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Slicing Up Global Value Chains

Marcel P. Timmer, Abdul Azeez Erumban,
Bart Los, Robert Stehrer and Gaaitzen J. de Vries

/ university of groningen   / groningen growth and development centre

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Marcel P. Timmer [a,*]
Abdul Azeez Erumban[a]
Bart Los[a]
Robert Stehrer[b]
Gaaitzen J. de Vries[a]

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Affiliations
[a] Groningen Growth and Development Centre, Faculty of Economics and Business, University of Groningen
[b] The Vienna Institute for International Economic Studies (WIIW)

* Corresponding Author
Marcel P. Timmer
Groningen Growth and Development Centre
Faculty of Economics and Business
University of Groningen, The Netherlands
m.p.timmer@rug.nl

Abstract

Studies of the effects of production fragmentation on factor income distributions typically analyze changes at the country, region, industry or firm level. In this paper we take the perspective of a product, and focus on the discrete activities in distinct locations, which altogether form a production network starting at the conception of the product and ending at its delivery. We take a macro-perspective and analyze factor content patterns for a wide set of manufacturing product groups, and study their development over time. Using a decomposition technique originally introduced by Leontief (1936), we 'slice up the global value chains' and trace the value added by all labor and capital that is directly and indirectly used for the production of final manufacturing goods.

We find that the process of international fragmentation as measured by the foreign value-added content of production has rapidly increased since 1995 in most global value chains, but is still far from 'completed'. We then turn to an analysis of the value distribution across production factors, and find a strong shift towards value being added by capital and high-skilled labor, and away from less-skilled labor. We also find a major shift in the production location, as the overall value added in advanced countries did not increase over the period 1995-2008 and all growth was realized in other emerging countries. Finally, we present evidence on the importance of manufactures GVCs for employment. We show how advanced nations increasingly specialize in activities carried out by high-skilled workers. Taken together the results suggest that the increasing possibilities for international production fragmentation had pervasive consequences for the factor income distribution both across and within countries.

1. Introduction

Fostered by plummeting costs of communication and coordination, opportunities for the international fragmentation of production processes are rising. Whereas in the past the various stages of production needed to take place near each other, it has become increasingly profitable to separate them and locate at the lowest-cost location. This process of 'unbundling' has a long history, at least going back to the 1970s when Japanese and US multinationals started to relocate activities to East-Asia and Mexico. European firms quickly seized the opportunity of integrating Eastern Europe after the break down of the Soviet bloc in 1989. The consequences for the distribution of income across and within countries have been hotly debated for a long time in the wider context of the effects of "globalization". In essence, international fragmentation of production expands the opportunities of countries to specialize according to comparative advantage and hence gain from trade. As such it is on average welfare improving for all countries involved, but not necessarily for all suppliers of production factors involved (Feenstra, 1998; Baldwin, 2006).

Recently, it has been suggested that the uneven effects have become more important as advances in information and communication technology continue unabated. And while in the past fragmentation was mainly regionally, the rise of China, India and other emerging economies offered unprecedented opportunities for re-organizing production on a truly global scale. Studies of the effects of production fragmentation on factor income distributions typically analyze changes at the country, region, industry or firm level (see Goldberg and Pavcnik 2007 and Harrison, McLaren and McMillan 2011 for recent overviews). Alternatively, one can take the perspective of a product, and focus on the discrete activities in distinct locations, which altogether form a production network starting at the conception of the product and ending at its delivery (as suggested by e.g. Grossman and Rossi-Hansberg 2007). In this paper we provide such an alternative approach and outline a new empirical framework to study the changes in the factor content and location of production. Thus we provide a comprehensive macro-economic analysis of international production fragmentation.

Our approach is inspired by detailed product-level analyses, in particular by Dedrick et al. (2010) which provided an already classic study of the *i*Pod. The *i*Pod is assembled in China from on several hundreds of components and parts that are sourced from around the world. The lead firm in this production network is Apple, a US-based multinational company, which is estimated to capture about a third of the output value. This is mainly compensation for Apple's provision of intangibles like software and designs, market knowledge, intellectual property, system-integration and cost-management skills and a high-value brand name. The remaining two-third of the value is added in the physical production process of the product, of which a major part goes as profits for manufacturing the high-value components, such as the hard disc drive and

display from Toshiba, a Japanese firm, and the memory from Samsung, a South Korean firm. All in all, the value added in China by assembling components, and testing and packaging the final product is estimated to be no more than three per cent of the output price. Other studies of tablets, mobile telephones and laptops suggest a similar division of activities and value in global production, in which advanced nations specialize in capital and high skilled labor, and capturing most of the value (see e.g. Ali-Yrkkö, Rouvinen, Seppälä and Ylä-Anttila, 2011). But how representative are these case-studies of high-end electronics? And how does the factor content change over time when production chains expand?

In this paper we take a macro-perspective, and analyze factor content patterns for a wide set of manufacturing product groups, and study their development over time. Using a decomposition technique introduced by Leontief (1936), we 'slice up the global value chains' to borrow the term from Krugman (1995). The novelty of our approach is that the unit of observation is not a firm, industry, region or country but a product group. We trace the value added by all labor and capital that is directly and indirectly used for the production of final manufacturing goods. We denote these goods by the term "manufactures". Production systems of manufactures are highly prone to international fragmentation as activities have a high degree of international contestability: they can be undertaken in any country with little variation in quality.[1] It is important to note that global value chains of manufactures do not only contain activities in the manufacturing sector. They also include activities in other sectors such as agriculture, utilities and business services that provide inputs at any stage of the production process. These indirect contributions are sizeable and will be explicitly accounted for through the modeling of input-output linkages across sectors. This has recently become feasible due to the development of the World Input-Output Database (WIOD). This database contains inter-industry and inter-national transactions for fifty-nine product groups produced in thirty-five industries in forty countries, alongside data on production factor requirements at the country-industry level (Timmer (ed.), 2012).

The main aim of the paper is to establish a series of stylized facts on global fragmentation of production that can serve as a starting point for deeper analysis of its causes and consequences. It is organized as follows. We start with analyzing fragmentation and the effects on factor contents of production in a simple Heckscher-Ohlin framework without factor price equalization (from Deardorff, 2001), and conclude that a wide variety of outcomes is feasible. These effects therefore become an empirical issue. A general "task" framework of production by Acemoglu and Autor (2011) appears

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[1] This is not to deny that particular business, insurance or finance services are also produced in global production networks. Insofar they are intermediates for manufacturing goods they are part of manufactures GVCs. Many services, such as for example personal or retail services require a physical interaction between the buyer and provider of the service such that a major part of the value added in these chains is not organised in extensive GVCs.

4

to be particular useful to organizing thinking on the trends found and is discussed as well. We then present the methodology and data, outlining the major issues at stake and referring the reader to other work for more detail. In turn, we discuss four major trends in global value chain production of manufacturing goods. To preview our results, the first finding is that the process of international fragmentation as measured by the foreign value-added content of production has rapidly increased since 1995 in most global value chains, but is still far from 'completed'. We then turn to an analysis of the value distribution across production factors, and find a strong shift towards value being added by capital and high-skilled labor, and away from less-skilled labor. We also find a major shift in the production location, as the overall value added in advanced countries did not increase over the period 1995-2008 and all growth was realized in other emerging countries. Finally, we present evidence on the importance of manufactures GVCs for employment. And we show how advanced nations increasingly specialize in activities carried out by high-skilled workers. Taken together the results suggest that the increasing possibilities for international production fragmentation had pervasive consequences for the factor income distribution both across and within countries.

