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Abstract

In the past five years, 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, suggesting that supply chains are regional rather than global. In this paper we offer a comprehensive review of the evidence based on the World Input-Output Database (WIOD), including new indicators counting the number of domestic and foreign production stages, border crossings and geographic length of the supply chains. The study covers 1995 to 2011. All evidence points in the same direction. The made in the world narrative is correct as far as the direction is concerned, but we still have a long way to go. On average, globalization proceeds at 40 kilometres a year.

Keywords

Fragmentation of production, vertical specialization, global value chain.

JEL Classification: F14, L16, L23.

1. Introduction*

In the past five years, 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 by policymakers to analyse structural changes in the global economy and how to position their own economy in these new structures. For example, at the Saint Petersburg Summit in September 2013, leaders from the G20, a group of the world largest economies, noted "the importance of better understanding the rapid expansion of global value chains and impacts of participation in GVCs for growth, industrial structure, development and job creation" (Saint Petersburg G20 leaders Declaration).

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. For example, Baldwin and Lopez-Gonzalez (2013) argue that GVCs "is a great buzzword" but "is inaccurate in aggregate". "Supply chain trade is not global – it's regional" and that "the global production network is marked by regional blocs, what could be called Factory Asia, Factory North America, and Factory Europe".
Because trade costs and the time to market increase with distance, there must be other costs savings to make it worthwhile to source from distant markets. If two inputs have the same characteristics and the same cost when produced in two countries, companies would prefer to source from the closest economy to save on transport costs and time. But if an input is only available in remote places or if transport costs and delivery times are offset by lower prices, it may be profitable to source from more remote locations. Falling trade barriers is another factor that allows companies to source inputs more globally than they did in the past.

Therefore, the question of whether global value chains are truly global or more regional is an empirical matter. And several types of indicators based on international input-output tables are now available to shed light on this question (Johnson and Noguera, 2012; Koopman, Wang and Wei, 2014; and Los, Timmer and de Vries, 2015). In this paper we offer a comprehensive review of the evidence based on the World Input-Output Database (WIOD), including new indicators counting the number of domestic and foreign production stages, border crossings and geographic length of the supply chains. Moreover, in order to distinguish between price and volume effects, the indicators are calculated both in current and constant prices using the ancillary WIOD tables in previous year's prices. The study covers 1995 to 2011 in current prices and 1995 to 2009 in constant prices. All evidence point in the same direction. The made in the world narrative is correct as far as the direction is concerned, but we still have a long way to go. On average, the globalization of the export industry proceeds at 40 kilometres a year.

The paper is organized as follows. Section 2 introduces the basic value chain tools and the World Input Output Database (WIOD) used in the empirical parts of the paper. Section 3 explains how to measure the internationalization of supply chains in the conventional way of decomposing the value-added by country. A new finding is that the internationalization is significantly faster when measured

* The views in this paper are those of the authors and do not necessarily reflect their institutional affiliations. Elements of this paper were presented in the EUI Global Governance Programme executive training seminar on policy implications of global value chains. An early version of this paper was circulated with the sub-title "new evidence on the internationalization of supply chains" and presented at the 22nd International Input-Output Association conference in Lisbon (July 2014). We thank Olle Grünewald for his contribution to the paper and are grateful for comments received from Bart Los and Norihiko Yamano.

The first draft of the paper was written when Håkan Nordström was chief economist of the National Board of Trade, Sweden.

in constant prices than in current prices. Section 4 shows how to decompose the value chain into production stages by country and into nationally clustered and cross-border production stages, building on Fally´s (2012) measure of embodied production stages. We find that only one in six production stages are cross border, but are at the same time the most rapidly growing segment of the supply chains. Section 5 reviews the evidence whether supply chains are regional or global. We present evidence both on the intra- and extra regional share of value added and geographic length of the supply chains, building on the analysis by Los and Temurshoev (2012). Section 6 of the paper concludes.

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. Readers familiar with the Leontief model will not find anything new in this section but may still want to skim through the text in order to get acquainted with the notation used in this paper.

2.1 One country closed economy model

The Leontief model is named after the Russian-American economist *Wassily Leontief* who received the Nobel Prize in 1973 for his pioneering work on input-output analysis in the decades around the Second World War. The cornerstone is a squared tabulation of the economic flows within and between sectors – the input-output (IO) table – borrowed from an earlier generation of economists including *Léon Walras* who developed the general equilibrium theory. By modelling how sectors were linked together in supply chains, Leontief was able to answer questions such as: how much additional steel must be produced in order to increase the production of cars by one million units, taking into account both the consumption of the motor vehicle industry and its supplying industries.

The IO-table of a closed economy is depicted in Table 1. The first $n \times n$ 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	Total
		Sector 1	Sector 2	…	Sector n	Demand	output
	Sector 1	z_{11}	z_{12}	…	z_{1n}	f_1	y_1
Supplying sector	Sector 2	z_{21}	z_{22}	…	z_{2n}	f_2	y_2
i =1, 2 ,… , n	…	…	…	…	…	…	…
	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 analyse the interaction between sectors, Leontief (1936) proposed a linear model with fixed input coefficients and constant returns to scale (CRS). The production functions were specified as,

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

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,

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

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,

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

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

[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,

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

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 $\boldsymbol{A}[\boldsymbol{I} - \boldsymbol{A}]^{-1}\boldsymbol{f}$.

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

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

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

If we apply this model on different country dataset 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),[2]

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

which measures the import content of the export vector.[3] 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 inter-country input-output model (ICIO) model is straightforward in theory but demanding on data.[4] 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,

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

2 The VS-index draws on earlier work by Feenstra and Hanson (1999).

3 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.

4 These models are also known as multi-regional input-output (MIRO) models.

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:

$$(7) \quad \boldsymbol{Y} = \boldsymbol{AY} + \boldsymbol{F}$$
$$= [\boldsymbol{I} - \boldsymbol{A}]^{-\mathbf{1}}\boldsymbol{F}.$$

Note that the off-diagonal blocks of $\boldsymbol{Y}$ constitute the global trade matrix. For example, $\boldsymbol{y}_{\mathbf{12}}$ 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 $(\boldsymbol{M} = \boldsymbol{X}')$ 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 that are crossed in a supply chain.

2.4 World Input-Output Database (WIOD)

The Leontief model is implemented on the World Input-Output Database (WIOD) that contains annual IO-tables for 40 countries for the period 1995 to 2011, representing about 85 percent of world GDP. We opt for the WIOD database for two reasons in this paper: First, it was the most updated database at the time (1995-2011); and secondly, IO-tables were available also in previous year prices (PYP) up to 2009, which allow us to distinguish between volume and price effects.[5] The WIOD database is sponsored by the European Commission and includes 27 member states plus 13 major trading partners to EU (Table 2.a). All other countries are subsumed in a Rest-of-the-World (RoW) region.[6] WIOD identifies 35 industries/sectors listed in Table 2.b. Data sources and information on how WIOD was built is available on the WIOD homepage (www.wiod.org) and accompanying notes by Timmer *et al* (2012) and Dietzenbacher *et al.* (2013).

[5] The OECD Inter-Country Input-Output tables used to build the OECD-WTO Trade in Value added (TiVA) database were only available up to 2009 and only in current prices; the IDE-JETRO database focuses on Asia; the Global Trade Analysis Project (GTAP) and the UNCTAD-EORA databases have much larger country coverage (100+) but uses estimated input-output data for most developing countries.

[6] Within the rest of the world, domestic and foreign transactions have a different meaning as exports among RoW countries are regarded as ’domestic’. These RoW-RoW trade flows are however very small as compared to the actual domestic transactions.

Table 2.a Countries in the WIOD dataset (November 2013 release)

ISO3	Country	Region	ISO3	Country	Region
AUT	Austria	EU27	ROU	Romania	EU27
BEL	Belgium	EU27	SVK	Slovakia	EU27
BGR	Bulgaria	EU27	SVN	Slovenia	EU27
CYP	Cyprus	EU27	ESP	Spain	EU27
CZE	Czech Republic	EU27	SWE	Sweden	EU27
DNK	Denmark	EU27	GBR	United Kingdom	EU27
EST	Estonia	EU27	RUS	Russia	Other
FIN	Finland	EU27	TUR	Turkey	Other
FRA	France	EU27	IND	India	Asia 6
DEU	Germany	EU27	CHN	China	Asia 6
GRC	Greece	EU27	JPN	Japan	Asia 6
HUN	Hungary	EU27	KOR	South Korea	Asia 6
IRL	Ireland	EU27	TWN	Taiwan	Asia 6
ITA	Italy	EU27	IDN	Indonesia	Asia 6
LVA	Latvia	EU27	AUS	Australia	Other
LTU	Lithuania	EU27	BRA	Brazil	Other
LUX	Luxembourg	EU27	MEX	Mexico	NAFTA
MLT	Malta	EU27	CAN	Canada	NAFTA
NLD	Netherlands	EU27	USA	United States	NAFTA
POL	Poland	EU27			
PRT	Portugal	EU27	ROW	Rest of World	Rest of World

Table 2.b Industries in the WIOD dataset (November 2013 release)

Sector	Definition*	Category**
Agriculture, hunting, forestry and fishing	A-B	G
Mining and quarrying	C	G
Food, beverages and tobacco	15-16	G
Textiles and textile products	17-18	G
Leather, leather and footwear	19	G
Wood and products of wood and cork	20	G
Pulp, paper, paper, printing and publishing	21-22	G
Coke, refined petroleum and nuclear fuel	23	G
Chemicals and chemical products	24	G
Rubber and plastics	25	G
Other non-metallic mineral	26	G
Basic metals and fabricated metal	27-28	G
Machinery, nec	29	G
Electrical and optical equipment	30-33	G
Transport equipment	34-35	G
Manufacturing, nec; recycling	36-37	G
Electricity, gas and water supply	E	S / (G)
Construction	F	S
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	50	S
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	S
Retail trade, except of motor vehicles and motorcycles; repair of household goods	52	S
Hotels and restaurants	H	S
Inland transport	60	S
Water transport	61	S
Air transport	62	S
Other supporting and auxiliary transport activities; activities of travel agencies	63	S
Post and telecommunications	64	S
Financial intermediation	J	S
Real estate activities	70	S
Renting of machinery and equipment and other business activities	71-74	S
Public admin and defence; compulsory social security	L	S
Education	M	S
Health and social work	N	S
Other community, social and personal services	O	S
Private households with employed persons	P	S

* International Standard Industrial Classification of all Economic Activities (ISIC), revision 3.0.
** G stands for manufacturing sectors (Goods) and S for Services sectors. “Electricity, gas and water supply” is a hybrid between goods and services.

