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HOW GLOBAL ARE GLOBAL VALUE CHAINS? A NEW APPROACH TO MEASURE INTERNATIONAL FRAGMENTATION*

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ABSTRACT. Denser networks of intermediate input flows between countries suggest ongoing international fragmentation of production chains. But is this process mainly taking place between countries within a region, or is it truly global? We provide new macroeconomic evidence by extending the Feenstra and Hanson (1999) measure of fragmentation to a multicountry setting. We derive the distribution of value added by all countries involved in the production chain of a particular final good. This is based on a new input–output model of the world economy, covering 40 countries and 14 manufacturing product groups. We find that in almost all product chains, the share of value added outside the country-of-completion has increased since 1995. This is mainly added outside the region to which the country-of-completion belongs, suggesting a transition from regional production systems to "Factory World." This tendency was only briefly interrupted by the financial crisis in 2008.

1. INTRODUCTION

Back in 2006, Hans-Werner Sinn labeled Germany a "Bazaar Economy" (Sinn, 2006). He argued that increasing wages led the German economy to specialize in capital-intensive activities. While exports were booming, labor-intensive activities were offshored and the share of value added in Germany itself declined. For illustration, he referred to a study estimating that only 33 percent of the value of a luxury car produced by the German firm Porsche was added in Germany (Dudenhöffer, 2005). Companies like Porsche relocated substantial parts of their production processes to cheaper foreign locations, enabled by reductions in the trade costs and fast progress in information and communication technology (Baldwin, 2006a). This international fragmentation of production has attracted much recent attention, both in international trade theory (e.g., Grossman and

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Rossi-Hansberg, 2008; Costinot, Vogel, and Wang, 2013) and empirical work (Feenstra and Hanson, 1999; Hummels, Ishii, and Yi, 2001; Johnson and Noguera, 2012a, 2012b; Baldwin and Lopez-Gonzalez, 2013; Timmer et al., 2013, 2014; Koopman, Wang, and Wei, 2014). Empirical studies mainly focus on the position of countries within global production networks, by estimating the domestic value-added content of a unit bundle of exports, also known as measures of vertical specialization in trade. By now, there is consensus that the network of international trade in intermediate inputs, including parts and components, natural resources and services, has become increasingly dense. Production processes are more and more split into separate activities and countries specialize more and more in particular stages of production.

It is less well known to what extent this international fragmentation[1] is mainly regional, taking place within groups of neighboring countries and regional trade blocs, or mainly global, involving countries outside the region. This is an issue with important implications for the design of trade policies. If value chains are mainly fragmented within regions, regional trade agreements might be sufficient to further enhance the welfare improvements due to supply chain trade, while truly global value chains would require multiregional agreements. The available evidence is mixed. Case studies of high-end electronics products suggest that activities required for the production of the consumer products are increasingly dispersed around the globe (e.g., Dedrick, Kraemer, and Linden, 2010). In their study of the global automotive industry, Sturgeon, van Biesebroeck, and Gereffi (2008) argue that car manufacturers prefer to locate their assembly activities close to end markets, often forced by government policies. Specialized suppliers tend to cluster around these assembly activities. The production of more standardized parts and components generally takes place in Asia, however, as a result of opportunities to realize substantial returns to scale. Production chains of cars thus seem to fragment both globally and regionally. In an econometric analysis of value-added trade flows, Johnson and Noguera (2012b) found a strong impact of geographical distance on bilateral trade in value added across countries, in addition to trade agreements, suggesting regionalization to be more important than globalization. And based on an analysis of trade statistics, Baldwin and Lopez-Gonzalez (2013, p. 18) state more boldly that "Supply chain trade is not global—it's regional" and "The global production network is marked by regional blocs, what could be called Factory Asia, Factory North America, and Factory Europe."

In this study, we will for the first time provide systematic evidence on the trends in the international fragmentation of value chains. To do so, we extend the fragmentation measure introduced by Feenstra and Hanson (FH) (1999) in a multicountry setting, in a way similar to how Johnson and Noguera (2012a) extended the Hummels et al. (2001) measure of vertical specialization in trade. FH calculated shares of imports in intermediate inputs on the basis of national input–output tables. An increase in these shares reflects international fragmentation under the assumption that all value of imports is added outside the country. But in a world with more than two production stages, it is likely that imports embody value that the importing country added itself in previous stages. Also, the shares do not convey any information on the geographical origin of value added beyond domestic and foreign and hence cannot be used to study the geographical scope of fragmentation. We therefore extend the FH measure to a multicountry setting, using global input–output tables. We define for each final product its value chain as the set of all value-adding activities that are needed in its production and trace the location of these activities. In the case of the Porsche, this involves value that is added in the last stage of production in Germany. But the production of intermediates that are delivered

[1]The term "international fragmentation" was introduced by Jones and Kierzkowski (1990).

to the car plant also generates value added, partly within Germany and partly abroad, as some of these are imported. Many more upstream industries, like iron ore mining and metal fabrication, are also involved, again both inside and outside Germany. Using an input–output model of the global economy, we can fully decompose the value of the car into value added in Germany and value added abroad, labeled "foreign value added." Increasing international fragmentation of value chains will be reflected in higher foreign shares in the value of final products. We subsequently split the foreign value added into value added within the region to which the final producer belongs and value added outside the region to analyze (i) to what extent global value chains are truly global and (ii) whether marked changes in the global scope of value chain fragmentation can be observed for the period 1995–2011.

The remainder of this paper is structured as follows. In Section 2, we introduce our foreign value-added (FVA) shares indicator. Section 3 gives a brief description of the data used. The computation of the value added in each stage of production requires international input–output tables that cover the world economy. We use the new World Input-Output Database (see Timmer, 2012; Dietzenbacher et al., 2013) for the years 1995–2011 to study developments immediately following the onset of the crisis in 2008. The data cover 40 countries and we are able to analyze developments in three regions: the European Union (EU) (i.e., the 27 countries that were EU members in 2011), NAFTA (Canada, Mexico, and the United States), and East Asia (China, Japan, South Korea, and Taiwan). The period studied includes major landmarks in the history of trade agreements, most notably the NAFTA agreement coming into force in 1994, China joining the WTO in 2001 and the accession of 10 new member states to the EU in 2004. In Section 4, we show that the great majority of product value chains have become increasingly fragmented since 1995. However, the degree and rates of change of international fragmentation vary considerably across different types of products. We do not find evidence that the global financial crisis caused a structural break in the pace of increasing fragmentation. Armed with these insights, we study the relative importance of increased fragmentation within regional blocs (regional fragmentation) and across these (global fragmentation) in Section 5. Our longitudinal analysis shows that regional fragmentation is still dominant in European value chains, but also shows that shares of value added outside the EU are increasing the fastest, pointing toward faster global fragmentation than regional fragmentation. Also, for production chains ending in NAFTA countries or in East Asia, value added outside the region is growing much faster than value added inside the region. Geographical proximity or belonging to a trade bloc still matters much for the distribution of value added within value chains, but much less so than 15 years ago. Section 6 concludes.

2. MEASURING INTERNATIONAL FRAGMENTATION OF VALUE CHAINS

Much of our knowledge on international fragmentation of value chains is based on detailed product case studies such as Dedrick et al. (2010), which are not necessarily representative. FH (1999) were one of the first to introduce a measure of fragmentation in a macroeconomic setting. Their aim was to indicate the extent of offshoring of activities by U.S. firms and they proposed a measure defined as the share of imported intermediate inputs in the value of all intermediate inputs used in a particular industry.[2] While straightforward and simple to calculate on the basis of national input–output tables, the

[2]In their empirical work, they present a "broad" and a "narrow" measure. The former includes all intermediate inputs used in a particular industry, while the latter only considers intermediate inputs sourced from the same industry. In the practical application, they restrict intermediates to be nonfuel manufacturing products only.

FH measure suffers from a number of shortcomings when used in analyses of international fragmentation. First, it only provides information on the domestic and the foreign origin of intermediates, but is silent on the particular country or region from which the imports originate. Without additional information based on bilateral trade data, it cannot be used to distinguish between international fragmentation within regions and global fragmentation (across regions). Second, the measure is insensitive to substitution of the use of domestic production factors for intermediates. For example, when production of a component previously produced "inhouse" is partly offshored, the share of imports in intermediates does not necessarily go up, although the share of foreign value added clearly has risen.[3] To account for substitution of domestic for foreign value added, a full decomposition of final output value into value added is needed. Third, the FH measure assumes implicitly that the domestic value-added content of imported intermediates is zero, and similarly for the foreign value-added content of domestic intermediates. This assumption does not hold, as highlighted by Johnson and Noguera (2012a) and Koopman et al. (2014) in the context of measuring vertical specialization in trade. It disregards the fact that the production of intermediates, in turn, requires additional production activities that take place both inside and outside the country. With increasing back and forth trade in intermediates, these effects can be sizeable.

To overcome these shortcomings, we generalize the FH measure and propose a metric that uses information from world input–output tables (WIOTs) to describe the international fragmentation of specific value chains. Our measure is based on final output values, takes into account all rounds of production, and traces the geographical origin of value added. This generalization of the FH measure in the context of a global input–output table is comparable in spirit to the attempts by Johnson and Noguera (2012a,b) and Koopman et al. (2014) to improve on the approach pioneered by Hummels et al. (2001) to measure vertical specialization of countries in trade. We will decompose the value of a final product into the value-added shares generated in all countries that contribute to its value chain. Thus, our measure does not only take into account the value added by the immediate suppliers of intermediates, but also valued added by suppliers further upstream.

This can be elucidated by referring to Figure 1, which is an extension of a diagram in Hummels et al. (2001). It refers to a simplified world economy consisting of three countries and depicts a value chain of a final product for which the last stage of production takes place in country 3. We call this the *country-of-completion*. To produce it, factor inputs are needed in country 3, generating domestic value added. In addition, intermediate inputs are needed, some of which are produced within the country itself and some of which are imported from country 2. To produce these, country 2 in its turn adds value. This is not limited to the industries producing the exported intermediate products (the first-tier suppliers in the production of the final product), but also involves industries in country 2 that act as second-tier suppliers by producing materials and components that are needed for the production by the first-tier exporters. Finally, second-tier suppliers are not only located in country 2, but also in country 1, such that country 1 also adds value. Based on information of the various production linkages in the production of the final product considered, the values added by countries 1, 2, and 3 can be calculated.