2. International fragmentation, tasks and factors of production: some recent conceptual frameworks

The unbundling of production has stimulated new ways of thinking about the nature of the production process in various sub-disciplines in the economics profession including, but not limited to, work in international trade, labor economics, macro-economics, economic geography and economic growth. Central in these new paradigms is the introduction of "tasks" as the units of work activity that produce output. Traditionally the production process was conceived of as a direct mapping from factor inputs to output. In recent thinking, output is generated as a result of a set of 'tasks' which are to be completed by various combinations of production factors. So rather than a direct mapping from labor and capital inputs to output, factors map into tasks, which map into output. Workers differ in their capabilities to perform various tasks. This allows for a much richer modeling of complementarities and substitution possibilities between various factors of production, and of the role of technological change. Obviously, the possible substitution between domestic and foreign factors is of particular interest for this study. Below we provide some examples of this work that will be useful in the interpretation of our findings later on.

5

2.1 Fragmentation and specialization in a Heckscher-Ohlin model

With fragmentation, one might expect that the broad Heckscher-Ohlin predictions will still hold: countries will carry out those tasks in GVCs that are relatively intensive in their relatively abundant factors. However, the dynamic implications are not obvious and countries do not necessarily specialize in their abundant factor. The actual shift in specialization of countries after fragmentation will ultimately depend on the factor intensities of all potential fragmented tasks, and many outcomes are possible. We briefly outline this logic in a simple Heckscher-Ohlin setting, elaborating on Deardorff (2001).

Assume a two country, two goods and two factors Heckscher-Ohlin setting. We will compare the factor content of production in both countries before and after fragmentation. Figure 1 shows the unit cost lines of the two countries: CD for the advanced, and AB for the emerging country. The unit cost line represents the combination of low- and high-skilled workers that together cost one dollar. The slope of this line depends on the wage ratio of the two groups, indicating that the emerging country is relatively abundant in low-skilled, and the advanced country in high-skilled. Note that we assume the absence of factor price equalization, such that the lines are different. Also drawn are the unit value isoquants of goods 1 and 2, reflecting the quantities of inputs needed to produce one dollar of output of the good. The production process of good 1 is relatively more skill intensive and will initially be produced in the advanced country. The amounts of labor used are given by OX. Similarly, good 2 is produced in the emerging country with inputs OY.

Now suppose that the production process of good 1 consists of two tasks. One task is relatively low-skilled intensive and uses OF inputs (one may think of this as assembly on the basis of components). The other task is high-skilled intensive and uses FX inputs (one may think of this as high-tech component making). It is obvious that there is no gain for the advanced country to fragment its production process domestically. The vector sum of OF and FX is equal to OX such that no profit can be made from fragmentation within the country. Potentially, a profit could be made by shifting the OF task to the emerging country to benefit from the lower price of low-skilled labor. In fact, any task with a skill intensity lower than OS can be cheaper carried out in the emerging country.

Initially the additional production costs of coordinating tasks across borders are too high, for example because of trade barriers, tariffs, transport costs, communication and other coordination costs. But now suppose that these costs are falling, such that international production fragmentation becomes profitable. What will happen to the factor content of production in the two countries? As the relatively low-skilled task is offshored, production in the advanced country will become more high-skilled, further specializing in its abundant factor. In the particular example given here, the skill intensity of production in the emerging country will also increase. The skill intensity of task OF is higher than of original production OY, such that average skill intensity in the emerging

country will also increase after fragmentation.[2] This was indeed the prediction of the seminal model of offshoring by Feenstra and Hanson (1996), who introduced trade in tasks, as capital moves from advanced to the emerging country.

However, it should be clear from the figure that this is just one possible outcome. If OF had a lower skill intensity than OY, the average skill intensity of production in the emerging country would actually decrease rather than go up. Even more, assume that the production of good 2 can also be fragmented. What will happen to the factor intensities in the advanced country? This will crucially depend on the skill intensity of the fragments in production of good 2. If one task is more skill intensive than the original production of good 1 (hence steeper than OX), the same prediction as before will hold: the advanced country will further specialize in skilled tasks. But it might also be the case that good 2 is fragmented in one task that is more skill intensive than OS such that it can be profitable carried out in the advanced country, but is less skill intensive than OX. In that case the skill intensity of production in the advanced country will go down as well. Summarizing, in these type of models, the possibilities to fragment production, and the characteristics of each task (in particular the factor intensity) drive most of the implications. As a result, the literature has produced an array of examples in which a whole variety of outcomes is possible depending on the precise way in which fragmentation is introduced.

In the example discussed so far, it was assumed that the fragmented tasks that are offshored constitute a sufficiently small part of the total economies such that fragmentation will not cause noticeable changes in factor prices in either country. In a full general equilibrium setting, Grossman and Rossi-Hansberg (2008) provide sharper implications of fragmentation. In a two-sector Heckscher-Ohlin model they assume that production requires a continuum of tasks for each sector and for each factor of production. All tasks are required to produce the good and each task can be carried out domestically or abroad. In the latter case a task-dependent cost is incurred. They show that a reduction in the average costs to offshore tasks performed by a given factor has analogous effects to technical change augmenting that particular factor. Depending on the strength of this so-called productivity effect, again various outcomes for factor incomes are possible (Feenstra, 2010).

2.2 A general framework for skills, tasks and technological change in production

Tasks as unit of analysis have also been introduced in recent models of labor demand. Acemoglu and Autor (2011) outline a general framework that revolves around differences in comparative advantages of factors in carrying out tasks: all workers can carry out all tasks, but some are relatively better in carrying out certain tasks. More specifically, they assume that higher skilled workers have an absolute advantage relative

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[2] Note that the example presumes that the production functions of activities are fixed proportions of factor inputs such that substitution is not possible (so-called Leontief fixed coefficients). Whether task OF is carried out in the advanced or emerging country will have no impact on its factor input proportions.

to less skilled workers in all tasks, but the comparative advantage by skill differs. Substitution of skills across tasks is possible, such that there is an endogenous mapping from workers to tasks depending solely on labor supplies and the comparative advantages of the various skill types. Technological change is then modeled through its effect on comparative advantages of various factors. The framework also allows for capital as input, by simply modeling it as another source competing with labor for the supplying of certain tasks. For example, new information technology might be much better in handling routine administrative tasks than skilled white-collar labor (Autor, Levy and Murnane, 2003).

The model encompasses off-shoring of the Grossman and Rossi-Hansberg (2008) type as a special case. Both foreign and domestic labor can supply tasks, and assuming perfect substitution, a task will be supplied through offshoring when this accomplishes the task more cheaply than any combination of domestic labor. Thus factor income shares are determined by the interplay of relative factor prices, elasticities of substitution between factors in carrying out tasks and the nature of technical change, for both domestic and foreign factors. By explicitly modeling these interactions in a comprehensive framework, this new generation of task-based models allows for much richer explanations of the drivers and consequences of international production fragmentation. For example, Costinot, Vogel and Wang (2012) introduce worker heterogeneity in a standard model of international trade, while incorporating sequential production through international input-output linkages. In this model, heterogeneous workers in countries sort themselves into various stages of the production process of a final good. They find that the consequences of opening up to trade on wage inequality may be very different from standard models, depending on the position of the workers in the chain. In particular, they find that in the less advanced country all workers move to earlier stages of production, decreasing wage inequality at the bottom of the skill distribution, but at the same time increasing it at the top.

We will draw upon these frameworks in the remainder of this paper when interpreting the main empirical patterns of factor use in global value chain production.

3. Slicing up global value chains: method and data

In this section we will provide the method and data used to slice up the value of final products into the value added by labor and capital in various countries. Before that however, a discussion of the basic concepts of the analysis and some preliminary definitions are in order.