3. Value added by country

Having equipped ourselves with the basic input-output tools, we shall now address the "made in" question posed in this paper. We begin by picking apart the some 1435 supply chains in WIOD 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) $\boldsymbol{i} = \boldsymbol{A}'\boldsymbol{i} + \boldsymbol{v},$

where $\boldsymbol{i}$ is a unit vector of output, $\boldsymbol{A}'\boldsymbol{i}$ is the costs of non-primary inputs and $\boldsymbol{v}$ is the value-added per unit of output.[7] If we iterate this accounting identity backward in the supply chain, as illustrated in Figure 1, we end up with an infinite series that decompose the value-added by stage of production:

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

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

Figure 1. Supply chain decomposition

	gross output	value added
Final assembly	$\boldsymbol{i}$	$\boldsymbol{v}$
1:st tier suppliers	$\boldsymbol{A}'\boldsymbol{i}$	$\boldsymbol{A}'\boldsymbol{v}$
2:nd tier suppliers	$\boldsymbol{A}'\boldsymbol{A}'\boldsymbol{i}$	$\boldsymbol{A}'\boldsymbol{A}'\boldsymbol{v}$
…	…	…
Cumulated	$[\boldsymbol{I} - \boldsymbol{A}']^{-1}\boldsymbol{i}$	$\boldsymbol{i}$

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,

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

$$= \underbrace{\begin{bmatrix} \boldsymbol{v}_1 & \boldsymbol{0} & \cdots & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{v}_2 & \dots & \boldsymbol{0} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{v}_m \end{bmatrix}}_{\substack{value\ added\ in \\ final\ assembly}} + \underbrace{\begin{bmatrix} \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_1\boldsymbol{v}_1 & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_1\boldsymbol{v}_2 & \cdots & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_1\boldsymbol{v}_m \\ \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_2\boldsymbol{v}_1 & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_2\boldsymbol{v}_2 & \dots & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_2\boldsymbol{v}_m \\ \vdots & \vdots & \ddots & \vdots \\ \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_m\boldsymbol{v}_1 & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_m\boldsymbol{v}_2 & \cdots & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_m\boldsymbol{v}_m \end{bmatrix}}_{\substack{upstream\ valued\ added \\ by\ country\ (j=1,2,\dots,m)}}$$

[7] The value-added could in principle be negative if a sector is operating with a loss, but that would not constitute an equilibrium since loss making enterprises would go out of business over time. Indeed, no negative coefficients are reported in WIOD.

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

The empirical analysis in this paper will focus on the vertical integration of the "export industry", by which we mean a sector composition equal to the composition of the aggregate exports of a country. The composition will thus differ from country to country and will also change over time as comparative advantages change. We should therefore be careful in comparing countries with each other (just as "apples and oranges" are not directly comparable); the focus is rather on the evolution *over time*.

Figure 2. Foreign value-added in total exports
- current prices and sector weights -

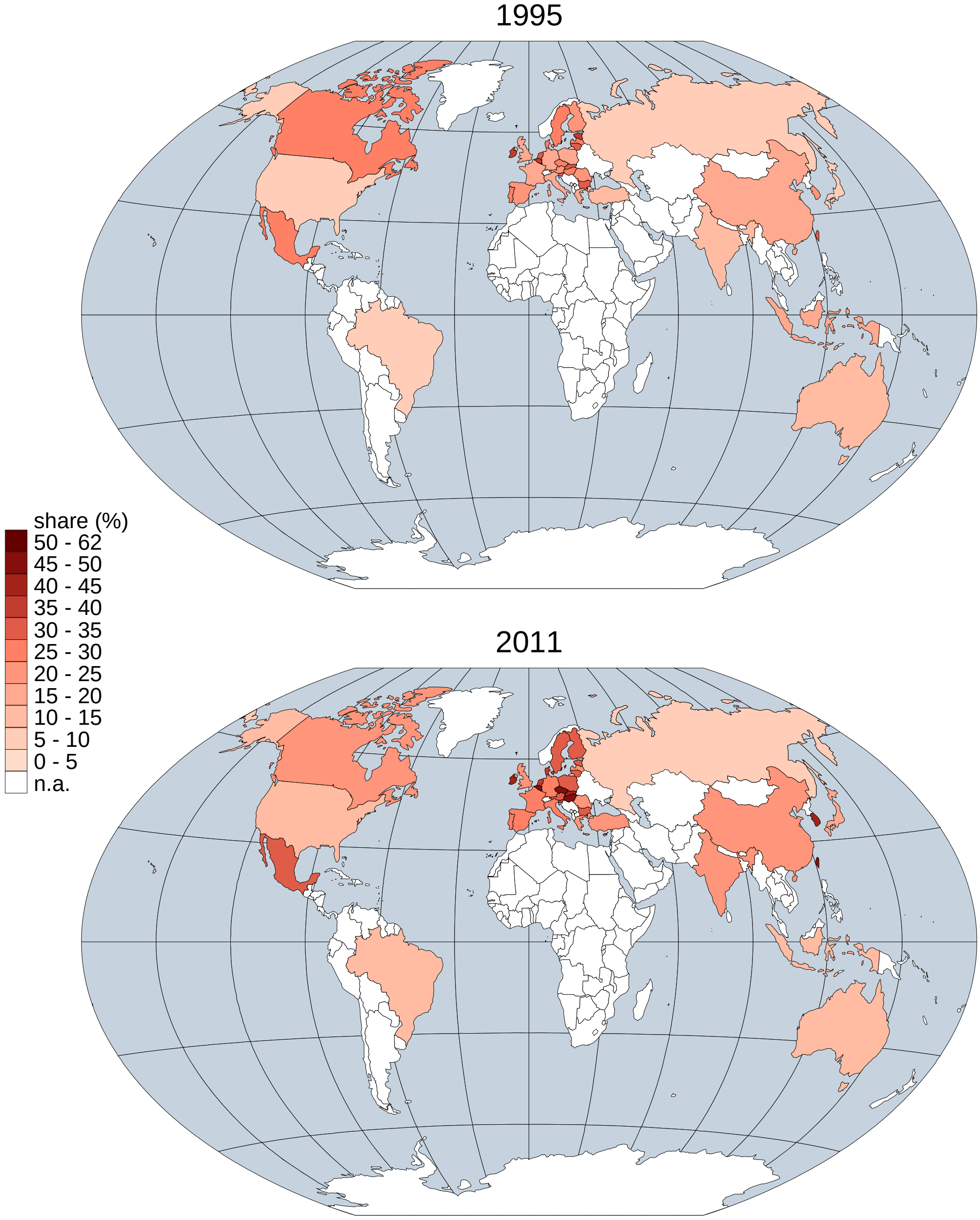
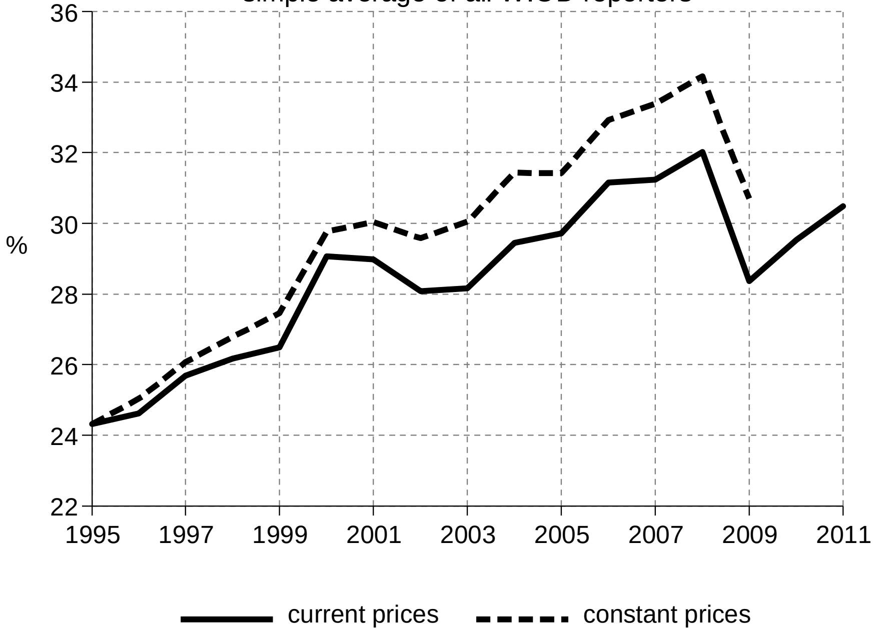


Figure 2 plots the foreign value-added share in total exports for 1995 and 2011, respectively, using current prices and sector weights in exports. The foreign shares range from 5 to 60 percent, with Russia at the low end and Luxembourg at the high. The most obvious reasons for the rather large differences 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. A case in point is Russia. 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. A case in point is Luxembourg. 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. Indeed, as observed in the plots, small economies tend to use relatively more foreign inputs than large economies.

A comparison of the maps suggests that most countries have become more dependent on foreign inputs over time. Indeed, as shown in Figure 3, the foreign value-added has increased in current prices from an average of 24.3 percent in 1995 to an average of 30.5 percent in 2011, with a pro-cyclical pattern. The trend is stronger still in constant prices,[8] so it cannot be dismissed as a pure price effect.