More formally stated, we will study value chains of final products that are identified by the last stage of production: a particular industry i located in a specific country

[3] If the production of the component is outsourced to both domestic and foreign plants, both the value of domestically and foreign purchased intermediates obviously will go up. The share of imports in total intermediates, however, might not change at all.

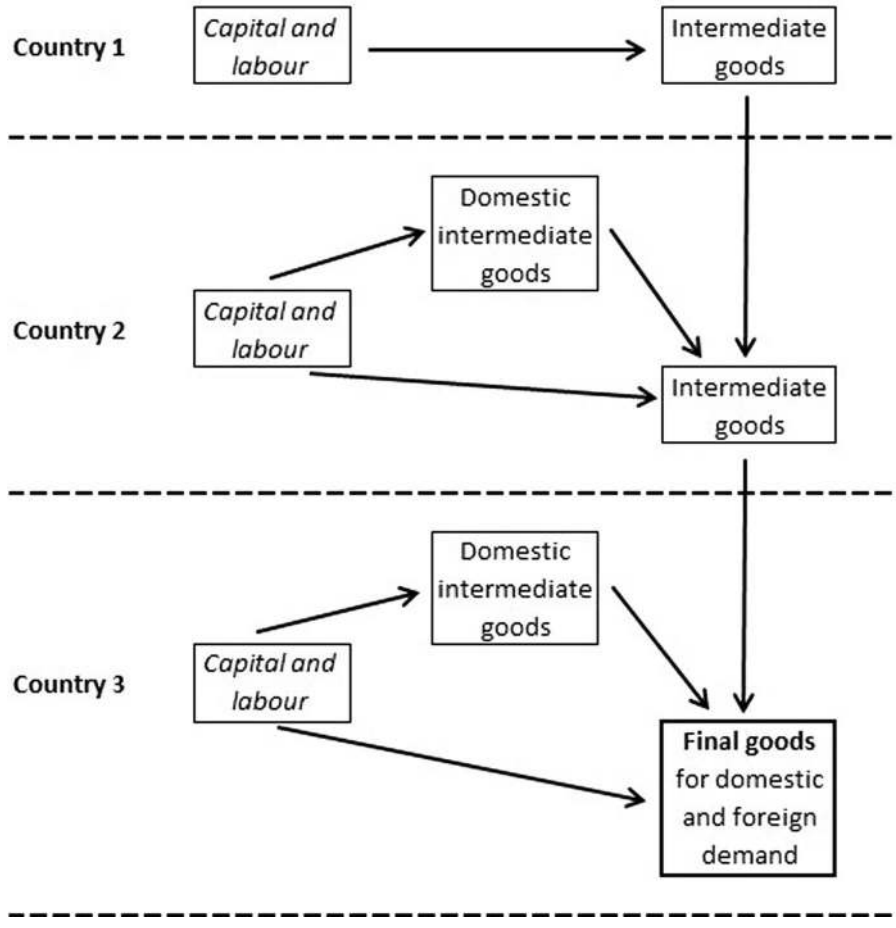


FIGURE 1: Stylized Representation of an Internationally Fragmented Value Chain.

j, denoted by (i, j).[4] To produce good (i, j), activities in industries $s = 1, \ldots, S$ in each of the countries $n = 1, \ldots, N$ are needed. To decompose its value, we need to start with finding the levels of gross output associated with the production of (i, j). These can be estimated by applying standard input–output methods to global input–output tables. Global input–output tables contain information on the values of intermediate input flows among all country-industries in the world, as well as on the values of flows from each of these country-industries to final use in each of the countries. These tables also contain information on value added generated in each of the country-industries. Combining information on values of sales and value added per dollar of sales leads to estimates of value added in each of the SN industries as a consequence of final demand for product (i, j). For this, we

[4]Industries producing wholesale and retail services, and transport services industries are not considered as industries-of-completion. Our data are at basic prices and hence the margins generated by these industries in delivery to the final consumer are not taken into account (see Section 3).

use an equation that has been a standard tool in input–output analysis for over decades (see Miller and Blair, 2009):

$$\mathbf{g} = \hat{\mathbf{v}}\,(\mathbf{I} - \mathbf{A})^{-1}\,(\mathbf{Fe}). \tag{1}$$

In this equation, $\mathbf{g}$ is the vector of value added created in each of the *SN* country-industries involved in a value chain. The choice for a specific final output matrix $\mathbf{F}$ determines which value chain is considered. Final output is output delivered for household consumption and investment demand.[5] $\mathbf{e}$ is a summation vector. $(\mathbf{I-A})^{-1}$ is the well-known Leontief inverse, the use of which ensures that value-added contributions in all tiers of suppliers are taken into account. $\mathbf{v}$ is a vector with value added over gross output ratios, for each of the country-industries.[6] Appendix 1 contains a technical discussion of the derivation of Equation (1).

The main result of this calculation for our purposes is that we are able to decompose the value of a final product into value-added contributions in any country in the world. As we are using tables that involve all regions in the world, this decomposition is exhaustive. Denote the final output value of product (i, j) by $\mathrm{FINO}(i, j)$ and the value added by country k in its production by $\mathrm{VA}(k)(i, j)$. The vector $\mathbf{g}$ contains the matching $\mathrm{VA}(k)(i, j)$ levels for each (i, j), such that

$$\mathrm{FINO}\,(i,\, j) = \sum_{k} \mathrm{VA}\,(k)\,(i,\, j)\,. \tag{2}$$

Summed over all countries, the value-added contributions to the production of (i, j) are equal to the final output value of (i, j).

Next, we define our measure of foreign value added as all value added outside the country-of-completion j:

$$\mathrm{FVA}\,(i,\, j) = \sum_{k \neq j} \mathrm{VA}\,(k)\,(i,\, j) = \mathrm{FINO}\,(i,\, j) - \mathrm{VA}\,(j)\,(i,\, j)\,. \tag{3}$$

To measure the importance of foreign value added, we express it as a share of all value added in the production of (i, j):

$$\mathrm{FVAS}\,(i,\, j) = \mathrm{FVA}\,(i,\, j)\,/\mathrm{FINO}\,(i,\, j)\,. \tag{4}$$

We will use this share to measure the extent of international fragmentation of value chains in Section 4. Subsequently, we decompose $\mathrm{FVAS}(i, j)$ into the value-added share of the region to which the country-of-completion belongs, and the remaining value-added share that is added outside the region. As an illustration, Table 1 shows the distribution of value added of two groups of products: those completed in the German transport equipment industry and in the U.S. electrical machinery industry, for 1995 and 2008, respectively. The first row gives the share generated in the country-of-completion. The remainder is generated outside the country and we distinguish four regions: the EU (including all EU27 countries as of 2011), NAFTA (including Canada, Mexico and the United States), East Asia (China, Japan, South Korea, and Taiwan), and other (rest of the countries in the world). This grouping of countries will be used throughout the paper. In both value chains, there is a substantial decline in the domestic share, indicating that the value chains have internationally fragmented over the period 1995–2008. One might expect that this international fragmentation first and foremost takes place within regional

[5]Note that all final demand for the output of (i, j) is considered, so it includes both domestic and foreign demand.

[6]Matrices are indicated by bold capital symbols and (column) vectors by bold lowercases. Hats denote diagonal matrices with the corresponding vector on the main diagonal.

TABLE 1: Examples of Distribution of Value Added in Value Chains of Two Product Groups (%)

	Transport Equipment from Germany		Electrical Machinery from the United States	
	1995	2008	1995	2008
Domestic value added	78.9	66.0	84.4	77.3
Foreign value added, of which	21.1	34.0	15.6	22.7
EU	13.2	18.6	4.4	5.6
NAFTA	2.5	3.1	3.2	4.9
East Asia	2.1	4.3	5.2	6.6
Other	3.3	8.0	2.7	5.7

Note: Shares in final output value based on national currency to US$ conversions at market exchange rates.
Source: Authors' calculations on World Input-Output Database (November 2013 release).

trade blocs. Indeed, the share of EU countries in the German value chain have increased, and likewise the share of Canada and Mexico in the U.S. chain. But, in fact, fragmentation outside the region is stronger than within. The non-EU share in German car value increased more than the EU share (7.5 versus 5.4 percentage points). This pattern will be confirmed for a larger set of value chains in Section 4.

Our measure based on FVA shares has a number of important characteristics. First, being a share, it is bounded between zero and one. It is zero if all value is added domestically and increasing with higher international fragmentation. It will never be equal to one as the final stage of production by definition takes place in the country-of-completion and must involve some value-added generation. Second, the contributions of countries do not depend on the stages of production in which they participate, as our measure is based on value added. Value added in each stage is defined as the gross output at the end of the stage minus the intermediate inputs needed in that stage. This is in contrast to measures based on gross output, which suffer from the so-called "double counting problem" as the value of intermediates used in all previous stages are included (see Koopman et al., 2014). As a corollary, the "ordering" of the countries in the production chain is inconsequential for measuring their value-added shares.[7] Third, the decomposition is based on values and not on quantities only. Changes in the quantities of inputs (and their origin) required for the production of a final product will affect the outcome of the decomposition, but it does not convey direct information on the physical fragmentation of production processes. Price changes might drive changes in value added without any underlying change in the actual process. But this only occurs when there is a change in the price of output relative to the price of inputs. If all prices rise to the same extent, for example, because of general inflation, value-added shares will remain the same. We therefore refer to the FVA share as a measure of international fragmentation of value chains.[8] Finally, it should be noted that value added is measured based on the location of production and not on the

[7]For example, it does not matter for value added-based measures whether the chain is organized as a sequence of multiple production stages or as a hub where components from various subcontractors are collected and assembled ("snakes" and "spiders," in the terminology of Baldwin and Venables, 2012).

[8]Our approach is based on a backward tracking of value, starting from the final product and tracing the value added in all stages that are needed to produce it. A related approach that is closer to measuring physical aspects of production is based on measuring the number of production stages a unit value will go through before it is sold for final use (Dietzenbacher and Romero, 2007; Fally, 2011; Antras et al., 2012).

ownership of production factors. It therefore measures the geographical distribution of value added, not necessarily of income. For example, part of the value added in foreign-owned firms might end up as income outside the country of production (see, e.g., Baldwin and Kimura, 1998). For the purposes of this paper, we are interested in the fragmentation of value added, not of income.