3.1 Preliminaries: concepts and definitions

A final product is a product that is consumed, and is distinct from intermediates that are used in the process of production. Consumption is broadly defined as private and public consumption, as well as investment. A global value chain (GVC) of a final product is defined as all tasks that are directly and indirectly needed to produce it. This GVC is identified by the industry-country where the last stage of production takes place before delivery to the final user (e.g. iPods from Chinese electronics manufacturing, or cars from German transport equipment manufacturing). The price paid by final users for a particular product will end up as income for all labor and capital employed in its GVC. This is illustrated in Figure 2. It depicts a simplified GVC of a final product from country 3, which includes tasks in country 3, as well as in countries 1 and 2.[3] To produce the good, domestic labor and capital is needed in the industry where the last stage of production takes place and in other domestic industries that deliver intermediates. By summing overall value that is added by domestic labor and capital, the domestic value added content of the product can be calculated. Embodied in imported intermediates, capital and labor in country 2 also contribute to the value of the final product, and similarly value is added in country 1, together making up foreign value added. By our construction method, the sum of domestic and foreign value added will equal the final product value. We will use the domestic share of value added as an indicator of the international fragmentation of production later on. Alternatively one can sum over value added by all labor, irrespective of its location, and similarly for capital. We will use these factor shares in value added to analyze the factor content of GVC production.

3.2 Decomposing GVCs using Leontief's method

In this section we outline our method to slice up global value chains (GVCs). By modeling the world economy as an input-output model in the tradition of Leontief (1936), we can use his seminal insight and trace the amount of factor inputs needed to produce a certain amount of final demand.[4] Leontief started from the fundamental input-output identity which states that all products produced must be either consumed or used as intermediate input in production. This is written as Q=BQ+C where Q denotes outputs, C

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[3] Production processes can be highly fragmented and take many forms, such as goods moving in a sequential manner from upstream to downstream industries with value added at each stage as depicted here, or multiple parts coming together in assembly to form a new component or final product body, described respectively as "snakes" and "spiders" by Baldwin and Venables (2010). Most production processes are complex mixtures of the two.

[4] Variations of this approach are also used in the bourgeoning literature on trade in value added. Our approach is particularly related to the work by Johnson and Noguera (2012a) which extended the results of Hummels, Iishi and Yi (2001) in a multi-regional setting. But rather than using Leontief's insight to analyse the value added content of trade flows, we focus on the value added content of final expenditure. See also Koopman, Wei and Zhang (forthcoming) and Bems, Johnson and Yi (2011) for other recent trade flow applications. The article by Johnson in this *Symposium* provides an overview.

is final consumption and B a matrix with intermediate input coefficients that describe how much intermediates are needed to produce a unit of output of a given product. BQ is then the total amount of intermediates used. The identity can be rewritten as Q=(I-B)$^{-1}$C with I an identity matrix.[5] (I-B)$^{-1}$ is famously known as the Leontief inverse. It represents the gross output value of all products that are generated in all stages of the production process of one unit of consumption. To see this, let Z be a vector column of which the first element representing the global consumption of iPods produced in China, and all other elements are zero. Then BZ is the vector of intermediate inputs, both Chinese and foreign, needed to assemble the iPods in China, such as the hard-disc drive, battery and processors. But these intermediates need to be produced as well and B^{2}Z indicates the intermediate inputs directly needed to produce BZ. This continues until the mining and drilling of basic materials such as metal ore, sand and oil required to start the production process. Summing up across all stages, one derives the gross outputs generated in the production of iPods by (I-B)$^{-1}$Z.[6]

To find the value added by factors we additionally need factor inputs per unit of gross output represented in matrix F. An element in this matrix indicates the value added by a particular production factor as a share of gross output. These are country- and industry-specific, for example the value added per dollar of output by labor in the Chinese electronics industry. To find the value added by all factors that are directly and indirectly involved in the production of a particular final good, we multiply F by the total gross output value in all stages of production given above such that:

$$K = F(I - B)^{-1}C$$

A typical element in K indicates the value added in the production of final good c by a factor f located in country i. By the logic of Leontief's insight, the sum over value added by all factors in all countries that are directly and indirectly involved in the production of this good will equal the output value of that product.[7] Thus we have completed our decomposition of final output into the value added by various production factors around the world.[8]

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[5] See Miller and Blair (2009) for an introduction to input-output analysis.

[6] This is because the summation across all rounds converges to $(I - B)^{-1}Z$ under empirically mild conditions.

[7] This is akin to the notion of "vertically integrated sectors" introduced by Pasinetti (1973). He demonstrated that the price of a commodity j can be regarded as the sum of wages and profits that must be paid in the vertically integrated „industry" j per one unit of product.

[8] In the empirical application we will analyse the value of of final products at basic prices, which is the ex-factory gate price before delivery to the final consumer. In particular, this means that retail trade margins and net taxes are not included. Retail margins can be sizeable, in particular for consumer products such as clothing that are sold in branded stores. While the WIOD provides data to analyse these margins as well, it is outside the scope of the present paper.

3.3 An illustrative example: the German car industry

In Table 1 we provide an example of such decomposition for the final output from the German transport equipment manufacturing industry, in short the car industry. Developments in the German car industry are illustrative for the strong changes that took place in the organization of production within Europe after the fall of the Berlin wall in 1989. With the new availability of cheap and relatively skilled labor, firms from Austria and Germany in particular relocated parts of the production process to Eastern Europe (Marin 2011). Between 1995 and 2008, the domestic value added content of final products from the German car industry dropped from 79 to 66 per cent. Domestic value added includes value added in the car industry itself, but also in other German manufacturing and non-manufacturing industries that deliver along the production chain. The drop is almost completely due to the decline in value added by less skilled workers in Germany, as shares of high-skilled workers and capital in Germany remained more or less constant. On the flipside, the foreign value added share increased as intermediates were increasingly imported generating income for labor and capital employed outside Germany. At the same time, the factor content of this GVC changed. Taken together the value added by domestic and foreign capital in the German car GVC increased from 29 to 35 per cent, while the share of German and foreign labor dropped from 71 to 65 per cent. This pattern is representative for many other product GVCs as we will see in the next section.

3.4 The World Input-Output Database

To measure value added in GVCs, we need to track for each country gross output and value added by industry, and the flow of products across industries and countries as reflected in a global input-output matrix. This type of data is available from the recently released World Input-Output Database that has been specifically designed and constructed for this type of analyses (Timmer, ed., 2012).[9] The WIOD provides a time-series of world input-output tables (WIOTs) from 1995 onwards. It covers forty countries, including all EU 27 countries and 13 other major economies namely Australia, Brazil, Canada, China, India, Indonesia, Japan, Mexico, Russia, South Korea, Taiwan, Turkey and the United States. In total it covers more than 85 per cent of world GDP in 2008. In addition a model for the remaining non-covered part of the world economy is made such that the value added decomposition of final output as given in the equation above is complete. The 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 is to have consistency in the tables over time to allow for inter-temporal analysis. National tables are only available for particular benchmark years

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[9] The World Input-Output Database (WIOD) is publicly available for free at www.wiod.org.

11

which are infrequent, unevenly spread over time and asynchronous across countries. Moreover, in contrast to National Accounts Statistics (NAS) 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 NAS, using a constrained least square method akin to the well-known bi-proportional (RAS) updating method. The solution exactly matches the most recent NAS data on final expenditure categories (household and government consumption and investment), total exports and imports, and gross output and intermediate inputs by detailed industry. Value added is defined in the standard way as gross output (at basic prices) minus the cost of intermediate goods and services (at purchasers' prices).[10]

The second challenge is 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,b). 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 descriptions for about 5,000 products (6-digit) in the UN COMTRADE database were used to allocate imports to three use categories: intermediate use, final consumption use, or investment use.[11] This was combined with the detailed HS-6 bilateral trade data to breakdown a country's import of each of the 59 products into the country-of-origin. In addition, data on bilateral trade in services, which in contrast to data on goods is not readily available, has been collected, integrating various international data sources. This includes payments for various kinds of business services, royalties and license fees.[12]

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[10] In fact, the WIOTs are based on imputation of supply- and use-tables, rather than input-output tables. SUTs provide a more natural starting point than input-output tables which are typically derived from the underlying SUTs with additional assumptions. Moreover, SUTs can be easily combined with trade statistics that are product-based and employment statistics that are industry-based. The national SUTs have dimensions of 35 industries and 59 product groups. The 35 industries cover the overall economy and are mostly at the 2-digit NACE rev. 1 level or groups there from. See Dietzenbacher et al. (2013) for technical details.

