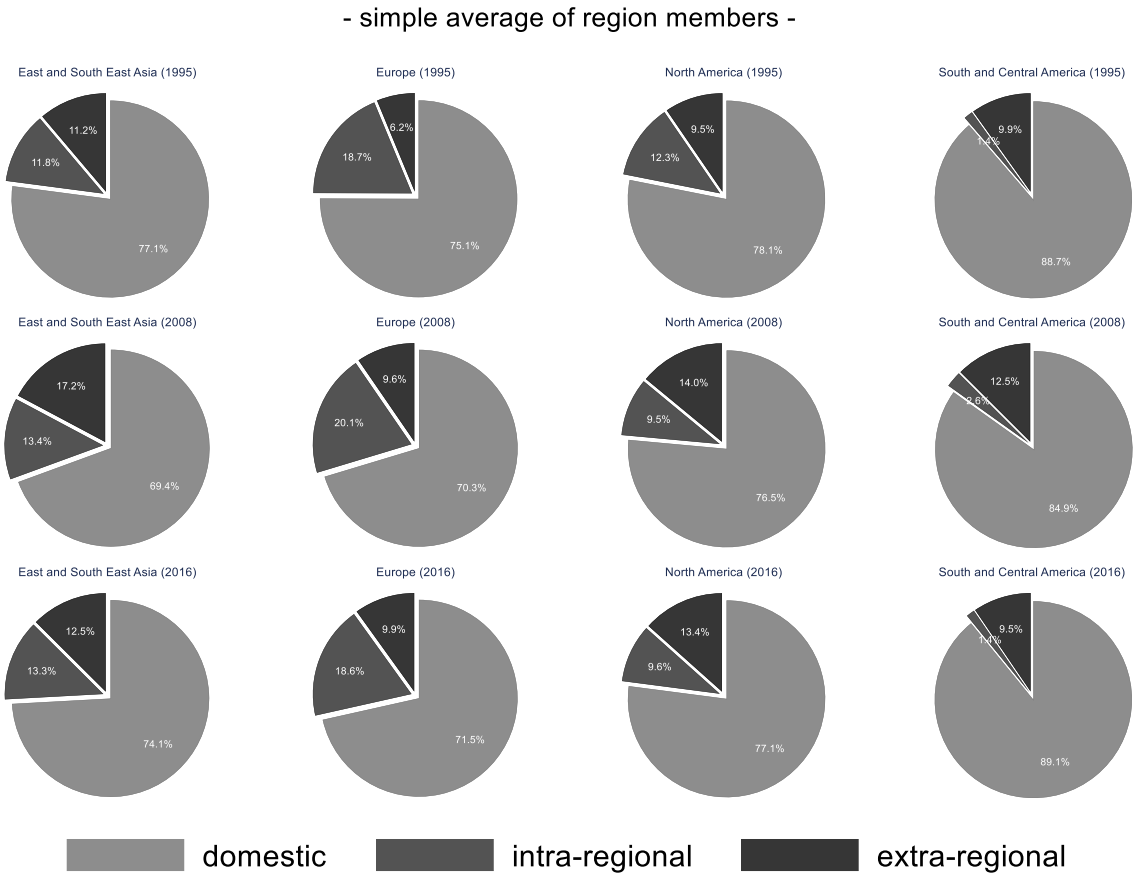


5. Global or regional?

A recurrent question in the GVC literature is whether supply chains are becoming more 'global' in a literal manner, or whether the internationalization of GVCs reflects regional integration, as suggested by Baldwin and Lopez-Gonzalez (2015). Now that we observe a decrease in the fragmentation of production, the question is also whether this decrease is affecting both the extra-regional and intra-regional part of GVCs or whether this decrease is associated with more regionalization of value chains.

To answer this question, we plot the change in the intra- and extra-regional value-added shares of the supply chains between 1995, 2008 and 2016. For the purpose of this exercise, we look at four regions for which the OECD ICIO covers the main economies: (i) East and South East Asia, (ii) Europe, (iii) North America, and (iv) South and Central America. The countries included in each of these regions can be seen in Table 2 in Section 2. The other individual countries of the ICIO are grouped with the 'rest of the world' and included only as extra-regional partners in this exercise.