3. THE WORLD INPUT–OUTPUT DATABASE

The computation of foreign value added relies on Equation (1), which requires the availability of a global input–output table. Such data have become available only very recently. By linking GTAP input–output tables to bilateral trade data from the same source, Johnson and Noguera (2012a) and Koopman et al. (2014) constructed global input–output tables.[9] These tables are not publicly available, however, and only cover one year. We use the newly constructed World Input-Output Database, which has the main advantage that it provides time series of global input–output tables, covering 35 industries in 40 countries in the world plus a region called "Rest of the World," for the period 1995–2009.[10] For the purpose of this paper, we have extended the data to 2011 using methodologies that were also applied for 1995–2009, but based on more limited data. Timmer (2012) and Dietzenbacher et al. (2013) provide extensive accounts of sources and methods, and a brief summary is given below.

Basically, a WIOT is a combination of national input–output tables in which the use of products is broken down according to country-industry of origin. Such a table can be seen as a description of the worldwide network of internationally fragmented production processes, which are much more complicated than depicted in Figure 1. Figure B.1 in the Appendix depicts the structure of a WIOT with N countries, which together constitute the world economy. The rows in the WIOT indicate the value of deliveries of output from a particular industry in a country. This can be used for intermediate use (in the blocks labeled $\mathbf{Z}$) or final use (in the blocks labeled $\mathbf{F}$), either domestically or abroad. A fundamental accounting identity is that total use of output in a row equals total output of the same industry as indicated by the sum of inputs in the respective column in the left-hand part of the tables. The columns convey information on the technology of production as they indicate the amounts of intermediate inputs needed for production. Intermediate inputs are either sourced from domestic industries or imported. The residual between total output and total intermediate inputs is value added ($\mathbf{w}'$, a row vector), which measures the direct contribution of domestic factors to output.

The world input–output database (WIOD)'s WIOTs have been constructed by combining national input–output tables with bilateral international trade data. We briefly discuss how two major challenges in the data construction have been dealt with. The first challenge was to have consistency in the tables over time, to allow for longitudinal analysis. National tables are only available for particular benchmark years and in contrast

Any measure of physical fragmentation of production processes requires tables with quantity information, which are rarely available.

[9]See Narayanan and Walmsley (2008) for a description of GTAP data. Notable earlier efforts to construct international input–output tables for Europe (and their uses) can be found in Van der Linden and Oosterhaven (1995) and Dietzenbacher, Hoen, and Los (2000). Furthermore, the Japanese government agency IDE-JETRO has a long tradition of constructing international input–output tables for East Asia (see, e.g., Meng, Zhang, and Inomata, 2013).

[10]Countries covered include all 27 EU countries as of 2011 and 13 other major economies namely Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey, and the United States. All WIOTs and underlying data sources are publicly available for free at www.wiod.org.

to National Accounts Statistics they are often not, or with considerable lag, revised when new information becomes available. Time consistency has been achieved through a procedure that imputes coefficients subject to hard data constraints from the National Accounts Statistics, using a constrained least square method akin to the well-known biproportional (RAS) updating method (Temurshoev and Timmer, 2011). The solution exactly matches the most recent national accounts data on final expenditure categories (household and government consumption and investment), total exports and imports, and gross output and intermediate inputs by detailed industry. All national tables have been harmonized, removing idiosyncrasies regarding price concepts, industrial classification, treatment of financial services, and negatives in the intermediate blocks.[11]

The second challenge was the allocation of imports to a use category and the disaggregation by country-industry of origin. Typically, researchers rely on the so-called import proportionality assumption, applying a product's economy-wide import share for all the uses the product is put (as, e.g., Johnson and Noguera, 2012a, 2012b). Various studies have found that this assumption can be rather misleading, as import shares vary significantly across various uses (Feenstra and Jensen, 2012). To improve upon this, the detailed product descriptions in the UN COMTRADE database were used to allocate imports to three use categories: intermediate use, final consumption use, or investment use, effectively refining the well-known "broad economic categories" (BECs) classification from the United Nations. In addition, data on bilateral trade in services, which in contrast to data on goods are not readily available, have been collected, integrating various international data sources. This includes payments for various kinds of business services, royalties, and license fees.[12]

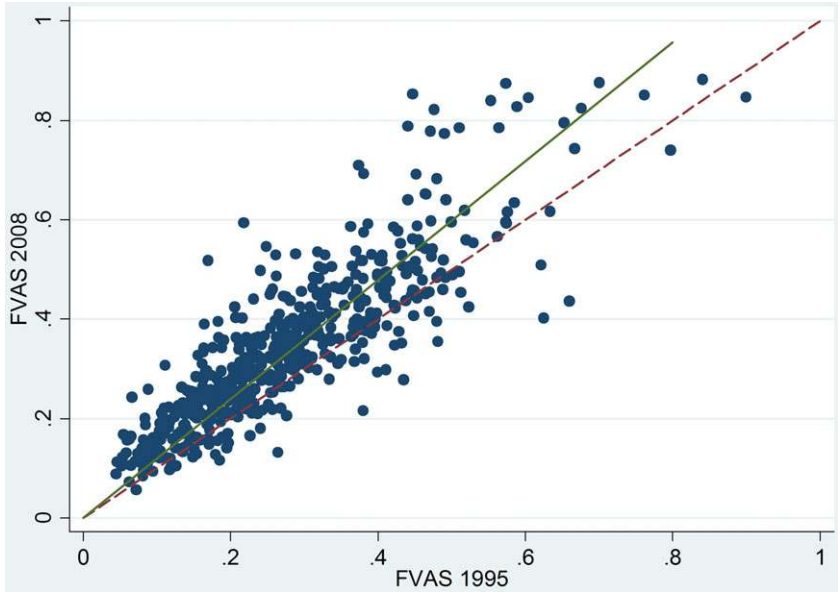
The WIOTs have been expressed in current U.S. dollars using official exchange rates from the IMF to convert tables in national currencies. All tables are expressed in basic prices, which is a price concept that excludes net taxes and trade and transportation margins. These margins have been allocated as output to the respective trade and transport industries. Value added in retailing services related to delivery of the product from the factory to the final consumer is thus not part of the value chain of the product, but value added in wholesale trade and transportation of intermediates is included as they are part of the production process.

4. TRENDS IN INTERNATIONAL FRAGMENTATION OF VALUE CHAINS

In this section, we investigate the trends in international fragmentation of value chains over the period from 1995 to 2011. We first focus on the precrisis period and

[11]Supply and use tables have been used if available, rather than input–output tables. Input–output tables are of the industry-by-industry or product-by-product type. Supply and use tables (SUTs) are of a product-by-industry nature and hence provide a better linking with product-based trade data and industry-based value-added data. The national SUTs have dimensions of 35 industries and 59 product groups. The 35 industries cover the overall economy and are mostly at the two-digit ISIC rev.3 level or groups there from. See Dietzenbacher et al. (2013) for technical details.

[12]Services trade data have not been collected at the same level of detail and accuracy as goods trade data and there is still much to be improved, in particular in the coverage of intrafirm deliveries (Francois and Hoekman, 2010). It should be emphasized, however, that the values of these services are not disregarded in our analysis as the decomposition of the products' value is complete. The location of the value added might be harder to trace, though. Take the example of a typical U.S. manufacturer of trousers that does not have any production capacity in the United States, but basically only governs foreign production and maintains brand and design at home (so-called "factoryless manufacturers"). The value of the trouser includes the compensation for brand and design and this will show up in the recorded value added in the U.S. clothing industry.



Notes: Each dot represents the share of foreign value added in the final output of a product in 1995 and 2008. This share is calculated according to Equation (4). Observations have been included for 558 manufactures value chains, identified by 14 manufacturing industries of completion in 40 countries. The dashed line is the 45-degree line. The solid line has been obtained by OLS regression through the origin.

Source: Authors' calculations based on World Input-Output Database (November 2013 release).

FIGURE 2: Foreign Value-Added Shares in Output of Final Manufactures (1995 and 2008).

answer the question to what extent fragmentation tendencies for some manufacturing products have been more pronounced than for others. Next, we study whether the global financial crisis in 2008 caused a structural break in the pace of increasing fragmentation. Bems, Johnson, and Yi (2011) found a deep collapse in international trade following the crisis. This might have long-lasting effects on fragmentation processes, as national governments might adopt policies to protect domestic industries, leading firms to relocate stages of production to the country-of-completion itself or the trade bloc to which it belongs.

Fragmentation Trends by Product Groups

Figure 2 shows a scatter plot of the FVASs for manufactures value chains in 1995 and 2008, based on Equations (1)–(4). As outlined above, we identify value chains by the country-industry-of-completion. We focus on final manufacturing goods, as the production processes of these goods have been particularly prone to fragmentation and activities in the chain have a high degree of international contestability.[13] All 14 manufacturing industries and 40 countries-of-completion for which we have data have been included. We have 558 value chains.[14] If value chains would have remained equally fragmented

[13]An increasing part of world trade is in business services, and intermediate services related to production of manufacturing products are included in value chains of goods.

[14]Two value chains had to be dropped, since there is no final output in 1995 for leather manufacturing and petroleum manufacturing in Luxembourg, so we have $14 \times 40 - 2$ is 558 observations.

TABLE 2: Foreign Value-Added Shares in Output of Final Manufactures by Product Group

Industry	ISIC rev. 3 code	Foreign Value Added Share 1995	2008	Change 1995–2008	Global Final Output in 2008
Petroleum products	23	32.9	53.7	20.8	678,571
Basic and fabricated metals	27, 28	17.7	30.2	12.5	386,895
Electronic products	30–33	18.3	29.1	10.8	1,405,650
Chemical products	24	17.4	28.0	10.5	707,378
Transport products	34, 35	20.4	30.3	9.9	1,834,003
Other machinery	29	14.9	24.0	9.1	1,326,246
Rubber and plastics	25	18.3	26.4	8.1	151,410
Other manufacturing prod.	36	15.6	23.6	8.0	467,998
Wood products	20	13.4	20.7	7.2	49,288
Other nonmetallic minerals	26	13.0	20.2	7.2	75,310
Food products	15, 16	12.1	16.9	4.8	2,438,968
Textile products	17, 18	16.7	20.4	3.7	577,356
Paper and printing products	21, 22	14.8	18.3	3.6	361,138
Leather products	19	17.5	18.5	1.0	140,314

Notes: Weighted averages of foreign value share in final output of 558 value chains (VCs), ordered by change in FVAS. There are VCs in 40 countries for each product group, except for leather products and petroleum products, for which there are no VCs in Luxembourg. Last column shows total final output in the world, in millions of current U.S. dollars at market exchange rates, in 2008.