[11] Effectively refining the well-known "broad economic classification" (BEC) from the United Nations

[12] As is well-known services trade data has not been collected with 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 intra-firm deliveries (Francois and Hoekman, 2010). This does not mean however that the values of these services are excluded in our decomposition. On the contrary, as the decomposition of the products' value is complete, it is accounted for, but the location of the value added might be harder to trace. Take the example of a typical US manufacturer of trousers that does not have any production capacity in the US, but basically only governs foreign production and maintains brand and design at home (so called "fabless manufacturers"). The value of the trouser includes the compensation for brand and design and this will show up in the value added by capital in the US clothing industry.

Apart from a world input-output table, one needs detailed value added accounts that provide information on the quantities and prices of labor and capital used in production.[13] In WIOD three types of workers are identified on the basis of educational attainment levels as defined in the International Standard Classification of Education (ISCED): low skilled (ISCED categories 1 and 2), medium skilled (ISCED 3 and 4) and high skilled (ISCED 5 and 6). This roughly corresponds to: below secondary schooling; secondary schooling and above, including professional qualifications, but below college degree; and college degree and above. For most advanced countries this data is constructed by extending and updating the EU KLEMS database using the methodologies, data sources and concepts described in O'Mahony and Timmer (2009). For other countries additional data has been collected according to the same principles, mainly from national labor force surveys, supplemented by household survey for relative wages. Numbers of workers include employees, self-employed and family workers. Prices for labor refer to wages and additional non-wage benefits, with an imputation for self-employed income (Gollin, 2002). Capital income is derived as gross value added minus labor income as defined above. It is the gross compensation for capital, including profits and depreciation allowances. Being a residual measure it is the remuneration for capital in the broadest sense, including tangible capital, intangible capital (such as R&D, software, database development, branding and organization capital), mineral resources, land and financial capital. We now turn to a discussion of the main findings obtained by applying Leontief's model on the WIOD to decompose global value chains.

4. Increasing International Fragmentation of Production: new evidence

As yet, there is little work providing an overall overview of the extent and development of international production fragmentation. Various empirical papers are studying fragmentation of production within multinational enterprises based on foreign investment flow data of firms and their affiliates. They have documented pieces of evidence that point to the increasing fragmentation of production across borders, such as (Fukao et al., 2003) and Ando and Kimura (2005) for Japanese firms; Hanson et al. (2005) for US and Dalia (2011) for German multinationals. More comprehensive cross-country and intertemporal evidence has been presented by Hummels et al. (2001) and extended in a multilateral setting by Johnson and Noguera (2012a,b). Based on similar type of data as in this study, these studies found for most countries a decline in the domestic contribution to exports, interpreted as increasing vertical specialization in trade. Here we provide complementary evidence that does not focus on vertical specialization of countries, but measures the fragmentation of production processes of particular goods,

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[13] We measure labour quantities in number of workers, although hours worked would be a preferable measure. This data is not available at a large scale.

which is closest to the notion of fragmentation in a GVC.[14] We measure the foreign value added content of various GVCs using the method outlined above, with value added to gross output shares as our direct factor input matrix F. A higher foreign share indicates increasing international fragmentation of the production process of the product. Products are identified by the industry-country of completion.[15] There is data for products out of each of fourteen manufacturing industries in forty countries, so we have potentially 14 times 40 is 560 observations.[16]

In Figure 3, we plot the foreign shares for each GVC in 1995 and 2008, together with a 45 degree line and a simple OLS regression line. The main finding of this analysis is that for 85 per cent of the GVCs the foreign value added share has increased over the period from 1995 to 2008. The (unweighted) average share rose from 28 per cent in 1995 to 34 per cent in 2008.[17] An OLS regression through the origin suggests a highly significant slope, indicating an average increase in the foreign share by one-fifth, irrespective of the type of products. For example petroleum products typically have very high foreign value added shares as most countries do not have access to domestic oil feedstock. On the other hand, manufactured food stuffs have relatively low foreign shares, as most of the intermediates are sourced from local agriculture. But for both type of goods the foreign value added share increased. In the Figure we also singled out observations for electrical equipment manufacturing which is typically regarded as the paragon of international production fragmentation. Indeed, for these products the foreign value added shares are high relative to most other manufacturing products in 1995 with an unweighted average of 33 per cent increasing to 40 per cent in 2008.

At the same time, it is clear that production in manufactures GVCs still has a large home bias. In a friction-less world with increasing returns and tradable differentiated intermediate products as in Helpman and Krugman (1985), the domestic share in a

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[14] Vertical specialisation of countries in international trade is defined as the share of a country's value added in the value of its exports (Hummels, Iishi and Yi, 2001), or of deliveries to foreign final demand (Johnson and Noguera, 2012a,b). See the contribution of Johnson to this *Symposium* for deeper discussion on the measurement, causes and consequences of vertical specialisation in trade. Our approach is actually more closely related to the work by Dietzenbacher and Romero (2007) and Antràs et al. (2012) who compute the average number of 'transactions' a dollar of a given product will go through before being sold for final use. Instead of measuring numbers of transactions, our measure focuses on the distribution of value added.

[15] The fact that a product is 'completed' in a particular country does not necessarily mean that domestic firms are governing the GVC. Apple governs the production network of iPods, although they are completed in China. For more on governance in GVC production, see e.g. Gereffi (1999).

[16] As there is no output in two industries in Luxembourg in 1995, the actual number of observations is 558.

[17] We focus on the period 1995 to 2008 as our data starts in 1995 and 2008 marks the end of a period as the global financial crisis struck. The increase was gradually over this period and the finding does not depend on the particular choice of begin- or end-year. We do not observe final output in 1995 for leather manufacturing and petroleum manufacturing in Luxembourg, so total of observations is not 560, but 558.

country's GVC should be equal to its share in world GDP. Even for the biggest countries this would suggest a foreign share of at least 80 per cent, which is much higher than the shares found above. This suggests that transport costs and many obstacles to international production fragmentation still remained, and one might expect continuing fragmentation in the future. But it might also indicate that certain high-value added tasks are clustered in space because of strong complementarities, such that they do not fragment easily. In that case, the fragmentation process might have large discontinuities (Baldwin and Venables, 2010).

Using an entropy index that measures the distance between the actual cross-country distribution of value added in GVCs and the cross-country distribution of world GDP, Los et al. (2013) found that the fragmentation trend is indeed still apace. The global financial crisis in 2008 and 2009 created only a temporary dip, and contrary to the anecdotes of multinationals reshoring production, there are no signs of a reversing macro trend yet. They do find a change in the geographical nature of fragmentation though. In the 1990s, it mainly involved the relocation of value added to nearby regions as production stages clustered within NAFTA, EU or Asian trade blocs. For the case of Europe they showed that with the advance of China as a supplier of intermediates, regionalization was slowly giving way to true globalization of the production process.

5. Increasing value added shares of capital and high-skilled labor in manufactures GVCs

Next we turn to an analysis of the changes in the factor content of manufactures GVCs. Factor shares are very much present in the political debate as a measure of how the "benefits of globalization" are shared between capital and labor, and between various types of workers. Insofar as fragmentation is driven by arbitraging differences in wages across countries it is expected to have not only an impact on the cross-country distribution of income, but also on the cross-factor income distribution. Indeed we will show that a standard Cobb-Douglas function, where the factor shares in output value are assumed to be constant, is not an adequate description of internationally fragmented production processes. Instead, we find that in manufactures GVCs the income shares of capital and high-skilled workers are increasing, while those of other labor are declining.