Figure 3. Foreign value-added in total exports (1995-2011)
- simple average of all WIOD reporters -



3.3 Foreign value-added by sector

Figure 4a-b plots the foreign shares at the sector level using a common scale (0–60%) to facilitate the comparison. As seen in the plots, the foreign input content is generally higher in manufacturing sectors than in services sectors. The most “globalized” industries measured from the input side are “Coke, refined petroleum and nuclear fuel”, “Electrical and optical equipment” and “Transport equipment”. The trend is positive in virtually all industries and services sectors, especially when measured in constant prices. Thus, the internationalization of supply chains is an economy-wide phenomena and not limited only to a few sectors.

[8] The constant price series are constructed by running the same experiment on both the current price and the previous year price (PYP) datasets of WIOD. The indicators derived from the PYP datasets are then chained into a constant price series using the annual real growth rates of the indicator.

Figure 4a. Foreign value-added by sector (1995-2011)

- simple average of all WIOD reporters -

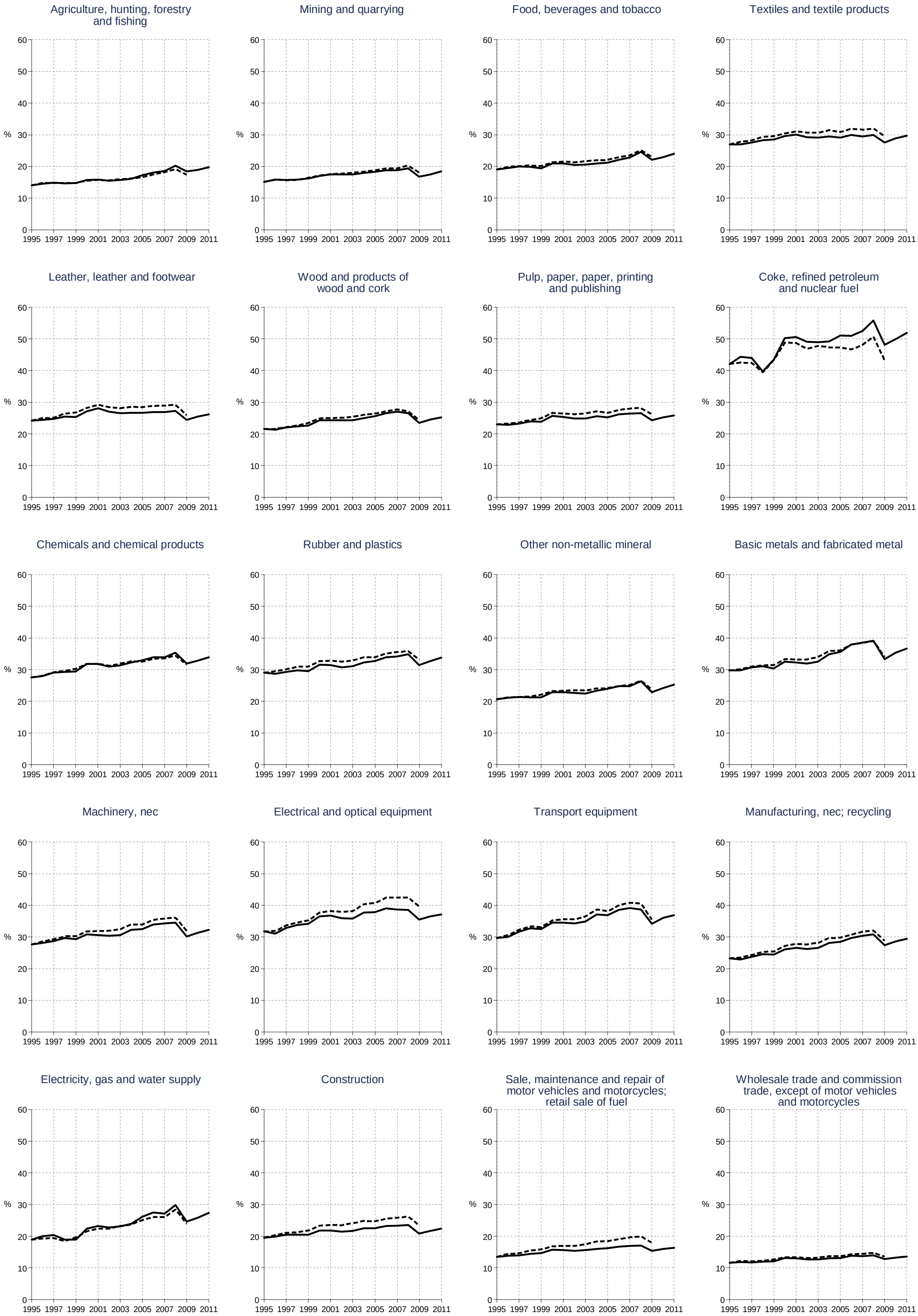
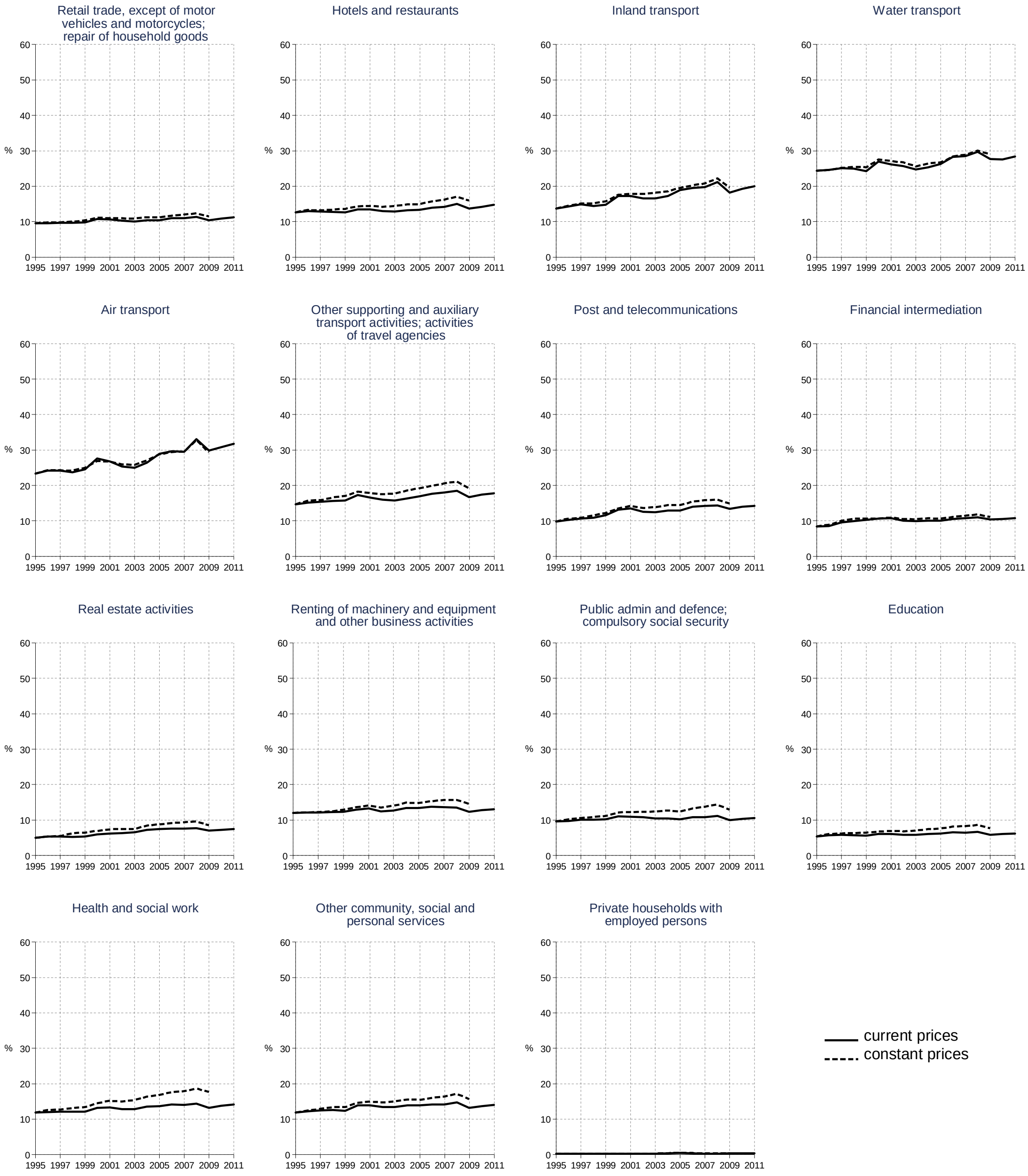


Figure 4b. Foreign value-added by sector (1995-2011)

- simple average of all WIOD reporters -



4. International production stages and border crossings

In this section we will furnish some additional evidence on the internationalization process by, firstly, calculating the number of production stages that take place outside the country-of-completion, and, secondly, the number of borders being crossed, taking into account that sequential production stages often take place in the same country because of the preponderance of using local suppliers. The latter indicator is new to the global value chain literature.