Source: Authors' calculations (for Equation (4)) based on the World Input-Output Database (November 2013 release).

over the period, the observations would have clustered around the 45-degree line. The vast majority of observations are above the 45-degree line, however, reflecting an increase in fragmentation (for 474 out of 558 value chains). The estimated slope of an Ordinary Least Squares (OLS) regression through the origin indicates that FVA shares increased on average by about 20 percent over the 13-year period considered.

The trend toward fragmentation can be found for many value chains, but there are also sizeable differences across manufacturing product groups. The FVA shares for products for 1995 and 2008 are shown in Table 2, as well as the change over this period. Products are grouped into the main industry of final production. The FVA shares for each group have been averaged over 40 countries-of-completion, weighted by the value of final output.[15] The results are sorted by the change in the FVA share over the period, from high to low. In the last column, the final output of the product group is given to indicate the relative importance of each group in value-added generation. This value is equal to the value of global consumption and investment demand for the product and is given for 2008.

Running (unreported) simple unweighted OLS regressions on the sets of 40 value chains for each product group reveals that the changes in FVA shares are positive for all product groups. Nevertheless, Table 2 reveals major differences in the pace of this fragmentation process across product groups. The FVA share of petroleum refining

[15]Wald tests rejected the hypothesis that the slope coefficient is equal to one at the 1 percent significance level, for all 14 products. Results based on unweighted averages show qualitatively the same results.

products increased most rapidly and was by far the highest among all products in 2008. FVA shares also increased rapidly for metal products, electronics, chemicals, transport equipment, and machinery, which are all important industries in terms of their final output value. In contrast, the fragmentation of the value chains of leather, textile, and food products proceeded only slowly.

How can these differences be explained? Degrees of fragmentation are the outcome of a complex interaction of various determinants, including trade costs (such as tariffs and standards compliance requirements), transportation costs, and coordination costs associated with offshoring, as well as the relative movements of input prices and substitution possibilities across intermediates. For example, the rapid increase in FVA shares for final oil products is not surprising as most countries do not have access to domestic oil feedstock and need to rely on imported intermediates to produce refined products such as gasoline. The price of crude oil more than quintupled in the period, which increased the share of the refined oil's value generated by crude oil producers, assuming limited opportunities for substitution for other intermediates. Given the general increase in prices of a wide variety of natural resources, similar fragmentation tendencies might be expected for other resource-intensive products.[16] Indeed, FVA shares in metal products increased next-fastest, and shares in chemicals and rubber and plastics products also rose well above the manufacturing average.

On the other hand, manufactured foodstuffs, by far the most important product group in terms of value, have relatively low and slowly increasing foreign shares. Most of the intermediates are sourced from local agriculture, as nontariff barriers on food products are known to be relatively high (Lee and Swagel, 1997) and so are transport costs, as a consequence of their low value-to-weight ratios. Hummels (2007) found that global transportation costs dropped for many goods, but roughly in proportion to their value-to-weight ratio. They dropped much faster for products that tend to be shipped by air. Besides, differences in the importance of timeliness of delivery can also have an impact on the choice for a domestic supplier or a supplier abroad, e.g., in the case of fresh vegetables. Probably, the low international fragmentation of leather and textile value chains has different drivers. The production processes of these products already underwent major fragmentation in the 1970s and 1980s, when Japan, South Korea, and Taiwan offshored production to other Asian countries. This fragmentation process accelerated due to the export restrictions laid down in the Multi Fiber Agreement, resulting in a wide variety of countries where the last stage of production took place. More recently, with the termination of the agreement in 2004, production activities increasingly clustered in a limited set of countries, and in particular China emerged as a major producer including many stages of production, extending backwards into, e.g., cotton production (Gereffi, 1999; Gereffi and Frederick, 2010).

While we find increasing value fragmentation for all products, it should be noted that there is still a large home bias in production. For example, electronics are often seen as the paragon of international fragmentation and FVA shares indeed increase rapidly, ranking third among the 14 product groups. But in 2008, 71 percent of the value was still added in the country-of-completion. Even in the case of China, well-known for its low-value adding assembly activities in electronics, 69 percent of the final output value is still added domestically. The findings of tiny shares (3 percent or lower) of Chinese value added in high-end electronics case studies such as in Dedrick

[16]The rapid price increase of natural resources started around 2001. Over the period 1995–2008, the price of energy in nominal U.S. dollars increased by a factor 5.1. This data are taken from World Bank (2013).

et al. (2010) are clearly not representative for the wider set of products produced in China.[17]

Value Chain Fragmentation after the 2008 Crisis

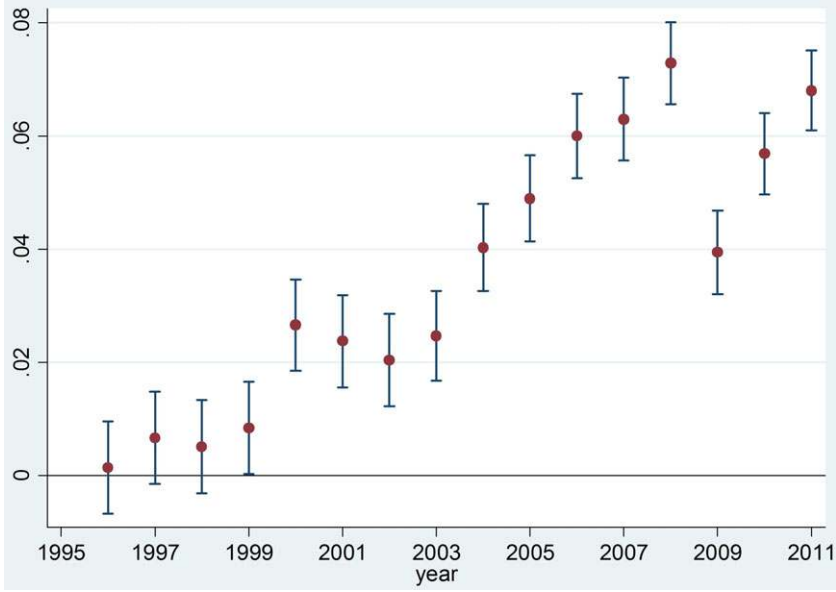
It has been hypothesized that the global financial crisis in 2008 would have major consequences for the organization of global production networks. The immediate consequences of the crisis were studied in a global input–output framework by Bems et al. (2011), who concluded that international trade declined considerably more than world GDP when the crisis started. This was explained by demand uncertainty leading firms to use remaining stocks of materials and components, instead of ordering the usual amounts of intermediate inputs. It might also indicate a more structural break in the process of international fragmentation, however, as firms experienced the vulnerability of long production chains. Other factors like increasing transport costs (as fuel prices continue rising) and an upward drift in Chinese wages might be additional drivers toward a long-term decline in fragmentation. Furthermore, it has been suggested in the popular press that crisis-induced protectionist government policies and "reshoring" decisions by multinational companies have reversed the fragmentation trend (see *The Economist,* 2013).

We obtain insights into what happened in the first three years after the start of the crisis by regressing our panel dataset of FVA shares for all 558 manufacturing value chains for 1995–2011 on dummies for country-of-completion, industry-of-completion, and year. The inclusion of the first two sets of dummies allows us to isolate year-specific effects on FVA shares. These effects give us insights into long-run trends, but also into the effects of the crisis. The sample consists of 9,436 observations, which have been weighted by the value chains' final output values. Figure 3 shows the estimated coefficients for the year dummies and the associated 95 percent confidence intervals. The dummy for 1995 has been omitted, so all point estimates have to be viewed as relative to 1995. The figure clearly reflects the across-the-board increase in FVA shares that was discovered before. The year dummies were found to be statistically larger than zero at a 5 percent level of significance from 1998 onward. The point estimates show an increasing trend in the FVA shares at the end of the 1990s. After a short period of stabilization in the degree of value chain fragmentation, its growth picked up again in 2003. The steady increases in international fragmentation continued until the onset of the crisis in 2008. The crisis induced a major dip, but this appeared to be a short-run effect though. The FVA shares rebounded and were back at the level of 2007 in 2011, showing no signs of faltering. It remains to be seen, however, whether the prolongation of the crisis might have more structural effects after 2011.

5. THE GEOGRAPHY OF VALUE CHAIN FRAGMENTATION

In his study on bilateral versus multilateral free trade agreements, Baldwin (2006b) made a distinction between international economic integration *within* regions and *across* regions. As the relative magnitudes of international (gross) trade flows within regions were much larger than those of trade flows between regions, he claimed that regionalization of production was a more important phenomenon than true globalization. Baldwin and Lopez-Gonzalez (2013, p. 18) even state that "Supply chain trade is not global – it's

[17]Koopman, Wang, and Wei (2012) found a domestic value-added share for China in 2007 of 34 percent when narrowing down the set of products to "electronic computers" and focusing only on goods produced for exports. For total merchandise exports, they found a figure of 61 percent (Koopman et al., 2012, Table 6).



Notes: Regression of foreign value-added shares on country-of-completion dummies, industry-of-completion dummies, and year dummies. The figure provides estimated coefficients and 95 percent confidence intervals for the year dummies, relative to 1995. The observations (9,436) are weighted by final output.

Source: Authors' calculations based on the World Input-Output Database (November 2013 release).

FIGURE 3: Trend in International Fragmentation of Value Chains.

regional" and "The global production network is marked by regional blocks, what could be called Factory Asia, Factory North America, and Factory Europe." In this section, we show that trends toward value chain fragmentation within regions might have been dominant in the 1980s and early-1990s, but that true global fragmentation (i.e., value chain fragmentation across regions) has been more important in the 2000s.