Figure 5. Intra- and extra-regional value added shares in supply chains (%), 1995, 2008 and 2016



As seen in the pie charts, both the extra-regional and intra-regional shares of the value chains have increased between 1995 and 2008, at the expense of domestic suppliers (with the exception of North America where the intra-regional share decreased). In all regions, the extra-regional share increased more than the regional share. GVCs were becoming more global until the Great Financial Crisis. Moreover, with the exception of Europe, more inputs were sourced from outside the region.

Between 2008 and 2016, the trend is different across regions. In East and South East Asia, value chains became more regional in relative terms. There was a strong decrease in the extra-regional share, from 17.2% to 12.5%. But inputs sourced from outside the region were replaced by domestic inputs and

not regional inputs. The regional share did not increase in absolute terms. In Europe, the share of intra-regional value-added decreased and the share of extra-regional value-added increased. Despite the economic integration within the EU, value chains in Europe became more global. But the share of intra-regional value-added is still twice the share of extra-regional value-added, confirming that Europe is the region with the most regional value chains. In North America, there is a slight shift towards regional supply chains but the decrease in extra-regional value-added after 2008 has benefited domestic supply chains. In South and Central America, a very small share of inputs is sourced regionally and this share has decreased between 2008 and 2016.

From the above evidence, there are two main trends to highlight. The expansion of GVCs before the financial crisis was clearly global. The decrease in domestic value-added shares was mostly compensated by an increase in extra-regional shares. Post-crisis and in the recent period of deglobalisation, some regions seem to shift towards more regional value chains but the main trend is towards domestic value-added.

6. Geographic length of supply chains

As a last piece of evidence we measure the geographic length of supply chains. This approach was pioneered by Los and Temurshoev (2012), who combined input-output data with the geographic distance between and within countries. Their distance measure includes both the intermediate legs of the supply chain and the final leg(s) to the consumers, whereas our focus is on the former. How far away do firms buy their inputs and are GVCs becoming also geographically shorter in the recent period?

As we have no data on the internal supply chains of firms, we can only measure the geographic distance of the *external* network of suppliers. And even here we run into some problems since we only have information on which sectors and countries that trade with each other but not their location in the countries. The best we can do is to assume that firms are distributed in the same way as the population at large, using distance measures calculated by CEPII.[4] The total length of a supply chain is calculated by adding the distance of each leg using the inputs coefficients of the final product as weights,

$$(17a) \quad \begin{aligned} \boldsymbol{d} &= \boldsymbol{d_1} + \boldsymbol{A'd_1} + \boldsymbol{A'A'd_1} + \cdots \\ &= [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\, \boldsymbol{d_1}\,, \end{aligned}$$

where $\boldsymbol{d_1}$ is a vector with input-weighted distances to the first-tier suppliers from the perspective of each sector and country in the OECD ICIO. The supply chain can in turn be divided into country legs by defining $\boldsymbol{d_1}$ as a block-diagonal matrix,

$$(17b) \quad \boldsymbol{D} = [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\, bdiag(\boldsymbol{d_1}).$$

The average length of supply chains for the export industry in 2016 is plotted in Figure 6, using sector weights in exports. As an aid for the eyes we plot spherical circles from the population-weighted centroids of each country with a radius equal to the length of the supply chains.[5] The circles are calculated under the assumption that supply chains propagates outward like ripples on the water (from Sweden, to Germany, to France, etc.) rather than slashing back and forth, and should therefore be interpreted with some caution. Notwithstanding, we find them helpful to illustrate the range of the supply chains on a map. Europe has generally the shortest supply chains, but still longs enough to cover most countries on the continent. In 2016, the longest supply chains are found in Mexico, Singapore, Viet Nam, Malaysia and China.