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:

$$(11) \quad \boldsymbol{i} = \underbrace{\underbrace{\underbrace{\underbrace{\boldsymbol{v}}_{1} + \boldsymbol{A'v}}_{\leftarrow 2} + \boldsymbol{A'^2v}}_{\leftarrow 3} + \boldsymbol{A'^3v}}_{\leftarrow 4} + \cdots \; .$$

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:

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

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):

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

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

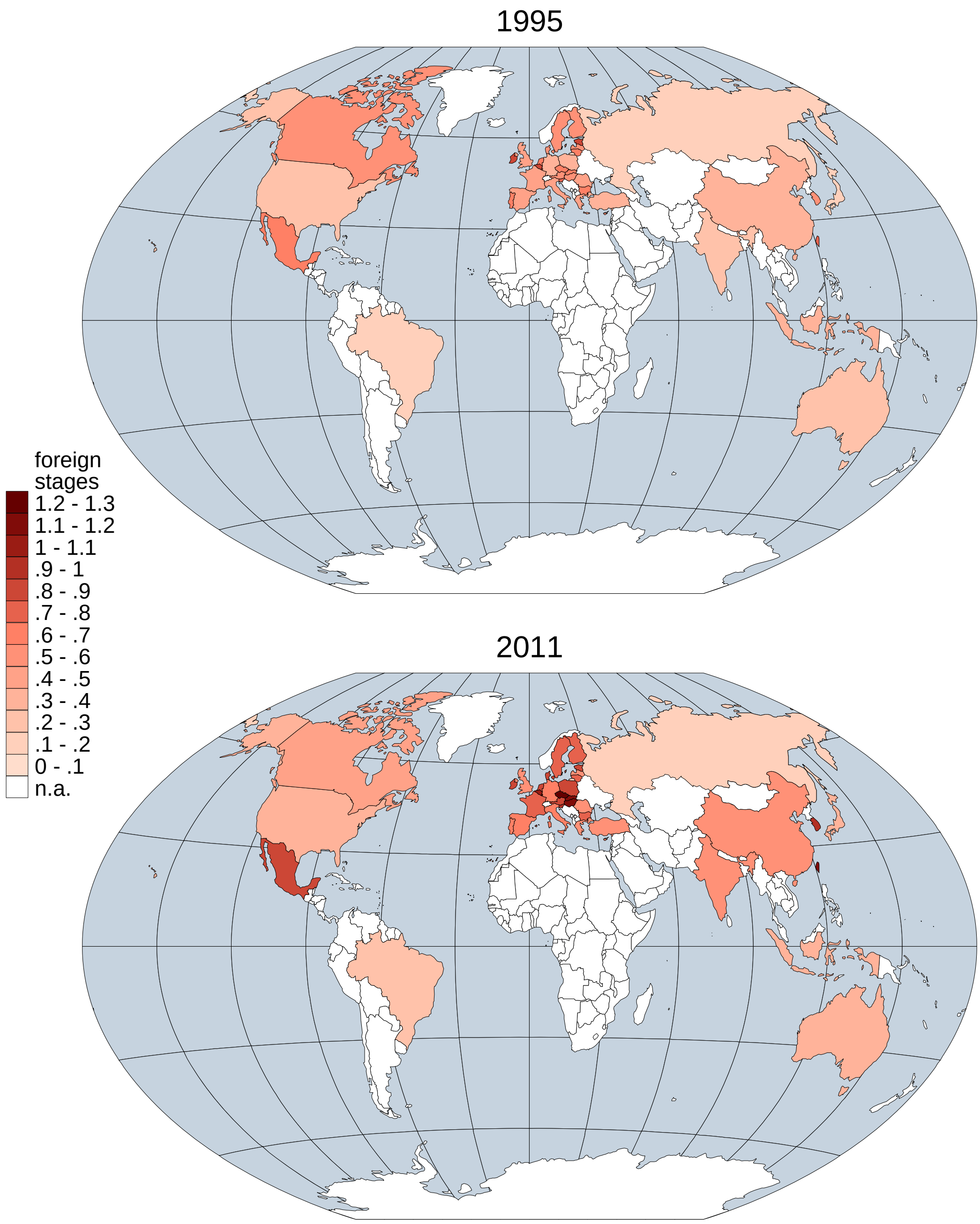
Now, using the same logic as for the value-added decomposition in section 3, we can decompose Fally´s measure into production stages by country,

$$(14)\quad \boldsymbol{N} = bdiag(\boldsymbol{i}) + \left[\boldsymbol{I} - \boldsymbol{A}'\right]^{-1}\boldsymbol{A}'bdiag(\boldsymbol{i})$$

$$= \begin{bmatrix} \boldsymbol{i}_1 & \boldsymbol{0} & \cdots & \boldsymbol{0} \\ \boldsymbol{0} & \boldsymbol{i}_2 & \cdots & \boldsymbol{0} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{0} & \boldsymbol{0} & \cdots & \boldsymbol{i}_m \end{bmatrix} + \begin{bmatrix} \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_1\boldsymbol{i}_1 & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_1\boldsymbol{i}_2 & \cdots & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_1\boldsymbol{i}_m \\ \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_2\boldsymbol{i}_1 & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_2\boldsymbol{i}_2 & \cdots & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_2\boldsymbol{i}_m \\ \vdots & \vdots & \ddots & \vdots \\ \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_m\boldsymbol{i}_1 & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_m\boldsymbol{i}_2 & \cdots & \langle[\boldsymbol{I}-\boldsymbol{A}']^{-1}\boldsymbol{A}'\rangle_m\boldsymbol{i}_m \end{bmatrix},$$

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 5. Foreign production stages in total exports
- current prices and sector weights -

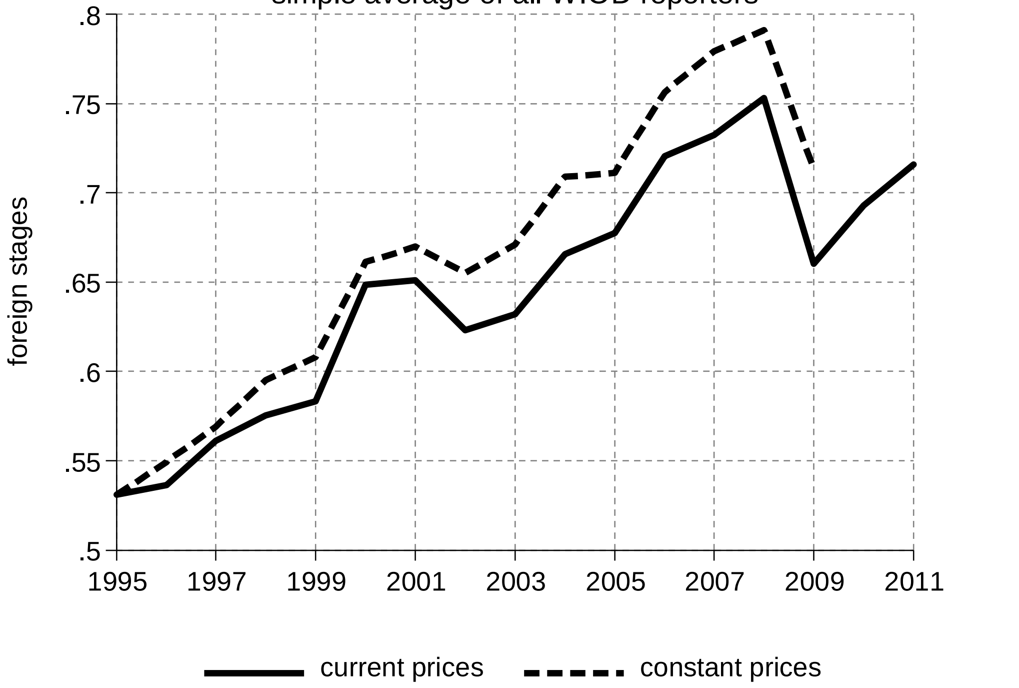


The data is plotted in Figure 5 for the initial and end year of the WIOD dataset using current prices and sector weights in total exports. As seen in the maps, the exports of smaller economies embody more foreign production stages than those of larger economies, which is natural if there are economies of scale in production. Thus, small economies tend to be more *vertically* specialized than large economies (in addition of being more horizontally specialized in certain sectors), and seemingly increasingly so if we compare the colour codes of the 1995 and the 2011 maps. The change is particularly striking for the new Eastern member states of the EU (entering in 2004 and 2007) that are gradually becoming more integrated into the production structures of EU15 through foreign direct investments and offshoring of labour-intensive tasks. But also large economies such as China and India are becoming more vertically specialized in the global economy as evident from the comparison between the 1995 and 2011 maps.[9]

The average development for the WIOD countries is plotted in Figure 6, which exhibits a similar pro-cyclical pattern observed earlier for the foreign value-added. Note also that the upward-sloping trend is stronger when measured in constant prices; and hence cannot be dismissed as a pure price effect.

Figure 6. Foreign production stages in total exports (1995-2011)

- simple average of all WIOD reporters -



4.3 Foreign production stages by sector

Figure 7a-b plots the trend for individual sectors. As a general rule there are more foreign production stages in manufactures than in services, with “Coke, refined petroleum and nuclear fuel”, “Electrical and optical equipment” and “Transport equipment” at the top. The trend is generally positive with a pro-cyclical pattern and stronger in constant prices. This corroborates the earlier findings that the internationalization of supply chains is an economy-wide phenomenon and not limited only to a few sectors.

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[9] In the case of China, a limitation when using the WIOD dataset is that the heterogeneity among producers is not taken into account. In the OECD ICIO, China is split for different categories of firms and in particular firms involved in processing trade. The use of such heterogeneous tables improves estimates for countries where processing trade is pervasive, such as China or Mexico. Our results are therefore underestimating the foreign production stages in the case of China and Mexico.