Based on the measures of foreign value added outlined in Section 3, we can define regional and global fragmentation in a straightforward manner. We split FVA as defined in Equation (3) into regional foreign value added (RFVA) and global foreign value added (GFVA). RFVA in the value of product i with country j as country-of-completion is defined as the value-added contribution of the region to which country j belongs minus the contribution of the country itself:

$$\text{RFVA}(i,j) = \sum_{k \in region of j} \text{VA}(k)(i,j) - \text{VA}(j)(i,j), \tag{5a}$$

and, analogously to Equation (4), we define the share of RFVA in the value chain of (i,j) as

$$\text{RFVAS}(i,j) = \text{RFVA}(i,j)/\text{FINO}(i,j). \tag{5b}$$

If the change in regional FVA share is positive, we say that the value chain of this product is fragmenting within regions. Along the same lines, we measure GFVA in this

value chain as the value-added contribution of all countries outside the region of country j, as follows:[18]

$$\text{GFVA}(i,j) = \sum_{k \in \text{outside region of } j} \text{VA}(k)(i,j) \tag{5c}$$

and

$$\text{GFVAS}(i,j) = \text{GFVA}(i,j)/\text{FINO}(i,j). \tag{5d}$$

We say that a value chain is globally fragmenting when the change in global FVA shares is positive. It should be noted that it is possible that a value chain fragments regionally as well as globally, when there is a decline in the domestic value-added share. The two decompositions shown in Table 1 illustrate this. For the German transport equipment value chain, for example, RFVAS increased from 13.2 to 18.6 percent, while global FVA shares grew from 7.9 to 15.4 percent.

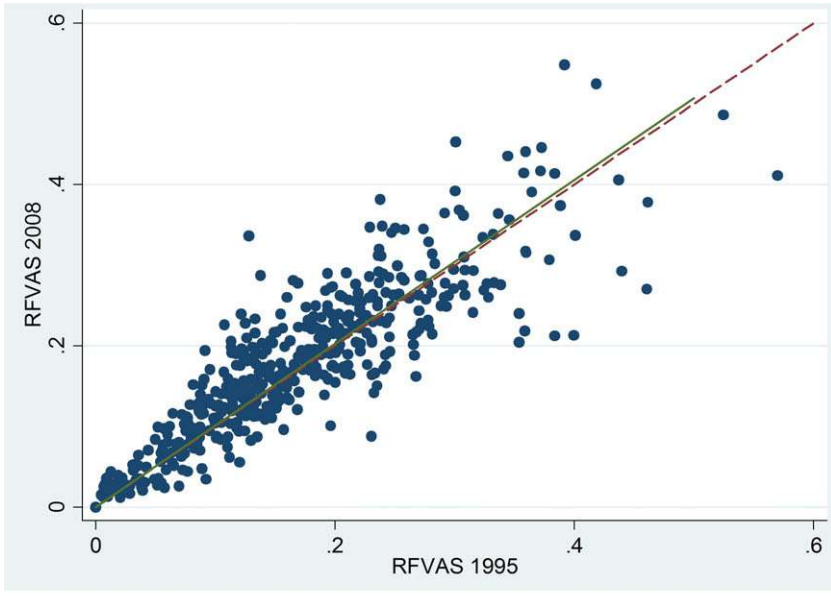
In line with Baldwin and Lopez-Gonzalez (2013), we distinguish three major regional trading blocs: EU, including the 27 member countries of the EU as of 2011; NAFTA, the North American Free Trade Agreement countries including Canada, Mexico, and the United States; and East Asia comprising China, Japan, South Korea, and Taiwan. While the latter region does not have an exclusive multilateral trade agreement among its members, it is characterized by strong trade and investment links. We analyze the changes in regional and global FVA shares for 474 value chains in these 34 countries. Figures 4(a) and 4(b) present simple plots of the observations of regional FVA shares and global FVA shares in 2008 against their values in 1995, as in Figure 2. Most regional FVA shares and global FVA shares were higher in 2008 than in 1995, which indicates that both regional and global fragmentation contributed to the international fragmentation of value chains. The differences in slopes of the regression lines through the origin are striking, though. For regional FVA shares, its slope is only 1.01 (significantly different from unity at a 5 percent level, according to a Wald test), while the slope is 1.36 for global FVA shares. This is a first indication that the trend toward value chain fragmentation across trade blocs has been more important than the trend toward fragmentation within trade blocs, in the 1995–2008 period.

Trends in Regional and Global Value Chain Fragmentation

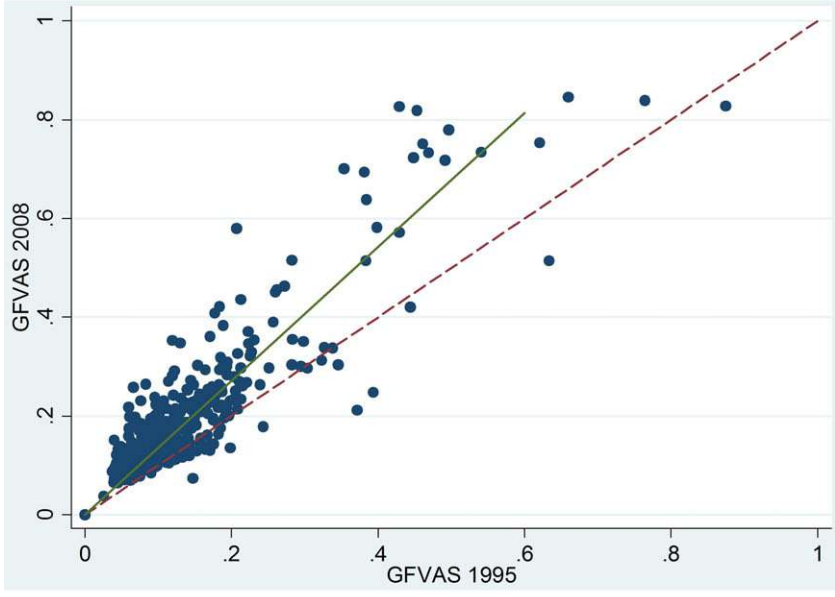
In Table 3, we have aggregated the FVA in product value chains by country-of-completion (using final output values as weights).[19] The first three columns present results for regional FVA shares. Regional FVA shares are given for 1995 and 2008, and the change over this period indicates regional fragmentation. The next three columns show the same, but for global FVA shares, which show trends in global fragmentation. The last three columns show the percentage point difference between levels and changes of global FVA shares and regional FVA shares. The first row, for example, refers to the

[18]The term "*global* foreign value added" is chosen to emphasize that this measure shows how much of a final product's value is added in countries that are really distant from the location of the last stage of production. It should not be conceived as value that is added anywhere in the world, because that would be equal to the value of the final product, by definition (see equations (3), (5a), and (6a)).

[19]The country-of-completion characteristic is by far the most important determinant of a product's distribution of value added. The regression of FVA shares on year dummies, industry-of-completion dummies, and country-of-completion dummies used to produce Figure 3 indicates that 42 percent of the variation in FVA shares can be attributed to variation in the country-of-completion. The industry-of-completion and year dummies account for 22 and 2 percent of the total variation, respectively.



(a) Foreign value added from within the region (Regional fragmentation)



(b) Foreign value added outside the region (Global fragmentation)

Notes: Each dot represents the share of foreign value added in final output of a product in 1995 and 2008. The shares for regional fragmentation are calculated according to Equations (5a–b), and for global fragmentation according to (5c–d). Observations have been included for 474 value chains, identified by 14 manufacturing industries-of-completion in 34 EU, NAFTA, and East Asian countries. The dashed line is the 45-degree line. The solid line has been obtained by OLS regression through the origin.

Source: Authors' calculations based on World Input-Output Database (November 2013 release).

FIGURE 4: Foreign Value-Added Shares in Output of Final Manufactures.

TABLE 3: Regional and Global FVA Shares in Output of Final Manufactures by Country

	Regional Foreign Value-Added Share (RFVAS)			Global Foreign Value-Added Share (GFVAS)			Difference between GFVAS and RFVAS (%-Points)		
	1995	2008	2008–1995	1995	2008	2008–1995	1995	2008	2008–1995
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
European Union									
Hungary	20.0	31.6	11.6	13.8	22.3	8.5	−6.2	−9.2	−3.0
Slovak Republic	20.5	29.4	8.8	13.0	23.8	10.8	−7.6	−5.6	2.0
Luxembourg	34.5	41.6	7.0	8.5	11.8	3.3	−26.1	−29.7	−3.7
Bulgaria	12.0	18.5	6.5	20.5	29.6	9.2	8.5	11.2	2.6
Poland	11.7	18.0	6.3	6.4	15.5	9.1	−5.3	−2.6	2.8
Austria	17.7	23.9	6.2	8.5	15.1	6.6	−9.2	−8.8	0.4
Ireland	20.8	26.6	5.8	19.2	24.5	5.3	−1.6	−2.0	−0.4
Czech Republic	22.7	28.5	5.8	10.8	20.8	9.9	−11.9	−7.7	4.2
Latvia	16.1	21.2	5.1	11.4	13.4	2.0	−4.7	−7.8	−3.1
Germany	10.1	14.4	4.4	8.0	15.7	7.7	−2.1	1.3	3.3
Sweden	18.3	22.4	4.0	10.5	17.6	7.1	−7.9	−4.8	3.1
Romania	10.8	14.6	3.9	10.3	13.6	3.3	−0.5	−1.0	−0.5
Denmark	17.3	21.1	3.8	8.6	14.4	5.7	−8.7	−6.7	2.0
France	13.0	14.8	1.8	8.8	16.4	7.7	−4.2	1.7	5.9
Spain	13.3	15.0	1.7	8.8	17.4	8.6	−4.5	2.3	6.9
Belgium	32.7	34.0	1.3	12.8	21.4	8.6	−19.8	−12.5	7.3
Finland	14.9	16.1	1.1	11.7	21.5	9.8	−3.2	5.4	8.7
Portugal	20.0	20.9	0.9	10.5	18.3	7.8	−9.4	−2.6	6.9
United Kingdom	12.0	12.2	0.2	9.9	14.0	4.1	−2.1	1.9	3.9
Italy	11.5	11.5	0.0	9.0	16.4	7.4	−2.6	4.9	7.5
Slovenia	27.0	26.8	−0.2	9.8	18.0	8.2	−17.3	−8.8	8.4
Netherlands	19.4	18.9	−0.6	16.7	26.8	10.1	−2.7	8.0	10.7
Lithuania	16.0	14.9	−1.1	21.6	32.0	10.5	5.5	17.1	11.6
Cyprus	19.6	17.8	−1.8	16.6	17.7	1.2	−3.0	−0.1	2.9
Greece	13.2	10.3	−2.9	7.6	25.6	18.0	−5.6	15.3	20.9
Estonia	27.4	21.6	−5.8	13.3	18.9	5.6	−14.1	−2.7	11.4
Malta	35.1	27.8	−7.3	13.3	18.8	5.5	−21.8	−9.0	12.8
EU27 region				9.5	17.3	7.8			
NAFTA									
United States	2.5	4.2	1.8	9.8	16.0	6.2	7.4	11.8	4.4
Mexico	16.3	12.5	−3.8	8.2	14.0	5.7	−8.0	1.5	9.5
Canada	20.0	14.6	−5.4	12.1	17.2	5.1	−7.9	2.6	10.5
NAFTA region				9.9	15.8	6.0			
East Asia									
South Korea	7.4	11.8	4.4	18.6	28.8	10.2	11.2	17.0	5.9
Taiwan	10.5	12.9	2.3	22.6	34.2	11.6	12.1	21.3	9.3
Japan	1.0	2.9	1.9	5.5	16.4	10.9	4.5	13.4	9.0
China	5.9	4.9	−1.0	8.7	15.9	7.2	2.8	11.0	8.2
East Asian region				8.2	17.7	9.5			