5.1 Empirical trends

In Table 2 we decompose the value of production of final manufacturing goods into the value added by four factors: capital, low-, medium- and high-skilled labor.[18] We focus on the changes in factor shares from 1995 to 2008, a period when growth in Europe

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[18] Note that factor shares in value added, in income and in costs are equivalent in our approach, and these terms will be used interchangeably.

and the US was still steady, while booming in emerging countries. Global expenditure on manufacturing consumption and investment goods increased by almost a third, from 6,586 to 8,684 billion US$.[19] This increase in demand coincided with a strong bifurcation in the factor content of production. The shares of value added by capital and high-skilled workers increased by 6.5 per cent and 1.5 per cent. In contrast, the shares of low- and medium-skilled workers declined by 3.8 and 4.2 per cent. In Figure 4 we provide trends in the share of capital and high-skilled combined on the one hand, and the share of other labor on the other. In 1995, the difference between the two groups was ten percentage points, growing to twenty-five points in 2008. The divergent trend was monotonic with accelerating divergence at the end of the 1990s and again from 2003 to 2006. The latter period coincides with a step up in the global presence of China after its accession to the World Trade Organization in 2001.

The figures shown so far are for all manufactures GVCs combined, and the aggregate factor change might simply be the statistical result of a shift in global demand towards more capital- and skill-intensive products, for example away from low-tech textiles towards high-tech machinery. If so, the results would not represent fundamental changes in GVCs at a detailed product level, but merely reflect the effects of shifts in the relative output levels of GVCs. To investigate this, we present in Table 3 an analysis of the changes in factor cost shares in GVCs at the detailed product level. As before we have in total 560 value chains: fourteen manufacturing product groups with forty possible countries of completion. The table provides distribution measures of the change in the value added shares between 1995 and 2008 across all chains. The results show that the aggregate trends in Table 2 are clearly a reflection of trends that are broadly shared across the product GVCs. In 83 per cent of the chains, the share of value added by capital and high-skilled labor has increased, with a median change of 6.5 per cent. A quarter of the chains had an increase of even more than 10.5 per cent. The increase in income shares for high-skilled workers was particularly pervasive and positive in 93 per cent of the chains. In contrast, the income shares for medium- and low-skilled labor dropped in 83 per cent of the cases. The unweighted average decline was less than the weighted, indicating that the decline was particularly severe in those GVCs where the final output was relatively high.

The table also provides a sharper focus on the role of capital by breaking down income into value added by capital that is deployed in the mining industry and by capital used elsewhere in the economy. Mining capital has become more important in virtually all GVCs (96 per cent) and increased its median value share by 1.8 per cent, and even by

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[19] Expenditures include consumption and investment by households, firms and government and are measured in constant 1995 US$. Expenditure in national currency is converted to US$ with official exchange rates and deflated to 1995 prices with the overall US Consumer Price Index. Expenditure is at basic price values, which means that net taxes and trade and transportation margins on final products are excluded.

4.1 per cent when weighted by GVC size. Given that its weighted share in 1995 was only 2.2 per cent, the mining capital share almost tripled over the period to 2008. This massive increase reflects rapid increases in the prices of natural resources, with presumably limited opportunities for substitution and resource-augmenting technical change. For example, oil prices more than quintupled in the period.[20] Non-mining capital shares did not suffer from the increased cost-share of natural resource inputs. They increased in almost half of the GVCs with a small negative median share change, but their weighted average change was clearly positive (2.4 per cent). This indicates that especially in the larger GVCs income shares for non-mining capital have increased, notwithstanding the concomitant increase of mining capital.

5.2 Possible interpretations

Summarizing, during 1995-2008 growth in most manufactures GVCs was clearly capital and high-skilled labor biased. What might account for this? From the task-based literature we know that factor shares are determined by the interplay of relative prices of factors, both domestic and foreign, their elasticities of substitution and the nature of technical change. The decline in the relative price of unskilled labor is clearly a first-order determinant: the opening up of China, India and other Asian economies provided an enduring increase in the global supply of labor. Fed by the large reservoirs of underutilized workers in the agricultural sector and the informal parts of the urban economy, the supply of unskilled workers at extremely low wages continued unabated. With a high elasticity of substitution between less skilled workers across countries, unskilled labor income shares should decline in all GVCs.[21] In addition, the opening up of international capital markets increased the opportunities for quick relocation of capital. With capital more footloose, a decline in the bargaining power of labor is to be expected around the world, further limiting the share of labor in value added vis-a-vis capital (Rodrik, 1997).

Another reason might be the substitution of labor for capital in response to rapid advances in the information and communication technology industry, driving down the relative price of capital (Jorgenson, 2001). When the elasticity of substitution between capital and labor is bigger than one, this will lead to an increase in the capital share. This substitution of labor for capital is likely to be non-homogenous. According to the so-called "routinization hypothesis" IT capital complements highly educated workers engaged in abstract tasks, substitutes for moderately educated workers performing routine tasks and has less impact on less-skilled workers performing manual tasks (Autor, Levy

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[20] The rapid price increase of natural resources started around 2001. Over the period 1995-2008, the price of energy in nominal $ increased by a factor of 5.1, of metals and minerals by 2.4, and of agricultural commodities 2.0 (source: World Bank, Global Economic Monitor (GEM) commodities)

[21] As in the classical surplus labour model of Lewis (1954), this kept returns to capital relatively high, stimulating further investment and industrial development in less advanced countries.

and Murnane, 2003). The latter is particular true for tasks that require personal interactions, such as in personal and retailing services. These activities however are less important in manufacturing GVCs, which is consistent with our observation that income shares for both low- and medium skilled workers are declining.

The increasing importance of intangible investment provides another potential explanation. Traditionally, capital was considered mainly as a set of physical assets, such as machinery, transport equipment and buildings. Physical assets are heavily traded however and cannot be a source of comparative advantage: the (risk-adjusted) returns will be comparable across countries. Recent investment in advanced countries is increasingly directed towards intangible capital such as intellectual capital (including software and databases, R&D and design), brand names and organizational capital (which is specific to firms). In a detailed data exercise Corrado et al. (2012) find that averaged over 1995 to 2009, investment in intangibles in the EU15 was about around 62 per cent of investment in tangibles. For the US, investment in intangibles was found to be even higher than in tangible capital.[22] In contrast to tangible, intangible assets often have the characteristic of being non-rival: this implies that they can be employed by many users simultaneously without diminishing the quantity available to any single user, such as a software system to automate orders. Various intangibles are proprietary knowledge and exhibit non-rivalness only within a firm's boundary, such as brand equity and organizational competencies. They are valuable, at least in part, because the firm is able to exclude competitors from gaining access to key information and technology. Deployment of intangibles typically gives rise to imperfect product markets and possibilities for mark-ups. When firms operating in such an environment enlarge their scale of operations, capital is likely to gain more relative to labor, as wages are determined in more competitive markets. In a dynamic model of growth, openness and trade might reinforce higher levels of investment in intangibles as it expands the incentives for their creation: the larger the market in which the new invention will be used, the higher the potential for profits accruing to the investor.[23]

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[22] McGrattan and Prescott (2009) refer to these intangible assets as "technology capital". They extend the neoclassical growth model by introducing intangibles and trace the welfare implications of technology transfer through foreign direct investments, concluding that this may be a major channel for gains from trade. Investments in these types of assets are typically not recorded as investment in the NAS, but are expensed as intermediate inputs. In the old System of National Accounts introduced in 2003 software expenditures were reclassified as investment. In the new System of National Accounts of 2008, a similar suggestion is made with respect to R&D expenditures. To measure a wider set of intangibles, one has to go beyond the investment statistics in the national accounts and Corrado et al. (2005) provide a framework to do so.

[23] However, this market size effect does not necessarily raise the return to intangibles above that of other factor inputs, as it might also increase the return to the latter when intangibles are used as an input in the production process, see Aghion and Howitt (1998).