Figure 7a. Foreign production stages by sector (1995-2011)

- simple average of all WIOD reporters -

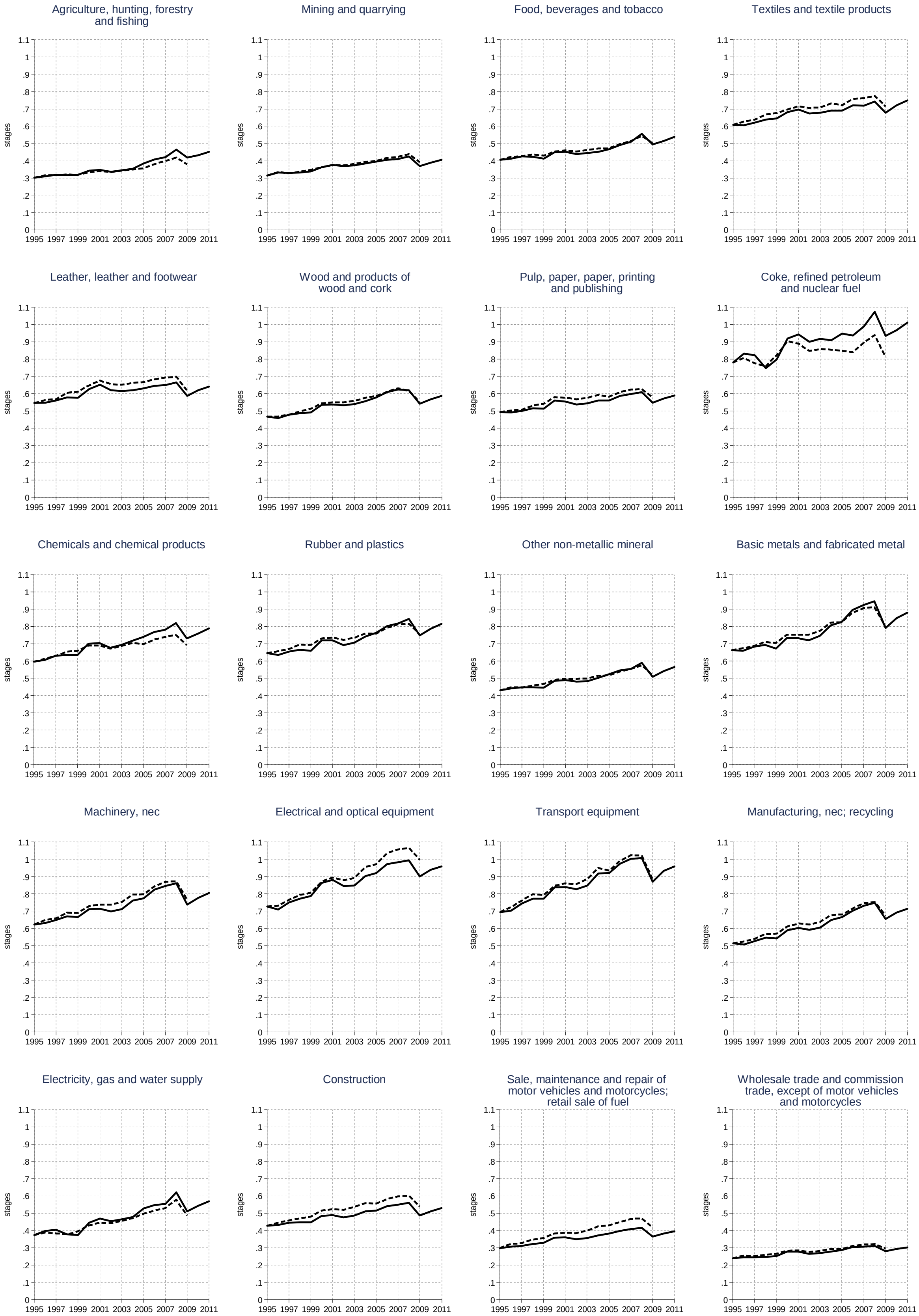
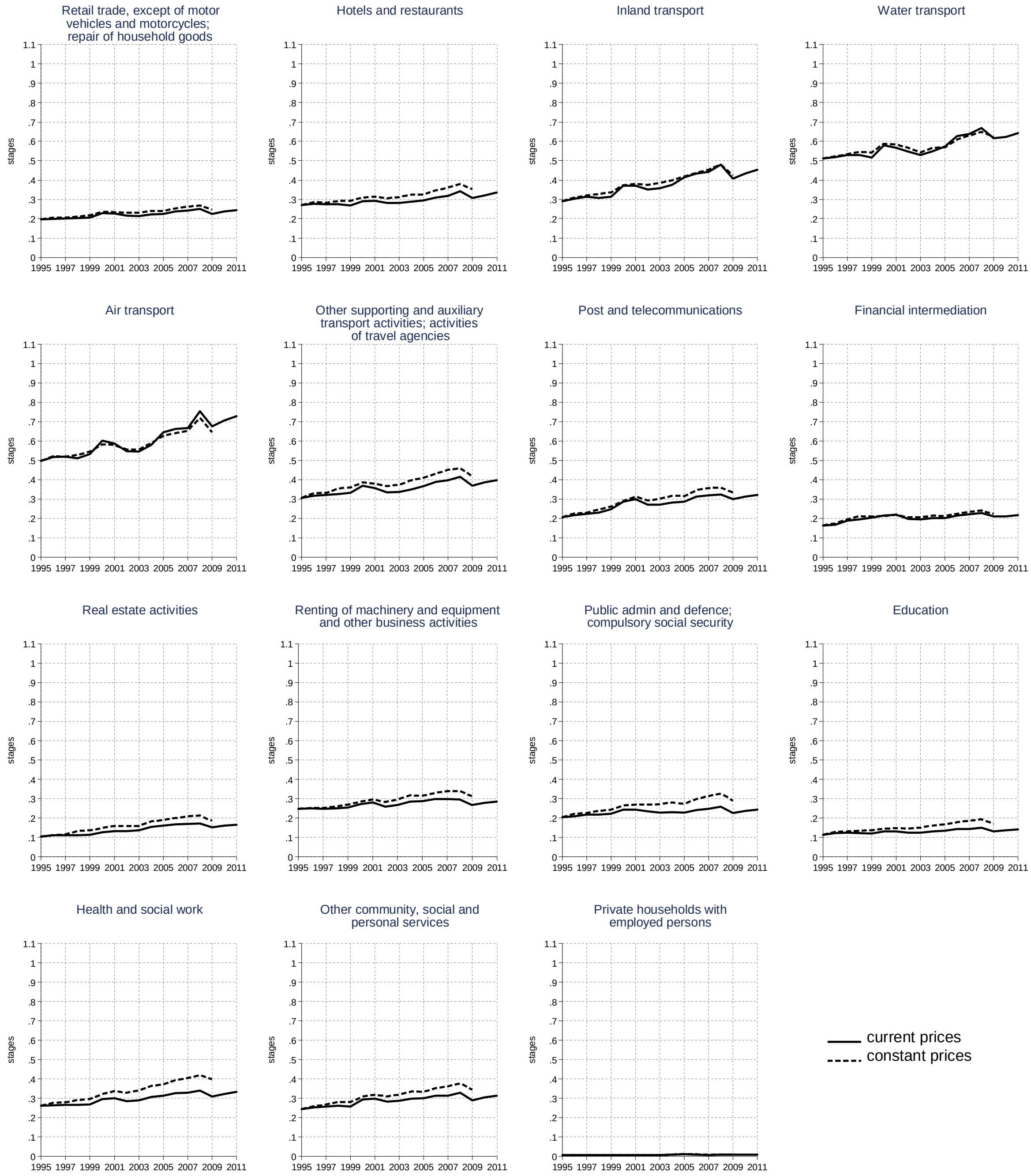


Figure 7b. Foreign production stages by sector (1995-2011)

- simple average of all WIOD reporters -



4.4 The border effect on supply chains

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 the 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. Falling costs of doing business with other countries should then be manifested not only in additional international fragmentation but also less national clusters in the supply chain.

To investigate this hypothesis, we begin by dividing $\boldsymbol{A'}$ into two parts,

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

where $\boldsymbol{A^{D'}}$ contains the domestic IO-links and $\boldsymbol{A^{M}} (= \boldsymbol{A^{X'}})$ 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 $\boldsymbol{n^{B}}$:

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

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

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 $bdiag(\boldsymbol{i})$**:**

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

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.[10]

The decomposition of equation 14 is presented in Figure 8, 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 the production stages are cross-border, but are at the same time the most rapidly growing

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

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

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

segment of the supply chains. The cross-border share has increased from 13.5 percent in 1995 to 17.1 percent in 2011 in current prices and somewhat more in constant prices (the share was touching 20 percent in 2008 before the decline in 2009 in conjunction with the financial crises).

Figure 8. Nationally clustered and cross-border production stages in total exports
- simple average of all WIOD reporters -

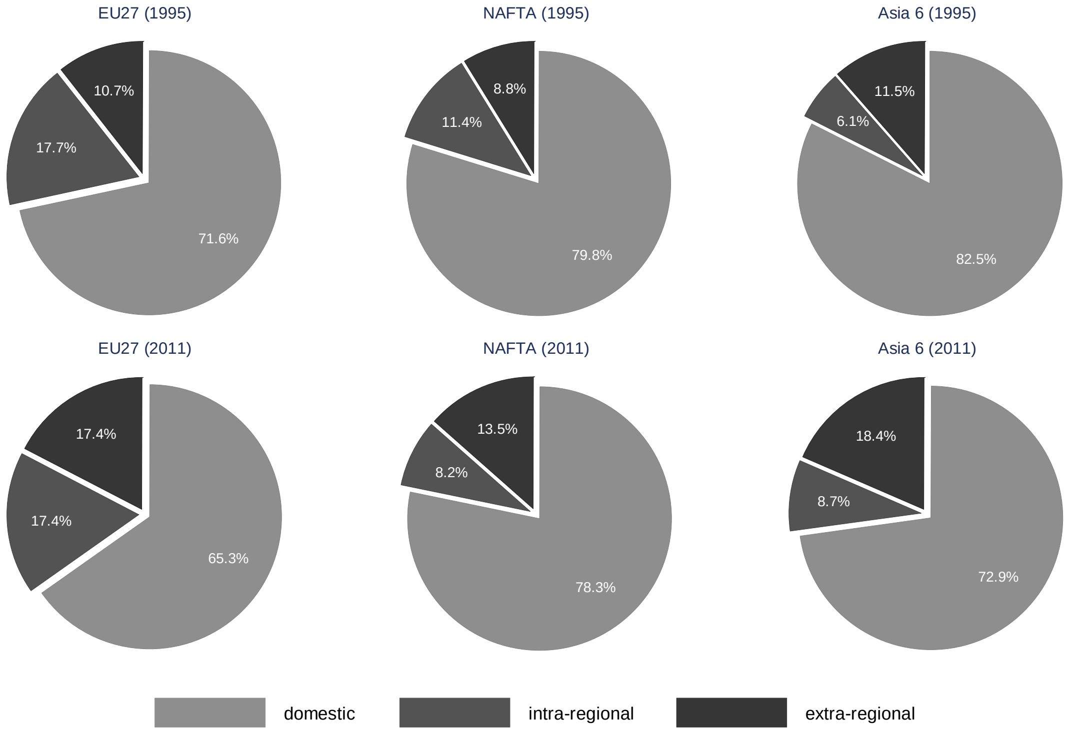
5. Global or regional?