Note: Weighted regional and global FVA (foreign value added) shares of 14 manufacturing product groups in final output of VCs, by country-of-completion. Shares are weighted with final output for each product group. Entries are grouped by region and sorted on change within each group.

Source: Authors' calculations based on the World Input-Output Database (November 2013 release).

weighted average of all 14 manufacturing value chains for which Hungary is the country-of-completion. The results indicate that over the period 1995–2008, a larger share of the value in Hungarian value chains was added within the EU (an increase of 11.6 percent, column 3), but also a larger share was added outside the EU (8.5 percent, column 6). The trend toward regional fragmentation was stronger than the trend toward global fragmentation as the latter was higher than the former (column 9). By definition, the domestic value-added share must have fallen by 20.1 percent (=11.6 + 8.5) over this period. This fall reflects the opening up of the Hungarian economy in the 1990s.

A number of observations clearly stand out from Table 3. Columns 3 and 6 reveal that value chains for virtually all countries became more internationally fragmented between 1995 and 2008, basically reconfirming our previous result. More importantly, it can be seen that this is mainly due to increases in global FVA shares rather than to increases in regional FVA shares. While both shares were increasing for almost all countries-of-completion, global FVA shares increased more for 35 out of the 40 countries, as shown in column 9. Hence, we can conclude that value chains got more fragmented internationally as a consequence of both regional fragmentation and global fragmentation, but that the latter type was more important. While in 1995, regional FVA shares were still higher than global FVA shares in 27 countries, this has dropped to 17 countries in 2008. If anything, value chains are becoming more global rather than becoming more intraregional nowadays, in contrast to the claim by Baldwin and Lopez-Gonzalez (2013). These general trends are found for all three regions, but there are also some clear differences. Trends toward global fragmentation have been strongest in the East Asian region as the weighted average of global FVA shares in East Asian value chains increased from 8.2 percent in 1995 to 17.7 percent in 2008. The increases of global FVA shares in EU value chains and in particular NAFTA value chains were more modest (from 9.5 to 17.3 percent and from 9.9 to 15.8 percent, respectively).

The strong increase in global FVA shares found for East Asia might be surprising. Product case studies suggest a highly integrated production system with Japan, South Korea, and Taiwan delivering complex components for further processing in China, before final products are exported to world markets. The small and declining East Asian share in Chinese value chains (column 3) does not contradict the case study results, but reflects that the highly integrated Asian production system pertains to a relatively small part of final manufacturing output in China. For Chinese electronics, for example, regional FVA shares were much higher and remained constant over the period (at 9.5 percent). For other manufacturing products, however, China mainly relies on non-East Asian providers of intermediates (in particular from other parts of Asia) and raw materials (mainly from Africa and Australia).

The NAFTA region value chains appear to have become less regionally fragmented since 1995. For both Canadian and Mexican value chains, other NAFTA members became less important. Only U.S. value chains became more reliant on other NAFTA countries, but the degree of regional fragmentation is still low. Of all regions, NAFTA is the least integrated with the rest of the world in 2008.

Within the EU, we find a trend toward fragmentation within the region for a subset of countries on the one hand, and a general trend toward global value chain fragmentation for all member states. The first is clearly related to the reconfiguring of production processes in Europe, as Eastern European countries were quickly integrated with the old members of the Union. The results in Table 3 are ranked by the change in regional fragmentation within the EU, and many new member states are in the top of the ranking. In particular, in Bulgaria, Hungary, the Slovak Republic, and Poland, value chains have shown some of the largest trends toward regional fragmentation. Value chains of major new member states appear to rely increasingly on upstream activities elsewhere in Europe. Much of this was

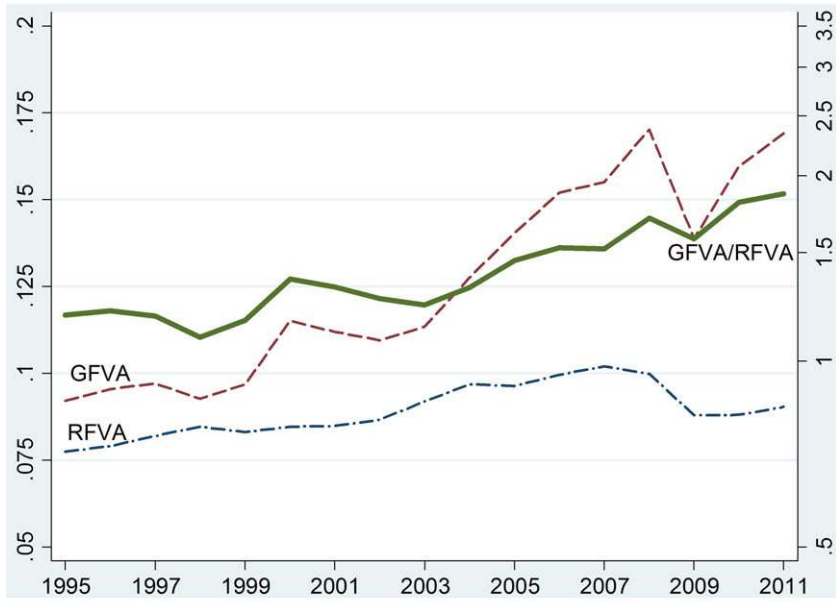
mirrored by fragmentation of production in old EU countries, in particularly Germany and Austria. These findings complement Marin's (2006) results about increasing integration of Eastern European countries in European value chains. At the same time, we find that a sizeable number of EU countries did not participate in this regional fragmentation. Regional shares in value chains in major economies like France, Italy, Spain, and the U.K. barely increased after 1995. Simultaneously, a strong process of globalization was taking place in European value chains. Column 6 shows that in all 27 countries that were EU members in 2011, global FVA shares increased over the period 1995–2008. In fact, the increase in the average global FVA shares was higher than the increase in the average regional FVA shares for all but five countries, as shown in column 9. Global FVA shares in major countries such as France, Germany, Italy, and Spain increased by 7–9 percent. Notwithstanding the strong tendency toward globalization, many value chains in the EU are still predominantly regionally fragmented. In 2008, the average regional FVA shares was still higher than the average global FVA shares for as many as 18 of the EU27 countries.

At first sight, our finding of increasing fragmentation outside regional blocks is at odds with Baldwin and Lopez-Gonzalez (2013), who argue that supply chain trade is mainly a phenomenon that can be observed within trade blocs. Their findings are based on the World Input-Output Database, like this study. They focus on an analysis of trade in intermediate inputs rather than in value added. This type of analysis suffers from the double-counting problems as studied by Koopman et al. (2014) as it is based on gross trade values. Hence, the value of intermediate products in downstream stages of production will also include the value added contributed in upstream activities. If trading within a trade block is more in downstream inputs than trading outside the bloc, within-region trade values will be overestimated. Our accounting framework does not suffer from this bias.

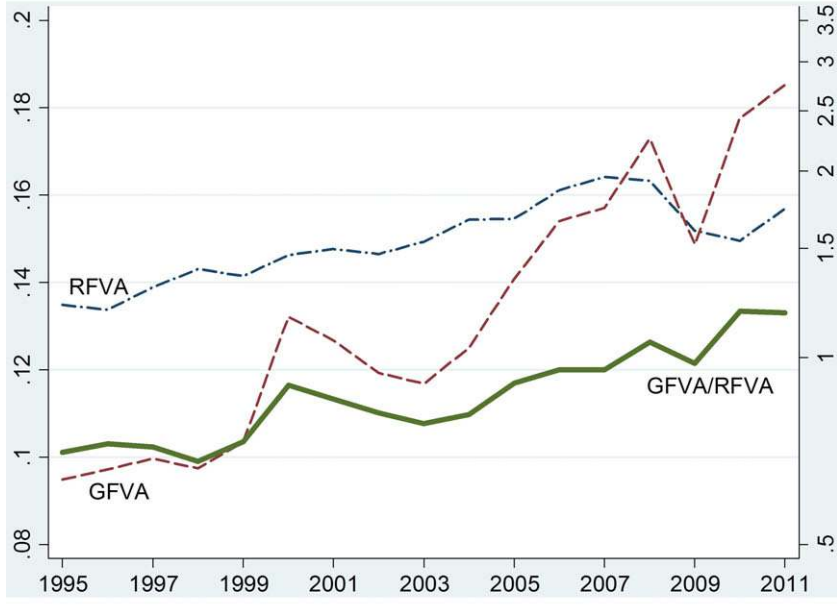
Before and After the 2008 Crisis

In Section 4, we studied to what extent the financial crisis of 2008 affected the international fragmentation of value chains and found that it had picked up quickly after the initial shock. To conclude our analysis, we address the question whether the nature of this international fragmentation has changed after the shock. Figure 5 presents evidence on the relative importance of regional FVA and global FVA, for the entire set of 34 countries studied and separately for the 27 countries of the EU. The results have again been obtained by aggregating over product value chains, weighted by their final output values.