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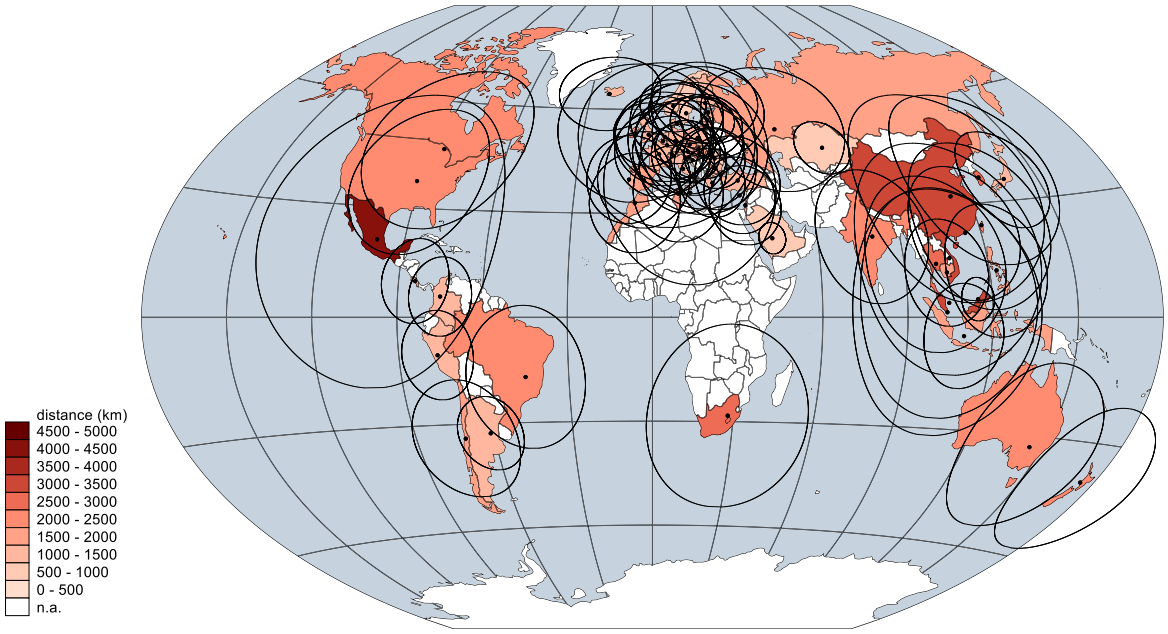
[4] Mayer and Zignago (2011). http://www.cepii.fr/anglaisgraph/bdd/distances.htm.

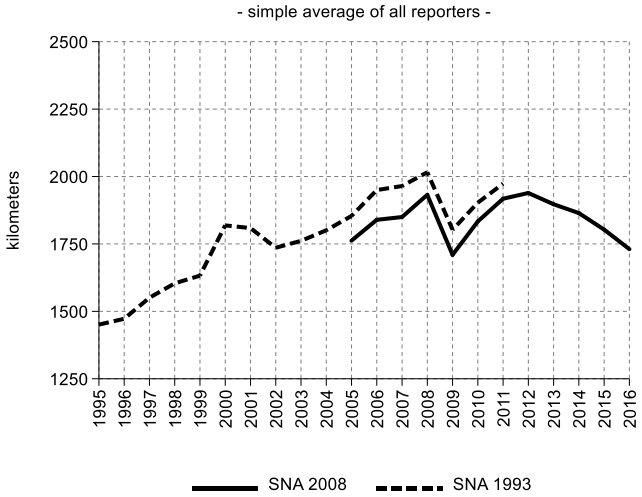
[5] The maps are plotted in Winkel-Tripel projection that makes the spherical circles look a bit distorted, especially when the radius is large.

Figure 6. Average length of supply chains for the export industry, 2016



As shown in Figure 7, the average length of supply chains has increased by more than 500 kilometres between 1995 and 2008. The trend exhibits the same pro-cyclical pattern we have observed for the other GVC indicators, with a decline in distance after the dot.com and financial crises in 2001 and 2008-2009 respectively. After 2012, the average distance has decreased by a bit more than 10% from 1940 to 1730 kilometres. The 'speed' of deglobalisation or the 'erosion in globalisation' can thus be estimated at about 52 kilometres per year.