Supply chains are becoming more international over time, as documented in section 3 and 4, but are they also becoming more "global" in a literal manner? Or is the trend reflecting regional integration, as suggested by Baldwin and Lopez-Gonzalez (2013)?

5.1 Intra- and extra-regional shares of the supply chains

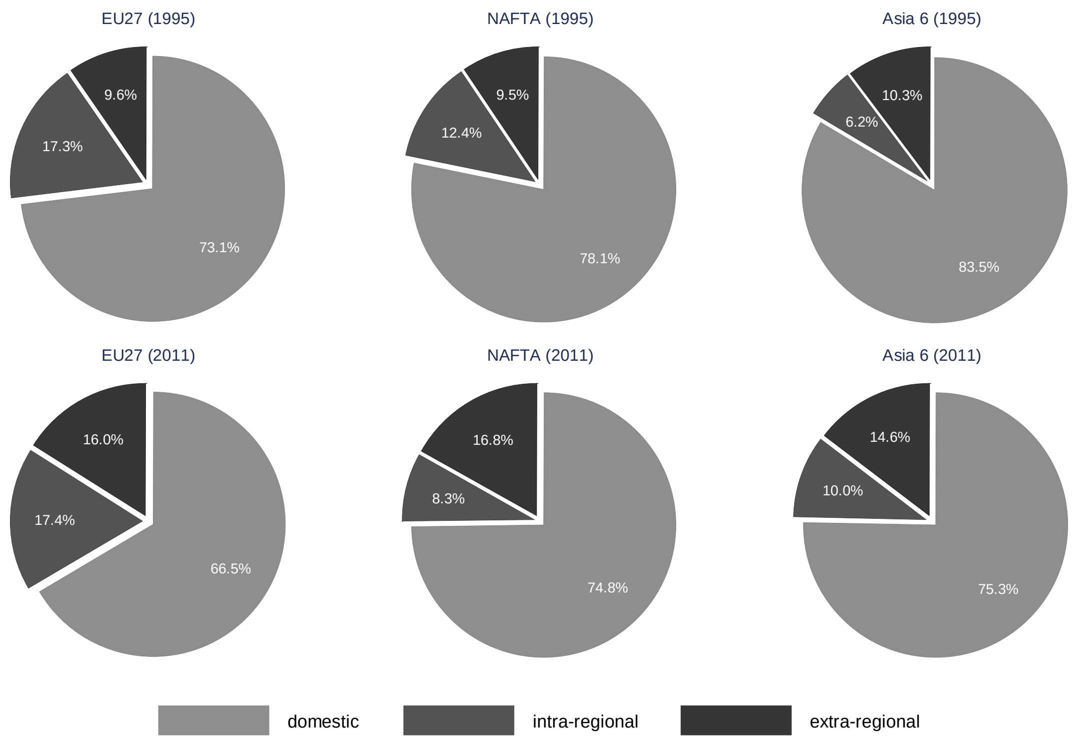
To get a first hint on the nature of the structural change in the world economy – more regional or more global? – we plot the change in the intra- and extra-regional value-added shares of the supply chains between 1995 and 2011. For the purpose of this exercise we identify three regions in WIOD: (i) EU27, (ii) North America Free Trade Agreement (NAFTA), comprised of Canada, Mexico and the United States, and (iii) Asia 6, comprised of China, India, Indonesia, Japan, South Korea and Chinese Taipei. EU27 and NAFTA are regions both in a geographic and trade policy sense, whereas "Asia 6" are primarily grouped on basis of geography (although some are connected also by free trade agreements). The other individual countries in WIOD (Australia, Brazil, Russia and Turkey) cannot be matched with any regional partners since they are subsumed in the RoW aggregate. They are therefore included only as extra-regional partners in this exercise. The results are reported in current prices and sectors weights in total exports, averaging the results over the members of each region.

Figure 9a. Intra- and extra-regional value added shares (%)
- simple average of region members -



As seen in the pie charts the extra-regional shares of the value chains have increased by 5-7 percentage points between 1995 and 2011, mainly at the expense of domestic suppliers. Still, between two-thirds and three-quarters of the value-added is domestic, of which roughly a third is added in final assembly. If we subtract the latter we find that domestic suppliers delivered on average 44% of the inputs in EU27 in 2011, compared to 60% in NAFTA and 59% in Asia 6. The EU would thus seem to be the most integrated region of the three, although comparisons of this type should also control for the size of the region to be neutral.

Figure 9b. Intra- and extra-regional production stages (%)
- simple average of region members -



The picture is similar if we plot embodied production stages divided between intra- and extra-regional stages (Figure 9b). Thus, both indicators suggest that the slicing-of-the-value-chain has primarily been extra-regional during this period.

5.2 Geographic length of supply chains

As a last piece of evidence we will measure the geographic length of the 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 have distance become less important over time?

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 measure calculated by CEPII.[11] 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,

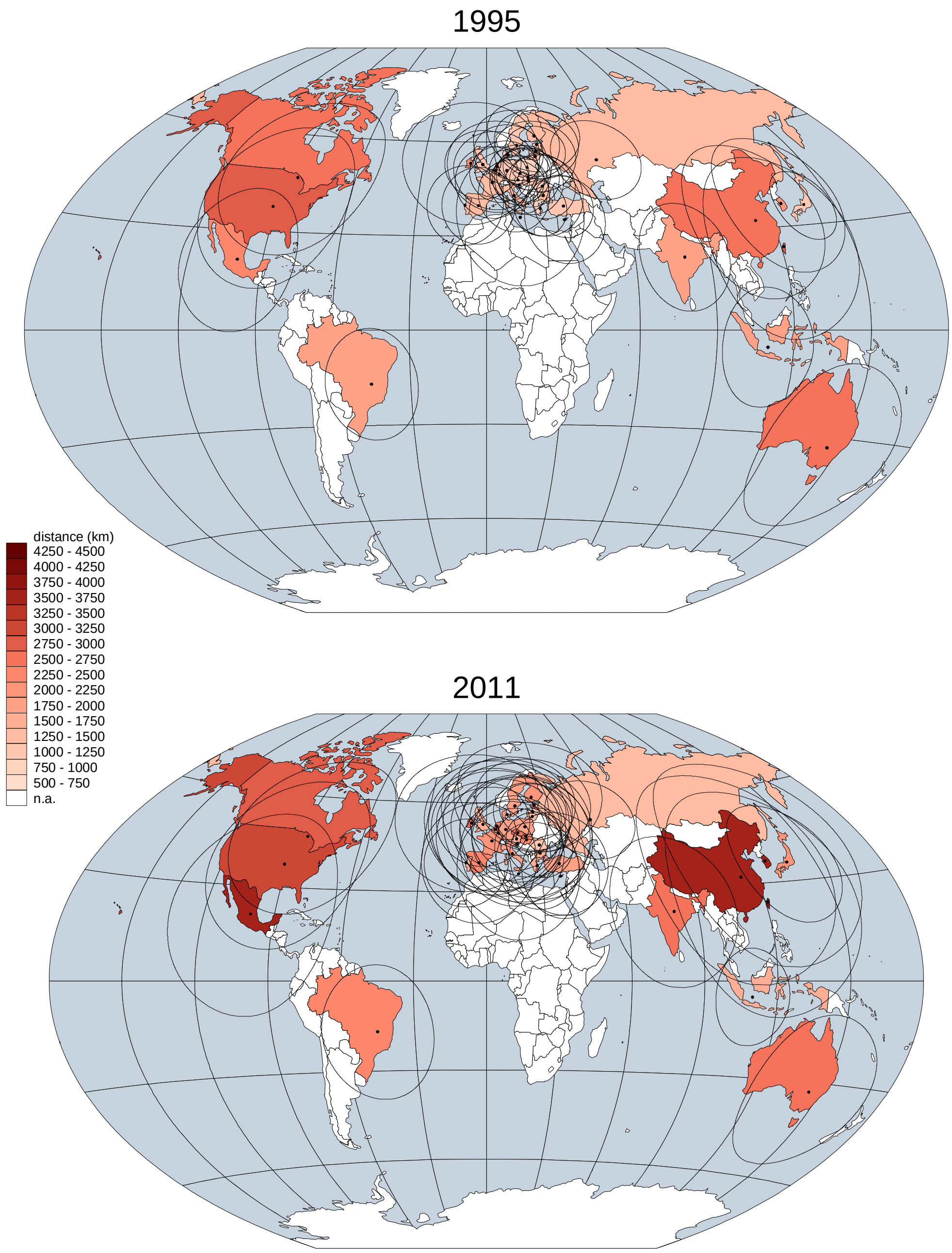
[11] Mayer and Zignago (2011). http://www.cepii.fr/anglaisgraph/bdd/distances.htm

$$(17a)\qquad \boldsymbol{d} = \boldsymbol{d_1} + \boldsymbol{A'}\boldsymbol{d_1} + \boldsymbol{A'}\boldsymbol{A'}\boldsymbol{d_1} + \cdots$$
$$= [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\,\boldsymbol{d_1}\,,$$

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 WIOD. The supply chain can in turn be divided into country legs by defining $\boldsymbol{d_1}$ as a block-diagonal matrix,