Averaged over all 34 countries, we see that the regional FVA shares increased rather steadily from about 7.5 percent in 1995 to 10 percent in 2008. In the crisis year, it dropped to about 8.5 percent and it did not increase afterward. Global FVA shares also increased almost monotonically until 2008 but at a faster pace: from 9 percent in 1995 to 17 percent in 2008. Contrary to regional fragmentation, global fragmentation of value chains picked up immediately after the crisis and had reached the precrisis level again in 2011. This increasing trend toward truly global fragmentation is illustrated by the increasing ratio of the global and regional FVA shares given in Figure 5. These patterns are also observed when focusing on the 27 countries of the EU only. Figure 5b shows that the tendency toward truly global fragmentation is even stronger in Europe than in the other regions, both before and after 2008. The ratio of global to regional FVA increased from 0.70 in 1995 to 1.06 in 2008. Just before the crisis, global FVA shares surpassed regional FVA shares. The gap has grown since, in particular because global FVA shares rebounded within a year to levels exceeding their precrisis values, while regional fragmentation did not recover immediately and had not attained its precrisis level in 2011. Similar calculations



(a) 34 countries-of-completion in EU, East Asia and NAFTA



(b) 27 countries-of-completion in Europe

Notes: Regional and global foreign value-added shares (RFVA and GFVA) in final output of manufacturing products, aggregated over 14 product groups and 34 and 27 countries-of-completion, respectively. Shares are weighted with final output for each product group. GFVA and RFVA shares are depicted on the left axis, and their ratio along the right logarithmic axis.

Source: Authors' calculations based on World Input-Output Database (November 2013 release).

FIGURE 5: Trends in Regional and Global Fragmentation of Value Chains of Final Manufactures.

for NAFTA and East Asia show comparable increases in the ratio of global to regional FVA until 2008. The drop in the crisis, however, was deeper, and had not been restored to precrisis levels in 2011, see Figure B1 in the Appendix.

Additional analysis reveals that China appears to have played an important role in the relocation of activities in European value chains. Over 2008–2011, Chinese value-added shares increased in the value chains of 23 of the EU27 countries, including all large economies. For example, for German value chains, Chinese shares were growing while the shares of all other non-EU countries taken together declined. These results might reflect a situation in which firms have been forced by the crisis to relocate stages of production outside Europe in a continuing search for lower production costs. Changes in the composition of consumption bundles may also have played a role. One might hypothesize that the prolongation of the crisis has led consumers to substitute away from high-quality products to cheaper varieties. Furthermore, it is plausible that European shares in the value chains of these lower quality product varieties are lower. The product aggregation level in the WIOD database is not fine-grained enough, however, to examine this hypothesis quantitatively.

The Role of Natural Resource Price Increases

One might argue that our finding of global fragmentation of value chains is driven mainly by the increasing price of natural resources, in particular crude oil and natural gas, but also mineral ores. These resources are clustered in a few countries outside the regions analyzed in this paper. Given limited substitution possibilities, this change in relative prices of mining products will drive up the foreign value added in manufacturing products, in particular value added outside the region. To test the robustness of our findings, we therefore redo the analysis, but leaving out all value added originating from mining industries in any country in the world. In Figure B2, we provide alternative graphs for regional and global FVA shares based on the new country value-added distributions. As expected, the ratio of global to regional FVA shares is smaller when mining value added is excluded. For example, for Europe, global FVA shares now remain below regional FVA throughout the period, reflecting the dependence of European production of final products on mining and drilling activities elsewhere in the world. At the same time, however, it is clear that the faster increase in global FVA shares found before is not driven mainly by the hike in resource prices: without mining the ratio is still increasing from 0.62 in 1995 to 0.97 in 2011, and similarly for the 34 countries as a whole (from 1.06 to 1.48).

6. CONCLUDING REMARKS

In this paper, we addressed the issue whether fragmentation of product value chains was mainly within or across regional blocs. To this end, we introduced a novel approach extending the fragmentation measure introduced by Feenstra and Hanson (1999) to a multicountry setting and applied it to a new set of WIOTs. Based on data for 40 countries and 14 manufacturing product groups for the period from 1995 to 2011, we found two main results.

First, value chains have become increasingly internationally fragmented. FVA shares are considerably higher in 2011 than in 1995, and the financial crisis in 2008 seems to have caused only a temporary dip. This result is observed for virtually all chains and does not depend on the nature of the product or the country in which the last stage of production took place.

The second finding is that global fragmentation of value chains has progressed much faster than regional fragmentation. Since 1995, FVA from outside the region is increasing much faster than from inside the region. Geographical proximity or belonging to a trade bloc still matters for the country distribution of value added within product value chains, but much less so than 15 years ago. The price increase in natural resources since 1995 explains only a small part of this increase. Rather the opening up of China and other countries with extremely low labor costs, combined with rapidly declining coordination costs, appears to trump the previous trend toward regional fragmentation. This tendency seemed to be propelled by the 2008 financial crisis. Global value chains are finally becoming truly global.

The present analysis suggests various avenues for future research. The World Input-Output Database does not only contain information on value added, but also provides information on the type of production factors involved: capital and labor of various skill categories. This type of information has extensively been used in Timmer et al. (2014, 2013) to study the competitiveness of European countries and to document stylized facts about the distributional consequences of the emergence of global value chains. Using the measures developed in this paper, one could empirically test the hypothesis that advanced countries are increasingly specializing in skill-intensive activities such as design, marketing, and research and development (e.g., Sinn, 2006; Baldwin and Evenett, 2012).

Another dimension along which more insights can be gained is the increase of detail at the subnational level. Cherubini and Los (2013) and Dietzenbacher, Guilhoto, and Imori (2013) have pioneered regional disaggregation of the Italian and Brazilian parts of WIOD's WIOTs. This allows them to study to what extent regional economies benefit from participation in national and global value chains, offering macroeconomic perspectives on the heterogeneous case-study-based results (Humphrey and Schmitz, 2002). It would, in particular, allow a sharper focus on the issue of complementarities of activities in value chains, and deeper insight into the geographical nature of various spillovers (Baldwin and Venables, 2012).

Finally, future research might focus on the role of potential determinants of international production fragmentation. For example, Johnson and Noguera (2012b) found that participation in bilateral free-trade agreements positively affects the vertical specialization of countries in trade. The increasing popularity of bilateral over multilateral agreements might have deep impacts on the future prospects of countries to benefit from international fragmentation. Further development of high-quality and fine-grained data is paramount in developing deeper insights into this process.

APPENDIX A: DERIVATION OF VALUE-ADDED CONTRIBUTIONS BY COUNTRY TO PRODUCT VALUE CHAINS (EQUATION 1)

To compute the value-added contributions of each of the countries to the value of final output of industry i in country j, a global input–output table as depicted in Figure A1 is taken as the point of departure. The number of industries in each of the countries is S, and the number of countries is N. The number of final demand categories per country is indicated by C. The $(SN \times SN)$-matrix $\mathbf{A}$ and the (SN)-vector $\mathbf{v}$ are obtained as $\mathbf{A} = \mathbf{Z}(\hat{\mathbf{x}})^{-1}$ and $\mathbf{v}' = \mathbf{w}'(\hat{\mathbf{x}})^{-1}$, respectively.[20] $\mathbf{A}$ gives the intermediate inputs required

[20] $\mathbf{Z}$ contains all submatrices $\mathbf{Z}^{11}$, $\mathbf{Z}^{1\cdot}$, $\mathbf{Z}^{NN}$. in Figure A.1. $\mathbf{x}$ should be interpreted in the same vein. A prime denotes transposition of a vector or matrix.

per unit of gross output, while $\mathbf{v}$ represents the value added generated per unit of gross output. As a first step in computing the income generated in the VC for (i,j), we derive the payments for capital and labor in the country-industry-of-completion. This equals $\mathbf{g}^{\text{tier0}} = \hat{\mathbf{v}}\tilde{\mathbf{F}}\mathbf{e}$, in which $\mathbf{e}$ is an (CN)-summation vector and $\tilde{\mathbf{F}}$ stands for a final demand matrix (of dimensions $(SN \times CN)$) in which only the cells in the row representing final demand for country-industry (i,j) have their actual values and all other final demand is set to 0. This implies that $\tilde{\mathbf{F}}\mathbf{e}$ is an (SN)-vector with a single positive element, which is obtained by adding domestic and foreign final demand for (i,j)'s products. The elements of $\mathbf{g}^{\text{tier0}}$ (which is an (SN)-vector with value added generated in the final production stage) equal zero for all industries other than (i,j). As the stylized example in Figure 1 in the main text shows, the production of these final product deliveries does not only require labor and capital inputs, but also intermediate inputs from (domestic and foreign) first tier suppliers. The gross outputs of these industries attributable to final demand for (i,j)'s products equals $\mathbf{A}\tilde{\mathbf{F}}\mathbf{e}$ and the value added by first-tier suppliers can be expressed as $\mathbf{g}^{\text{tier1}} = \hat{\mathbf{v}}\mathbf{A}\tilde{\mathbf{F}}\mathbf{e}$. The intermediate products $(\mathbf{A}\tilde{\mathbf{F}}\mathbf{e})$ delivered by first-tier suppliers in their turn require intermediate inputs, from second-tier suppliers. These output levels equal $\mathbf{A}(\mathbf{A}\tilde{\mathbf{F}}\mathbf{e})$ and the associated second-tier global value-added contributions are $\mathbf{g}^{\text{tier2}} = \hat{\mathbf{v}}\mathbf{A}(\mathbf{A}\tilde{\mathbf{F}}\mathbf{e})$. Continuing this line of reasoning for higher tier suppliers and adding over tiers, we can write for the vector of *total* value-added levels (see Miller and Blair, 2009, for the mild conditions under which the summation converges):