Intangibles are also thought to be highly complementary with high-skilled workers. In an extended Heckscher-Ohlin framework, Haskel et al. (2012) assume that skilled workers are more productive in tasks involving working with intangible capital, whereas they are no more productive than unskilled workers in tasks involving less capital. In this model, an increase in the demand for the output of the intangible-intensive sector will obviously raise the returns to intangibles. But it can also increase returns for the complementary high-skilled workers that benefit from the productivity effect. In contrast, returns for unskilled workers will always fall relative to capital and skilled workers. Haskel et al. (2012) discuss some real world examples of this intangible-skill complementary, and the reasons for increased demand for their output.

6. The changing location of value added in manufactures GVCs

So far we did not analyze the location of the production factors in manufactures GVCs. In this section we focus on the shifts in the geographical distribution of the value added and their impact on factor income distributions. As shown in Figure 5, the location of value added has clearly shifted away from the advanced towards the emerging regions.[24] Up to 2007 the value added in the US and the European Union (EU15, including all European countries that joined the European Union before 2004) has been roughly constant. Value added in East Asia (including Japan, South Korea and Taiwan) declined strongly in the 1990s, exacerbated by the East Asian financial crisis in 1997, but stabilized in the 2000s. The drop in the crisis year 2009 was large for all mature economies, and recovery slow. In contrast, emerging regions have rapidly increased value added. China is responsible for the major part of this increase, accelerating growth after its WTO accession in 2001. Between 2002 and 2008 it tripled its value added and it overtook the East Asian level in 2007. Value added also rapidly increased in other emerging economies, more than doubling in Brazil, Russia, Indian, Indonesia, Mexico and Turkey since 2002. These countries were also withstanding the global crisis much better and continued their upward trend. In 2011, the value added in China in manufactures GVCs was even higher than in the US for the first time in recent history.[25]

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[24] Value added is expressed in US$ using current exchange rates and deflated to 1995 value using the US CPI to allow for comparisons over time and across countries. The movements over time, but not the relative shares across countries are sensitive to the numerair currency used. The $/euro rate declined during 1995-2001 followed by a recovery returning near its 1995 value in 2008. The euro was introduced in 2001 and we are referring to the $/DM rate before that date. The Yen/$ rate fluctuated around a long-term constant for this period, and the Yuan/$ rate was effectively fixed.

[25] We made preliminary estimates for 2010 and 2011 using the same construction methodology as for the other years to analyse the trends through the global economic crisis, but it should be noted that the quality is somewhat lower as less source material could be used due to limited availability of input-output tables for recent years.

However, the location where the value is being added is not necessarily identical to where the generated income will eventually end up. The building of global value chains is not only through arms-length trade in intermediate inputs, but also involves sizeable flows of investment and part of the value added in emerging regions will accrue as income to multinational firms headquartered in advanced regions through the ownership of capital. To analyze capital income on a national rather than a domestic basis as in this paper data on foreign ownership is needed. This type of information is notoriously hard to acquire, not in the least due to the notional relocation of profits for tax accounting purposes, and further research is needed in this area and not pursued here (Baldwin and Kimura, 1998; Lipsey 2010).[26]

Instead, we analyze the factor content of the value added in the various regions to gauge the importance of domestic capital vis-à-vis labor in production. To this end, we group East Asia, US and the EU15 together and do the same for all other countries in the world. Table 4 shows for each group the shares of factors in the total value added. The value added by the advanced economies in manufactures GVCs remained more or less constant over the period from 1995 to 2008. The share of capital increased from 36 to 39 per cent, while the share of labor declined correspondingly.[27] But the major income shift was within labor. The value added by high-skilled workers increased by 5.0 percentage points, while the share of medium- and low-skilled combined declined by 7.9. The rise of China and other emerging economies accelerated the erosion of mature economies' comparative advantage in labor-intensive production tasks, while simultaneously offering new opportunities for off-shoring. Fragmentation is adding a pull-factor to a push-factor, in particular for tasks by less-skilled workers in advanced nations (Hanson, 2012). Revealed comparative advantage in these countries is rapidly shifting towards tasks performed by high-skilled workers, as we will analyze in more detail in a later section.

Value added in the rest of the world more than doubled, and incomes increased for all factors of production. But the share by low-skilled workers declined sharply (-6.3 percentage points) and the increase mainly benefitted other workers and in particular capital. This is because the share of capital in value added in these countries is particularly high. In 1995, the share was 55 per cent compared to 36 per cent in advanced regions. One would expect the share of rapid growing countries to converge towards the levels of more advanced nations, but it actually increased by 3.2 percentage points, which is faster than in advanced regions. As the mass of value added in manufactures GVC moved away from advanced nations, the global capital income share increased even more than the rise in the separate regions. Including the locational shift effect the global capital

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[26] To establish the full link from production value added to factor incomes and finally to personal income distributions, one would additionally need data on the actual ownership of firms.

[27] The erosion of labor shares in advanced countries around the world since the 1990s has been discussed already for quite some time, see e.g. Blanchard (1997) for early work finding some evidence of the role of capital-biased technological change, in combination with changes in the distributions of rents.

income share increased with 6.5 points, as shown in Table 2. This finding is compatible with a world in which MNEs relocate capital in search of higher returns, or simply benefit from expanding their scale of production in combination with increasing returns to intangible assets.

7. The number and nature of jobs in manufactures GVCs

Many policy concerns surrounding globalization issues are ultimately about jobs. How many, and what type of, jobs are related to the global production of manufactures? In this section we zoom in on the structure of employment and analyze the changes in the number of workers directly and indirectly involved in the production of manufacturing goods, in short GVC workers. We will use the same decomposition method as before, but now the elements in the production requirement matrix F consist of the number of workers needed per unit of gross output in each industry-country.

7.1 The importance of manufactures GVCs for employment

Table 5 presents employment in manufactures GVCs for the eleven biggest advanced and nine biggest emerging countries covered in WIOD database. The number of GVC workers is expressed as a percentage of the total number of workers in the economy. For the nine biggest emerging countries, manufactures GVCs are much more important for employment than for advanced countries, with shares of about 30 per cent in the former against 17 per cent in the latter in 2008. As domestic demand in richer economies is more geared towards services, this difference is not surprising. But the variance across countries within the two groups, and in particular the dynamics over time are much harder to explain from a domestic demand perspective. Over the period 1995-2008, the importance of manufactures GVCs for employment in China increased to more than 33 per cent, alternatively interpreted as an overreliance on foreign demand due to distorting export promotion policies, or more positively as a sign of Chinese strength in competing in international markets. Also in Turkey the share increased, but not in the other countries. In Indonesia and Mexico these shares declined by more than five percentage points, reflecting a loss in their ability to compete with other countries in global GVC production.

The importance of manufactures GVCs as a provider of jobs in advanced countries rapidly declined with more than four percentage points. But there is large heterogeneity within this group, both in levels and in changes. On the one hand GVC workers still make up about 26 per cent of all workers in the German economy, and this share has been stable over the period. Successful integration of Eastern Europe and a severe wage restraint provided the necessary elements for the much-touted success of Germany in export markets. On the other hand, 4.6 million GVC jobs were lost in the US

and the share declined from 16 to only 11 per cent, by far the lowest across all countries. A comparable trend is seen for Japan and the UK, where 2.9 and 1.6 million GVC jobs were lost, and the shares dropped by 3 and 7 percentage points.

These declines stirred policy concerns about manufacturing decline, and prompted various initiatives for "re-industrialisation". However it is important to realize that manufactures GVC production involves not only jobs in the manufacturing sector, as a sizeable share of the tasks is carried out in other sectors of the economy. In fact, in 2008 almost half of the jobs in advanced countries in manufacturing GVCs was outside the manufacturing sector, and this share was growing (Timmer et al., 2013). With fragmenting production, sectors are becoming the wrong operational unit when framing policies and evaluating performance. Competitiveness is no longer solely determined by a domestic clusters of manufacturing firms, but relies increasingly also on the successful integration of other tasks in the chain, domestic and in particular foreign. Trade, labor and industrial policies should take into account this increasing vertical integration of production within and across countries (Baldwin and Evenett, 2012).