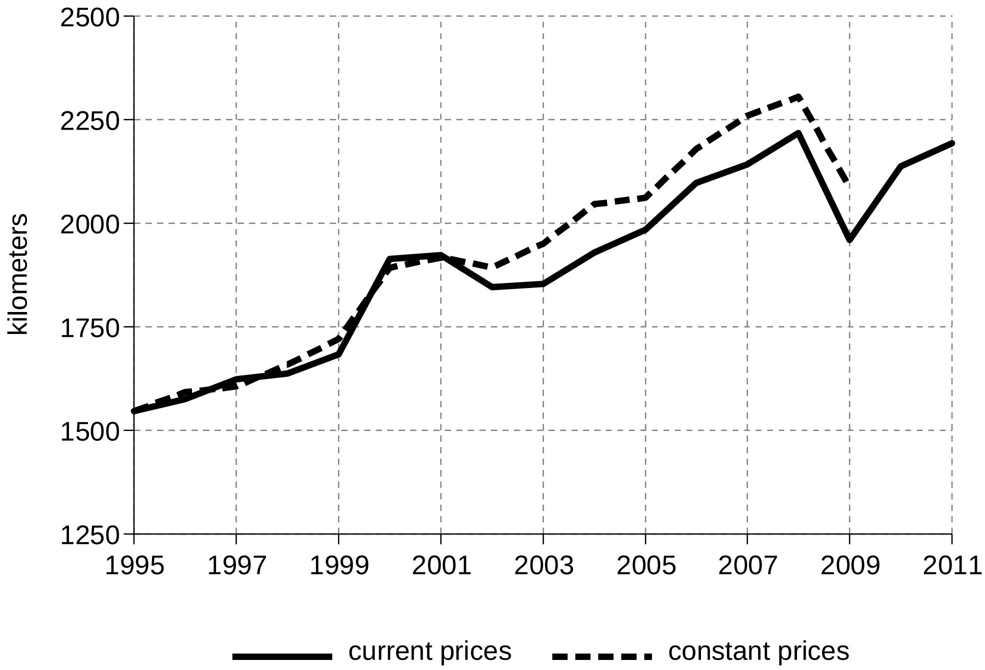
$$(17b)\qquad \boldsymbol{D} = [\boldsymbol{I} - \boldsymbol{A'}]^{-1}\, bdiag(\boldsymbol{d_1}).$$

Figure 10. Average length of the supply chains for the export industry
- current prices and sector weights in exports -



The average length of the supply chains for the export industry is plotted in Figure 10, using current prices and 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.[12] The circles are calculated under the assumption that supply chains propagates outward like ripples on the water (from Sweden, to Germany, to France, etcetera) 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 and how they grow over time. Europe has generally the shortest supply chains, but still longs enough to cover most countries on the continent. The longest supply chains are found in Asia with Chinese Taipei, China and South Korea in the top. Also Mexico stands out.

Figure 11. Average length of the supply chains for the export industry
- simple average of all WIOD reporters -



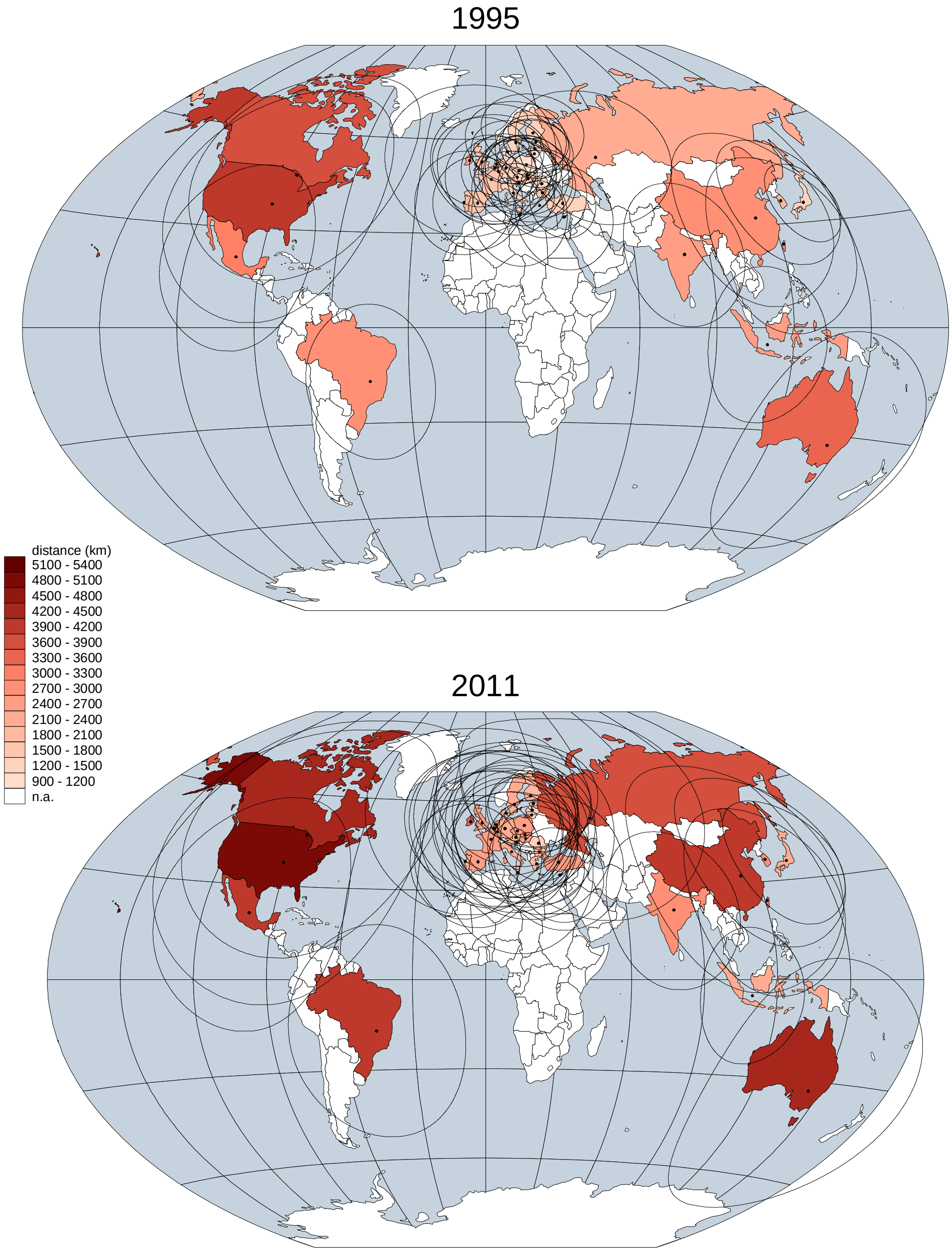
As shown in Figure 11, the supply chains in the export are becoming longer over time, on average with 40 kilometres a year. The trend exhibits the same pro-cyclical pattern we have observed for the other GVC indicators. Aside from the decline in distance after the dot.com and financial crises in 2001 and 2008-2009 respectively, the average distance covered by inputs has increased every year. In 1995, the average distance was 1545 km, which is almost exactly the distance between Stockholm and Paris (where the authors of this paper resides). By 2011, the supply chains had grown to 2200 kilometres, taking us from Stockholm to the Spanish border (time to brush up on the Spanish), an increase by 42 percent. The supply chains of the domestic industry are 30-40 percent shorter than those of the export industry and are also growing slower (about 20 kilometres a year). This reflects a different sector composition with more weight on (public) services and less weight on manufacturing.

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

Sector	1995	2011	+/-
Agriculture, hunting, forestry and fishing	1016	1484	46 %
Mining and quarrying	1002	1402	40 %
Food, beverages and tobacco	1541	1971	28 %
Textiles and textile products	1683	2278	35 %
Leather, leather and footwear	1717	2155	26 %
Wood and products of wood and cork	1529	1926	26 %
Pulp, paper, paper, printing and publishing	1510	1872	24 %
Coke, refined petroleum and nuclear fuel	2662	3388	27 %
Chemicals and chemical products	1794	2433	36 %
Rubber and plastics	1830	2448	34 %
Other non-metallic mineral	1369	1891	38 %
Basic metals and fabricated metal	1921	2658	38 %
Machinery, nec	1850	2457	33 %
Electrical and optical equipment	2214	2990	35 %
Transport equipment	1975	2789	41 %
Manufacturing, nec; recycling	1586	2253	42 %
Electricity, gas and water supply	1297	1998	54 %
Construction	1368	1792	31 %
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	873	1190	36 %
Wholesale trade and commission trade, except of motor vehicles and motorcycles	821	1083	32 %
Retail trade, except of motor vehicles and motorcycles; repair of household goods	698	907	30 %
Hotels and restaurants	1053	1292	23 %
Inland transport	1010	1609	59 %
Water transport	1582	2226	41 %
Air transport	1559	2453	57 %
Other supporting and auxiliary transport activities; activities of travel agencies	1045	1454	39 %
Post and telecommunications	782	1203	54 %
Financial intermediation	651	858	32 %
Real estate activities	393	594	51 %
Renting of machinery and equipment and other business activities	919	1115	21 %
Public admin and defence; compulsory social security	751	942	26 %
Education	478	602	26 %
Health and social work	916	1143	25 %
Other community, social and personal services	926	1185	28 %
Private households with employed persons	103	62	-40 %

The average length of supply by industry is presented in Table 3, including the percentage change between 1995 and 2011. As shown in Table 3, all sectors experience a significant growth in average distance, except for “Private Households with employed persons”. The longest supply chain is found in the Coke, Refined Petroleum and Nuclear Fuel sector. Manufacturing sectors have generally longer supply chains than services sectors. There is also some considerable variation between countries in the same sector, as illustrated by the transport equipment plot below. Note in particular the long supply chains for the US transport equipment sector, which exceeds 5000 km on an input-weighted basis. The plots for the other sectors will be uploaded on an electronic annex.