Figure 7. Average length of supply chains for the export industry (1995-2016)



The average length of supply chains by industry is calculated in Table 4, including the percentage change between 1995 and 2008 and between 2008 and 2016. All sectors experienced a significant growth in average distance between 1995 and 2008, except for 'mining'. The longest supply chains were found in

the 'ICT & electronics' and 'electrical equipment' sectors, based on SNA 1993 figures. Manufacturing sectors have generally longer supply chains than services sectors.

Between 2008 and 2016, the overall trend is a decline but there is a lot of variation across industries. For example, there is a strong increase in the distance of inputs for IT services (+37%). The highest decline is observed in 'coke and petroleum' industry (-15%).

Table 4. Average length of supply chains for the export industry, by industry (1995, 2008 and 2016)

Industry (ISIC 3/ISIC 4)	TiVA SNA 1993			TiVA SNA 2008		
	1995	2008	1995/2008	2008	2016	2008/2016
Agriculture	1393	1799	29%	1767	1668	-6%
Mining	888	870	-2%	790	1032	31%
Food products	1732	2251	30%	2052	1986	-3%
Textiles & apparel	1981	2994	51%	2388	2470	3%
Wood	1809	2517	39%	2084	2245	8%
Paper and printing	1582	2190	38%	2009	2030	1%
Coke, petroleum	2455	3561	45%	3750	3172	-15%
Chemicals	1661	2738	65%	2418	2149	-11%
Rubber & plastics	1789	2752	54%	2510	2364	-6%
Non-metal minerals	1304	2434	87%	2051	2174	6%
Basic metals	2080	3285	58%	3201	3016	-6%
Fabricated metals	1793	2856	59%	2641	2595	-2%
ICT & electronics	2922	4234	45%	3725	3398	-9%
Electrical equipment	2223	3473	56%	2913	2897	-1%
Machinery	1763	2763	57%	2466	2394	-3%
Motor vehicles	2304	3200	39%	2807	2719	-3%
Other transport	2364	3443	46%	2941	2846	-3%
Other manufacturing	1951	2813	44%	2315	2307	0%
Utilities	823	1222	49%	1476	1359	-8%
Construction	1344	1849	38%	1509	1804	20%
Wholesale & retail	748	1058	41%	983	1029	5%
Transport & storage	1209	1863	54%	1848	1593	-14%
Hotels & restaurants	1166	1374	18%	1262	1324	5%
Publishing, broadcasting				1378	1225	-11%
Telecoms	854	1247	46%	1278	1521	19%
IT services	1116	1255	12%	1112	1525	37%
Finance & insurance	783	1124	44%	1238	1358	10%
Real estate	461	541	17%	609	597	-2%
Other business services	817	1192	46%	1043	1028	-1%
Public admin	1262	1496	19%	840	796	-5%
Education	705	875	24%	590	625	6%
Health	798	1124	41%	962	946	-2%
Other services	1027	1224	19%	1177	1212	3%

6.1 Average distance from output to final consumption

In the previous section, we calculated the average length of supply chains, looking backward at all the suppliers of inputs. Once goods and services are produced, they also have to cover some distance before reaching final consumers. This can be seen as the last leg in the value chain from "farm to table", although we prefer to treat it separately since firms sourcing decisions may be more sensitive to the cost and time of distance than the "sourcing" decisions of the consumers.

The calculation of this average distance is straightforward as the final products travel only once and the country of final consumption is directly indicated in the ICIO. The distance from output to final consumption in industry *j* is simply an average of the bilateral distance between the country of industry *j* (country of final production) and the country *k* of final consumption, weighted by the share of each country *k* in final consumption of products from *j*,