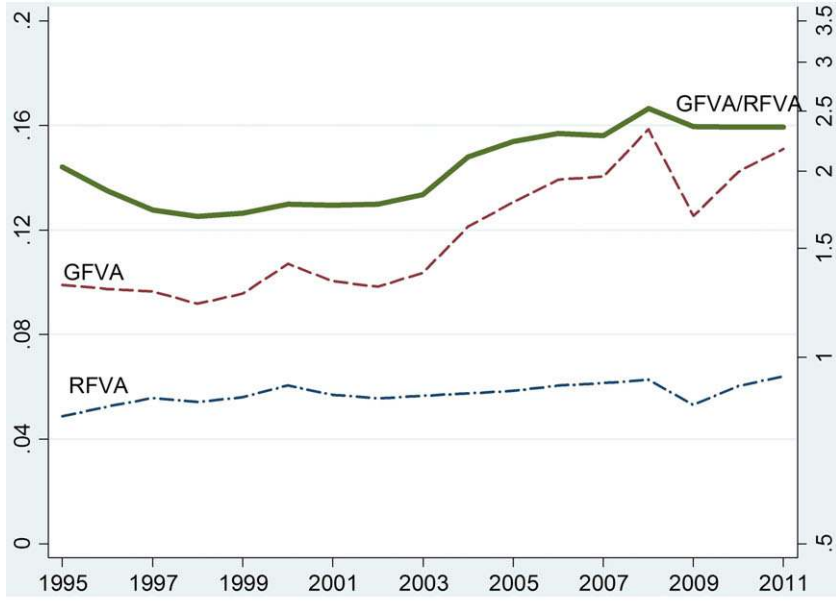
$$\begin{aligned}\text{(A.1)}\qquad \mathbf{g} &= \mathbf{g}^{\text{tier0}} + \mathbf{g}^{\text{tier1}} + \mathbf{g}^{\text{tier2}} + \mathbf{g}^{\text{tier3}} + \cdots = \hat{\mathbf{v}}\,(\mathbf{I} + \mathbf{A} + \mathbf{A}^{\mathbf{2}} + \mathbf{A}^{\mathbf{3}} + \cdots)(\tilde{\mathbf{F}}\mathbf{e}) \\ &= \hat{\mathbf{v}}(\mathbf{I} - \mathbf{A})^{-1}(\tilde{\mathbf{F}}\mathbf{e}).\end{aligned}$$

Equation (A.1) is identical to Equation (1) in the main text. The matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is the well-known Leontief inverse. $\mathbf{g}$ contains the value added generated in each of the industries in each of the countries that can be attributed to the global value chains for country-industry (i,j)'s final products. In order to obtain value added to (i,j)'s value chain by country, the elements of the (SN)-vector $\mathbf{g}$ that correspond to industries in a country are simply added to each other.

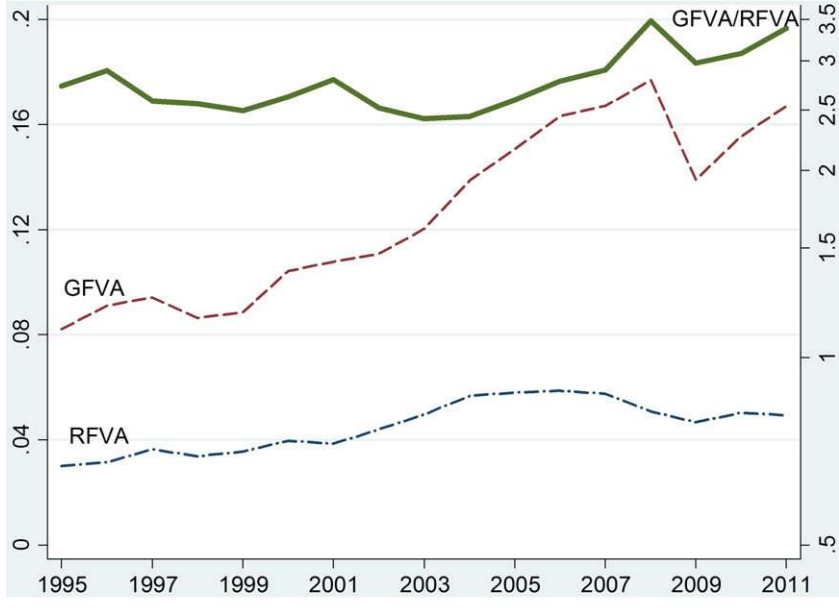
	Intermediate use (S columns per country)			Final use (C columns per country)			Total
	1	...	N	1	...	N	
S Industries, country 1	$\mathbf{Z}^{11}$	$\mathbf{Z}^{1\cdot}$	$\mathbf{Z}^{1N}$	$\mathbf{F}^{11}$	$\mathbf{F}^{1\cdot}$	$\mathbf{F}^{1N}$	$\mathbf{X}^{1}$
...	$\mathbf{Z}^{\cdot 1}$	$\mathbf{Z}^{\cdot\cdot}$	$\mathbf{Z}^{\cdot N}$	$\mathbf{F}^{\cdot 1}$	$\mathbf{F}^{\cdot\cdot}$	$\mathbf{F}^{\cdot N}$	$\mathbf{X}^{\cdot}$
S Industries, country N	$\mathbf{Z}^{N1}$	$\mathbf{Z}^{N\cdot}$	$\mathbf{Z}^{NN}$	$\mathbf{F}^{N1}$	$\mathbf{F}^{N\cdot}$	$\mathbf{F}^{NN}$	$\mathbf{X}^{N}$
Value added	$(\mathbf{w}^{1})'$	$(\mathbf{w}^{2})'$	$(\mathbf{w}^{N})'$				
Output	$(\mathbf{x}^{1})'$	$(\mathbf{x}^{2})'$	$(\mathbf{x}^{N})'$				

FIGURE A1: A Stylized World Input–Output Table.

APPENDIX B: ADDITIONAL FIGURES



(a) Three countries-of-completion in NAFTA

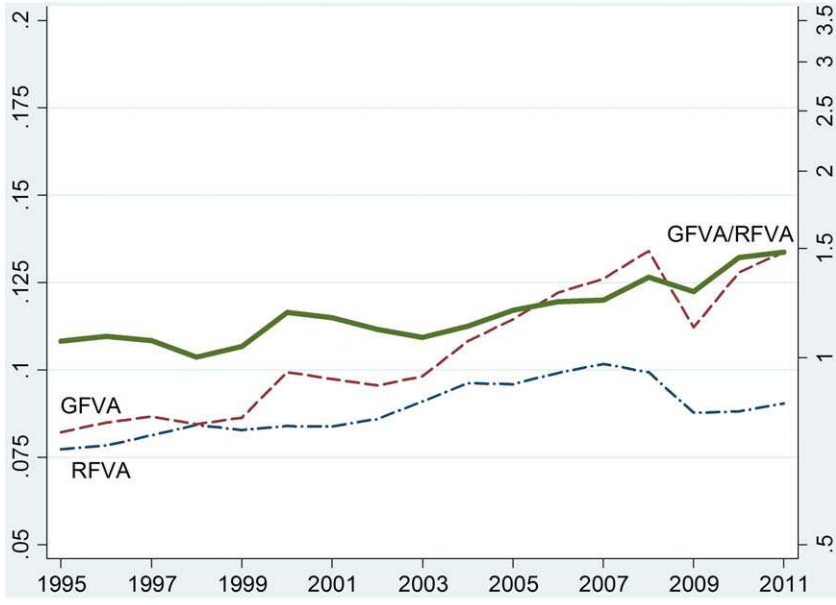


(b) Four countries-of-completion in East Asia

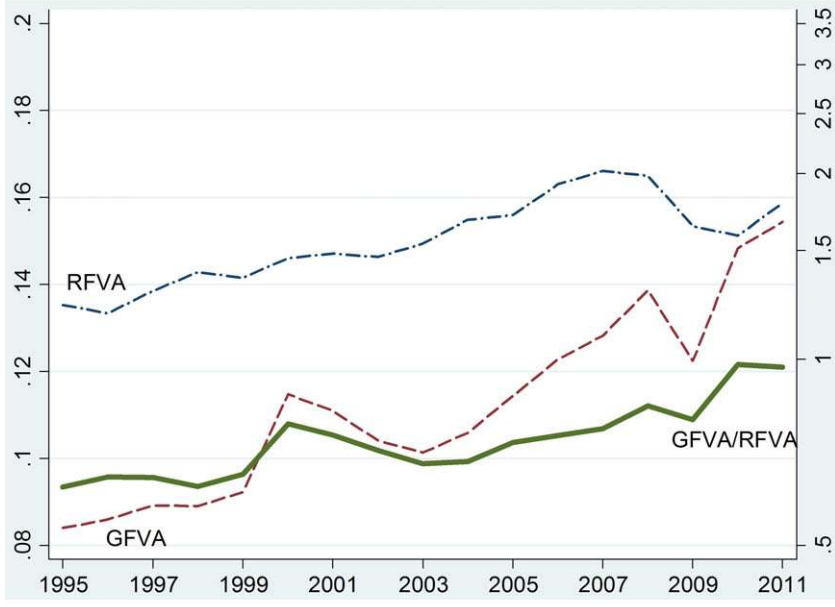
Notes: Regional and global foreign value-added shares (RFVA and GFVA) in final output of manufacturing products, aggregated over 14 product groups and three and four countries-of-completion, respectively. Shares are weighted with final output for each product group. GFVA and RFVA shares are depicted on the left axis, and their ratio along the right logarithmic axis.

Source: Authors' calculations based on World Input-Output Database (November 2013 release).

FIGURE B1: Trends in Regional and Global Fragmentation of Value Chains for NAFTA and East Asia.



(a) 34 countries-of-completion in EU, East Asia and NAFTA



(b) 27 countries-of-completion in Europe

Notes: Regional and global foreign value-added shares (RFVA and GFVA) in final output of manufacturing products, aggregated over 14 product groups and 34 and 27 countries-of-completion, respectively. Shares are weighted with final output for each product group. All value added in mining and quarrying industries has been excluded from the computations. Shares are weighted with final output for each product group. GFVA and RFVA shares are depicted on the left axis. Their ratio is measured along the right logarithmic axis.

Source: Authors' calculations based on World Input-Output Database (November 2013 release).

FIGURE B2: Trends in Regional and Global Fragmentation of Value Chains, Exclusive of Value Added in Mining Industries.

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