Figure 12. Length of the supply chains
- Transport equipment -



5.3 Average distance from output to final consumption

In the previous section we calculated the average length of the 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 the 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 WIOD. 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*,

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

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 (2011), 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 13. Average distance to final consumption for the export inudstry
- current prices and sectors weights in exports -

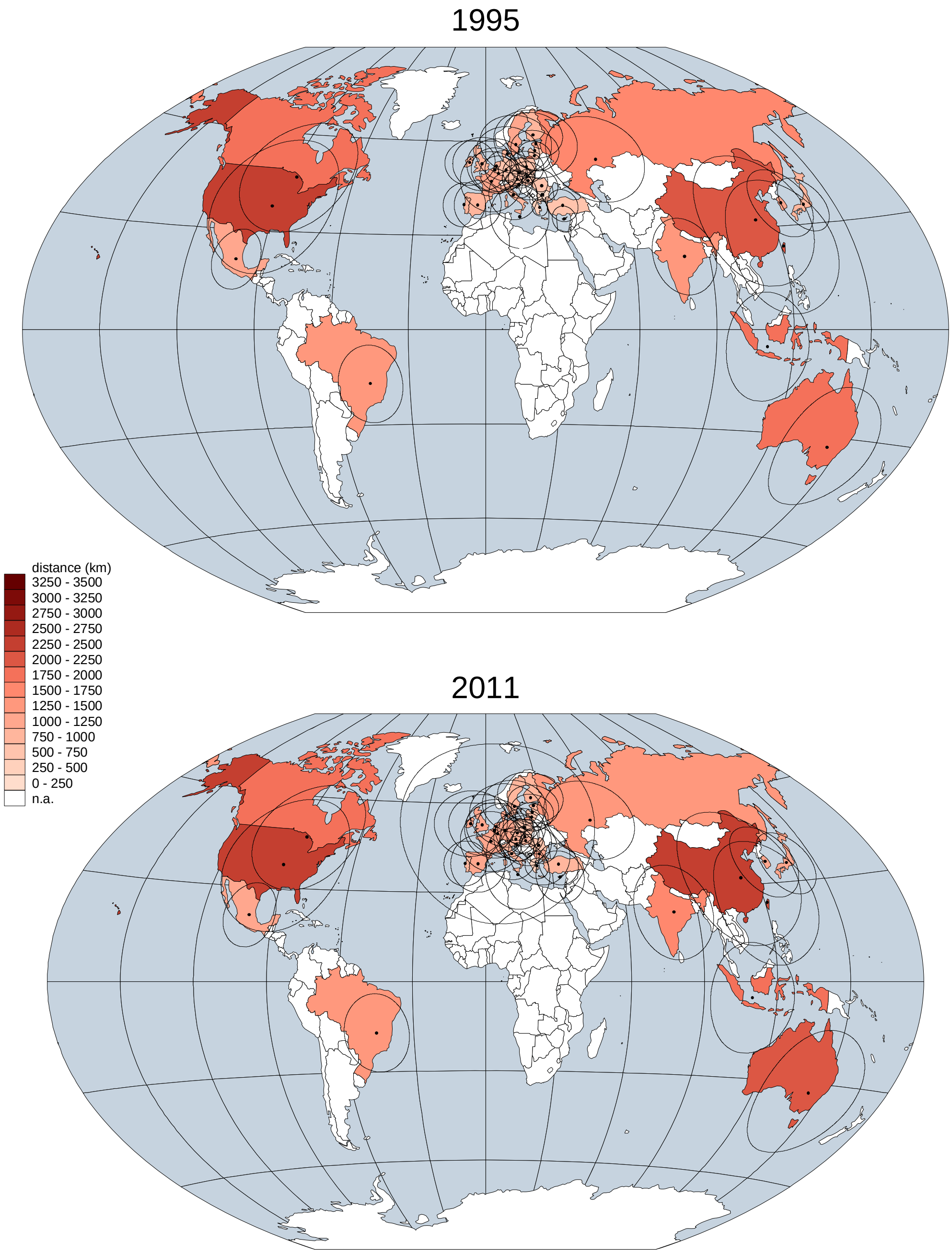


Figure 13 illustrates the average distance to the final markets for the export industry, using current prices and sector weights in exports. Luxembourg, the US and China are the countries with the longest *average* distance to the final consumption markets, where the global reach of the financial sector put Luxembourg at the top spot. The shortest distance to the final consumption markets are enjoyed by European countries.

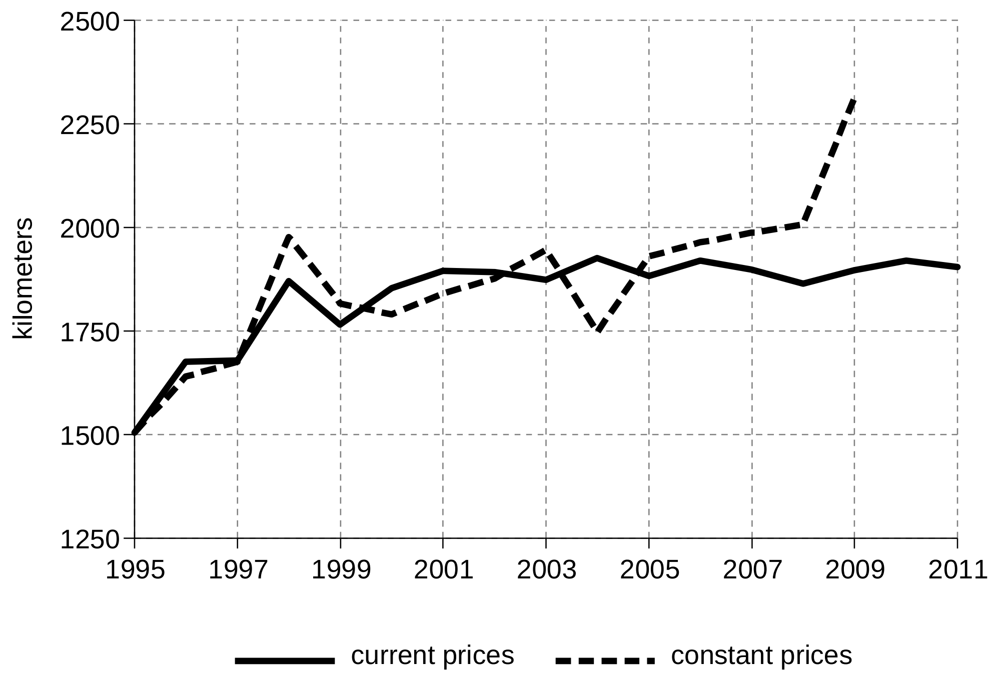


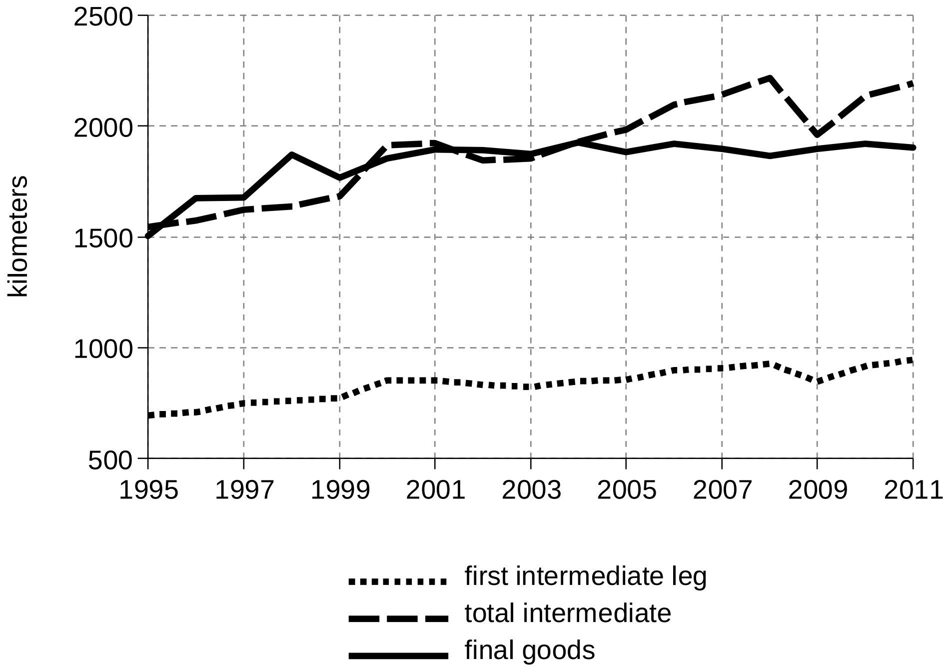
Figure 14. Average distance to final consumption for the export inudstry
- simple average of all WIOD reporters -

Over time, we do not see the same increase in the average distance travelled by final goods and services as the one observed for inputs (Figure 11). Note also the “spike” in the constant price index at the midst of the financial crises in 2009, which suggests that crises-ridden countries offloaded huge volumes at discounted prices to “non-traditional” markets in other regions to keep the wheels moving in the industry. What happens after the crises we cannot say at this moment since WIOD´s IO-tables in previous year’s prices ends in 2009, but will post an update on the electronic annex as soon as the 2010-2011 numbers are released.

5.4 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 current prices and 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 what they sell their final goods? As evident in Figure 15 the answer is yes: distance matter more for inputs than for final goods.

Figure 15. The sensitivity to distance in the export industry
- simple average of all WIOD reporters -



6. 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 1995-2011. The evidence points in the same direction. There is a fragmentation and an internationalization of production over time that justifies the new paradigm of "global value chains".

Most of the inputs used in exports remain domestic and between one third and one quarter of the value added in exports is of foreign origin. Foreign inputs are mostly sourced from countries that are geographically close (as would be expected in a gravity framework) but our analysis points out that the share of intra-regional value-added has been stable over time. In the period under review (1995-2011), this is the extra-regional value-added that has increased in exports. The same trend is observed when looking at the length of production chains through the number of embodied production stages in exports or through the geographic distance travelled by inputs and final products.

Therefore, the global value chains are becoming more global and when looking at the average distance travelled in supply chains for export industries we can say that globalization proceeds at 40 kilometres per year. Our paper is the first to test the robustness of these results when using constant prices. Our analysis highlights that GVC indicators are affected by the evolution of prices and we find in all our results a downward bias. The fragmentation of production is higher when measured in constant prices.

This empirical analysis has important implications for trade policy. A bilateral or regional approach in the negotiation of trade agreements is not likely to cover all the barriers that affect supply chain trade. In all GVCs, we observe a significant share of inputs sourced from countries that are outside the region. It would be interesting to test whether trade costs with more distant countries have been reduced or if this trend is mostly explained by increased supply and demand from emerging economies. Moreover, our data highlight the pro-cyclical nature of foreign sourcing. The lack of progress in multilateral trade liberalisation combined with the financial crisis has slowed down the expansion of global value chains in the past seven years.

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