7.2 Enhanced specialization in skilled labor in advanced countries

Starting from a world in which most value is added in advanced nations, broad Heckscher-Ohlin models would predict that with declining international fragmentation costs advanced nations would specialize further in tasks carried out by high-skilled labor, as less skilled tasks are offshored. We confirm this enhanced specialization hypothesis in Figure 6. In this Figure we plot for each of the 40 countries in the WIOD the share of high-skilled GVC workers for 1995 and 2008. The share is calculated as the number of high-skilled GVC workers in a country divided by the total number of GVC workers in a country. All observations are above the dotted 45 degrees line, indicating a global shift towards use of relatively more high-skilled workers in GVCs. But this shift is clearly not uniform across countries. A simple OLS regression (the dotted line) shows that countries with higher initial shares of high-skilled workers showed faster increases: the slope of the line is 1.32. The constant of the regression line is 0.029 reflecting the increase in the share worldwide from 2.2 to 4.2 per cent. Countries with low initial shares had increases of the same magnitude. For example, in China the share increased from 1.4 to 3.7, and in India from 4.6 to 6.6 per cent. In Mexico the share only increased from 7.5 to 8.4 per cent which is even below the world average increase. In contrast, the shares in countries with initially higher shares increased much faster. In the US the share increased from 23 to 28, in Germany from 18 to 23 and in Japan from 17 to 23 per cent. The improvements in Ireland and South Korea stand out in particular from 15 to 32 and from 23 to 40 per cent, the highest for all countries considered. The results indicate enhanced specialization in advanced countries in those tasks carried out by high-skilled workers.

8. Concluding remarks

In this paper we presented some new facts on the international fragmentation of production and the distribution of value added by capital and various types of labor. In contrast to the traditional framework in which the production function is a characteristic of a firm, or an industry or even a country, we modeled the production process of final products. Using Leontief's seminal insight, we decomposed the output value of a product into income for all labor and capital that is needed in any stage of production. In particular, by using an international input-output model and incorporating intermediate inputs, we were able to trace the use of factors across many industries and countries. Four main trends in the production of final manufacturing products stand out.

First, production has become increasingly internationally fragmented in the past two decades, indicated by rising shares of foreign value added in production over the period 1995-2008. Second, the factor distribution of the value added in this production has shifted: for most products the shares of capital and high-skilled labor have increased, while the shares of medium- and low-skilled labor declined. Third, value added in traditional industrial strongholds (EU, Japan and the US) remained constant over this period, but more than doubled in the rest of the world, mainly contributing to capital income. Fourth, advanced countries increasingly specialized in GVC tasks performed by high-skilled workers.

Taken together these trends fit a broad story in which firms in mature economies relocate their unskilled-labor intensive production activities to lower-wage countries, while keeping strategic and high value-added functions concentrated in a few urban regions where the high-skilled workers and intangible capital they need are available (Baldwin 2006). This raises new questions: Will the international fragmentation trend continue, and deepen by affecting more goods and possibly services?[28] What are the characteristics of the tasks that remain in mature economies? What is the role of firm and non-firm specific intangible capital?[29] What are the complementarities and substitution possibilities between capital and various types of workers, both domestic and foreign? How does this affect inequality within and across countries? To address these issues much progress has been made by conceptualizing production as a set of tasks to be performed by combinations of factor inputs. Using these frameworks to explain the trends found in this paper should lead to a better understanding of the impact of international production fragmentation on trade, incomes and technological change.

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[28] The extent to which services involve personal interaction will be an important determinant of the substitution possibilities between domestic and foreign labor, see discussion in Blinder (2009).

[29] Increased possibilities for fragmentation of production are also intimately linked to the organizational question for firms of *how* to produce, including the decisions where to locate activities and whether to keep all activities within the firm or outsource parts of it, and which parts (see Antràs and Rossi-Hansberg 2009 for an overview).

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**Figure 1 Specialization when fragmentation is possible.**
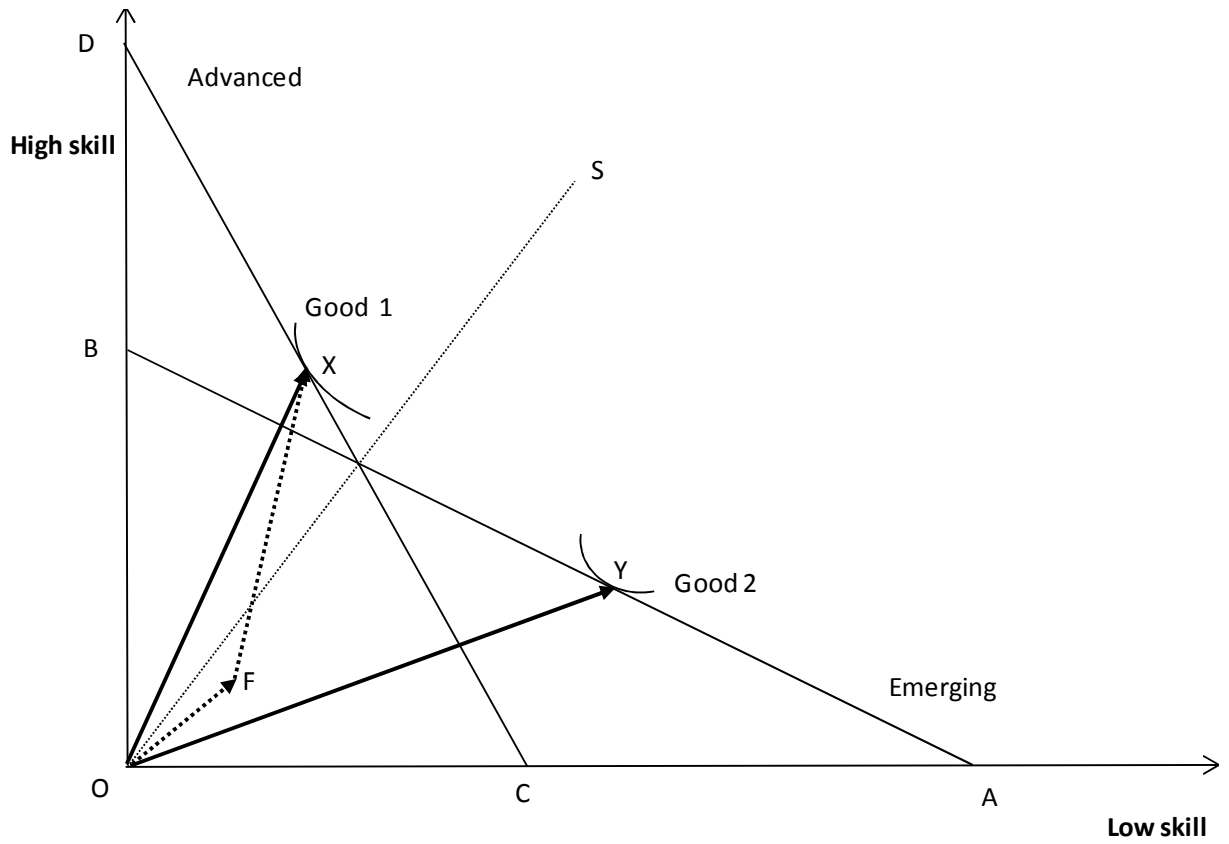
Note: this example is elaborated from Deardorff (2001)