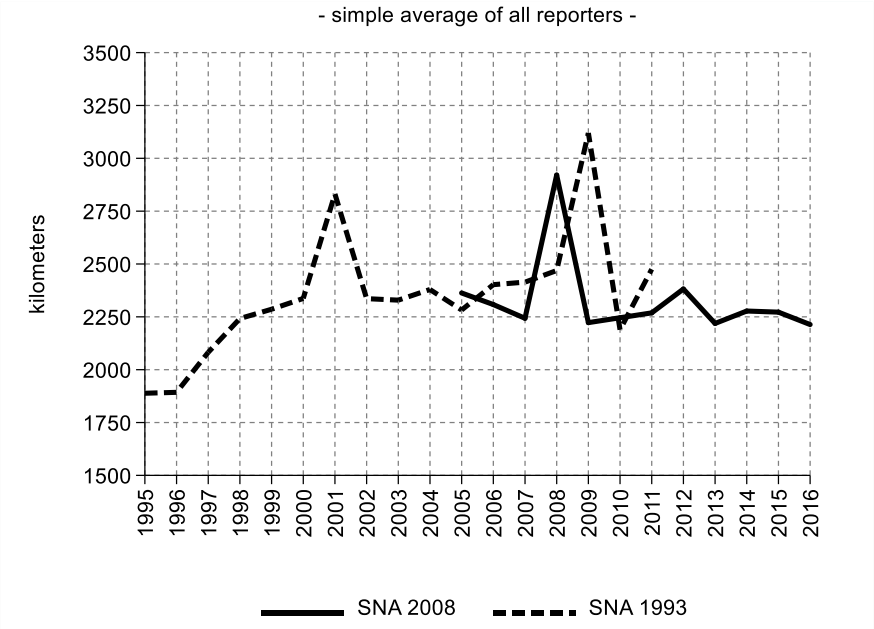
$$d_j^F = \sum_k \alpha_{jk} d_{jk}, \quad (18)$$

where $\alpha_{jk} = F_{jk} / \sum_k F_{jk}$. Note that this measure is therefore different from the "expected distance to final destination" calculated by Los and Temurshoev (2012), which includes both the intermediate legs of the supply chain (forward in the input-output structure of the world economy) and the final leg(s) to the consumers.

Figure 8 illustrates the average distance to final markets for the export industry. Between 1995 and 2008, we observe an increase in the average distance travelled by final goods and services, but not as important as the one observed for inputs (Figure 7). Note also the "spikes" in the index at the midst of the financial crises in 2001 and then in 2008-2009. During crises, the consumption of durable goods generally falls more than the consumption of non-durable goods (Bems et al., 2010) thus modifying the geography of trade. Bulky durable goods travel less and are subject to higher trade costs. Crises-ridden countries may also have offloaded huge volumes at discounted prices to "non-traditional" markets in other regions to keep the wheels moving in the industry.

Interestingly, the decline in the distance to final consumption after 2012 is also less pronounced than the one observed for inputs. It is consistent with protectionist measures targeting intermediate inputs rather than final goods before the 'tariff war' (Bown, 2018). Moreover, while firms may find some advantages in reducing the length of their supply chains, it is less in their interest to limit the geographic scope of consumers they serve. There are however trends, such as the servitisation of manufacturing (Baines et al., 2009), that would push for production closer to consumers (which can still be served by global firms through foreign affiliates).

Figure 8. Average distance to final consumption for the export industry (1995-2016)

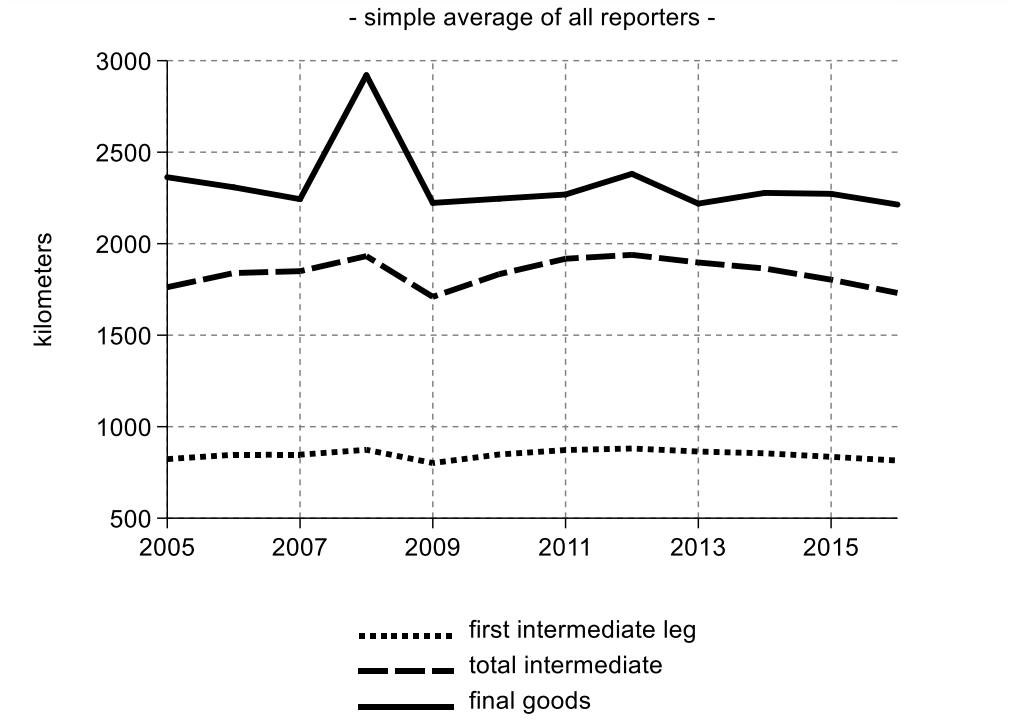


6.2 The sensitivity do distance: comparing intermediate and final goods

Let us finally compare the sensitivity to distance for intermediate and final goods for the export industry, using sector weights in exports. We already know from the previous analysis that inputs travel more legs and therefore longer distances in total throughout the input-output structure of the world economy than final goods that cover only one leg. However, to compare the sensitivity to distance of inputs and final goods, we should rather compare a typical intermediate leg (read, the average distance to the first-tier suppliers) with the final leg to the consumption markets. In other words, do firms source inputs from more nearby markets than when they sell their final goods? As evident in Figure 9 the answer is yes: distance matters more for inputs than for final goods.

Figure 9 confirms that whether it is the impact of protectionism or some structural change, the decrease in the length of value chains is for intermediate inputs. But interestingly, the decrease is smaller for the first intermediate leg, suggesting that it is more upstream that value chains have shrunk. Coming back to Table 4, it is indeed in some raw material industries ('coke and petroleum' and 'chemicals') that the length of supply chains has decreased the most.

Figure 9. The sensitivity to distance in the export industry (1995-2016)



7. Concluding remarks

Using the Leontief model in an international setting, this paper has provided an empirical analysis of the share of foreign value-added in exports, the number of production stages embodied in exports and the average length of supply chains over the period 1995-2016. The evidence points in the same direction. There was first a fragmentation and an internationalization of production between 1995 and 2008 that justifies the emergence of the concept of 'global value chains' in the last decade.

However, at the same time that the concept of GVC was mainstreamed in economic analysis and in policy fora (Gereffi, 2019), globalisation has slowed down and based on the indicators presented in this paper we can indeed confirm that GVCs are becoming shorter both in terms of the number of production

stages and the average geographic distance travelled by inputs. If we define globalisation narrowly in terms of international fragmentation of production, there is a deglobalisation since 2012.

Even at the peak of globalisation (in 2008 before the Great Financial Crisis or in 2012 where the pre-crisis levels of fragmentation were observed again), most of the inputs used in exports were domestic. If the share has decreased in the recent period, there is still between one third and one quarter of the value added in exports which is of foreign origin. Foreign inputs are mostly sourced from countries that are geographically close (as would be expected in a gravity framework). But when GVCs were expanding between 1995 and 2008, this is the extra-regional value-added that increased in exports, while regional shares were remaining stable. In the recent period, we see more regional value chains in some region.

Our data document a decline in the international fragmentation of production but cannot explain the main drivers behind this phenomenon. The chronology, countries and industries affected point to protectionism as one of the main determinants of the recent changes observed. However, the data suggest that value chains are becoming shorter rather than just shifting from being international to domestic. This indicates that, in addition to protectionism, there are other structural changes that could be related to technological advances (the digital transformation) or some shift in consumer tastes (ageing of population, environmental challenges) or business models (servitisation of manufacturing, mass customisation). Input-output data need to be tested against other types of indicators to further investigate the causes of deglobalisation.

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