Figure 2 Factor content of a global value chain: graphical representation
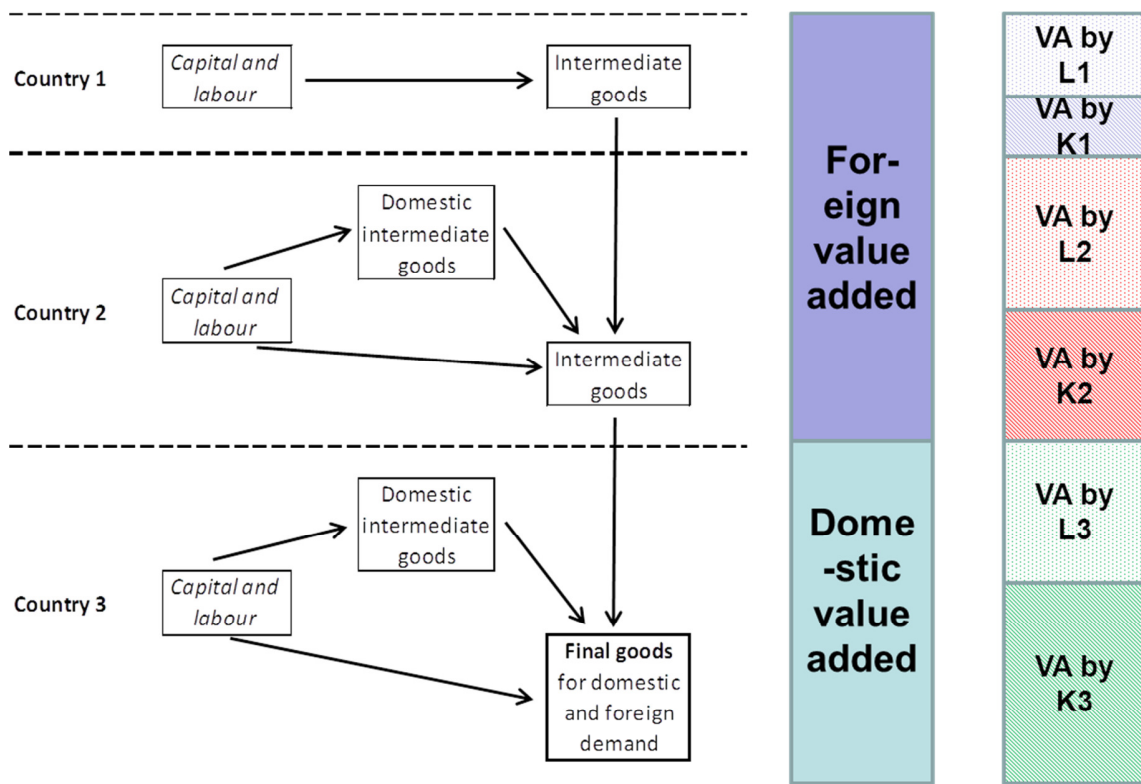
Note: The lefthand side of this figure depicts a simplified flow of inputs needed in the production process of a final product that is completed in a particular country (country 3). The stacked bars at the right show how the value of this final product consists of the value added by labour (L) and capital (K) in the domestic economy (country 3) and by labour and capital in foreign countries that deliver intermediate inputs for production, either directly (country 2) or indirectly (country 1).

Figure 3 Share of foreign value added in output of final manufactures
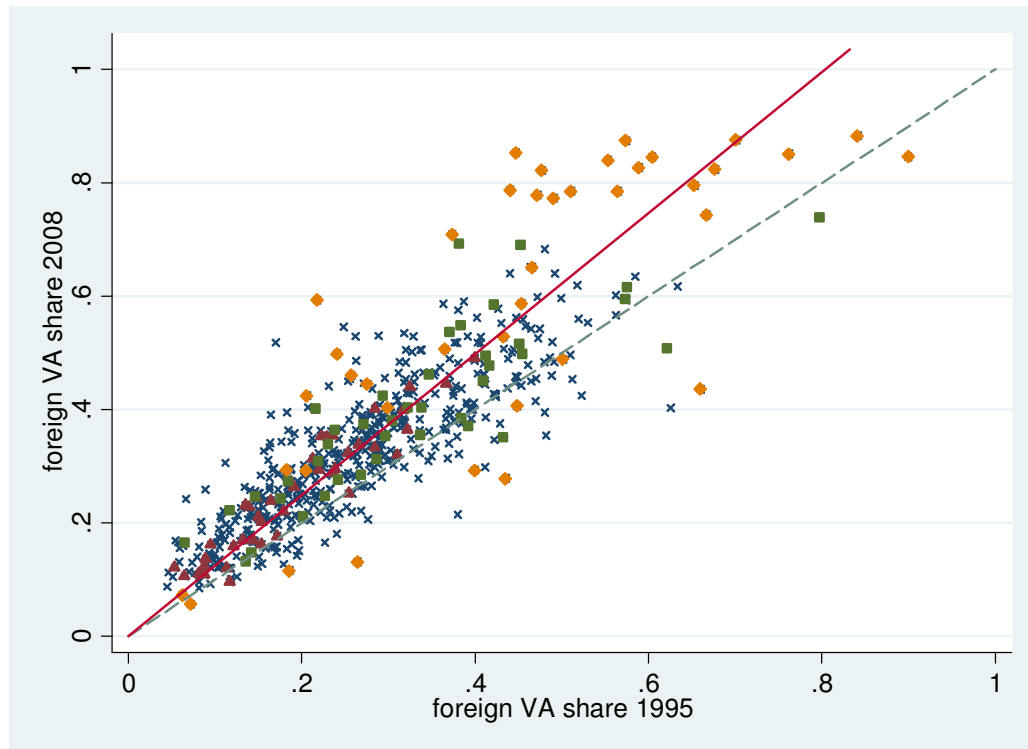
Notes: Each dot represents the share of foreign value added in final output of manufacturing sector in a country in 1995 and 2008, as a ratio of final output. This share is calculated according to equation in the main text. Observations have been included for 558 manufactures GVCs, identified by 14 industries of completion in 40 countries. Triangles indicate food manufacturing (ISIC rev 3 industries 15 and 16), squares electrical equipment (30-33) and diamonds petroleum refining (23) GVCs. All other GVCs are represented by crosses. The dashed line is the 45 degree line. The solid line has been obtained by OLS regression through the origin with slope coefficient of 1.20.
Source: Author's calculations based on World Input-Output Database, April 2013.

Figure 4   Value added by labour and capital (share of global final manufactures output).
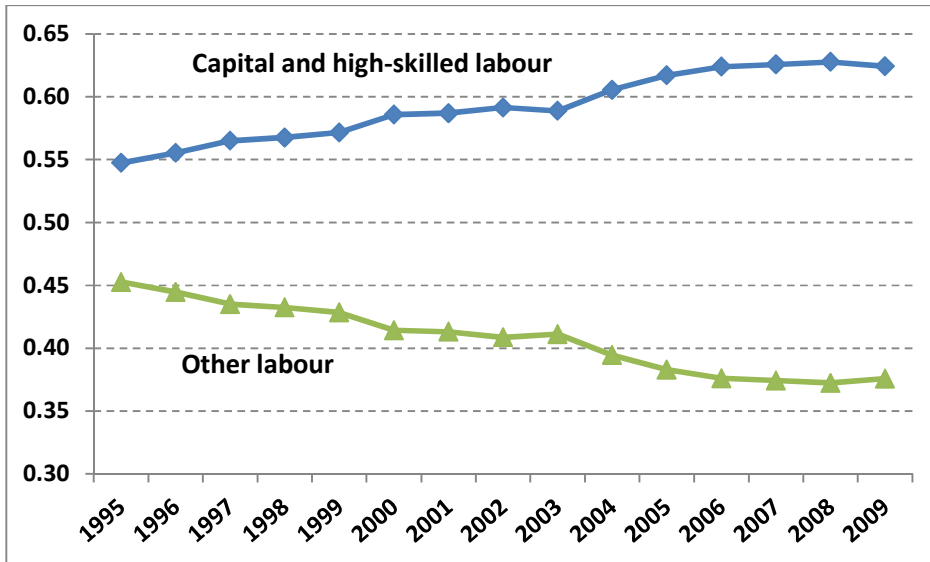
Notes: Value added to global output of final manufacturing goods. Value added by labour is measured as wages and salaries and other employer costs, and includes an imputation for self-employed workers. Capital compensation is residually defined as non-labour value added such that the labour and capital shares add up to one. High-skilled workers are defined as having college education or above.
Source: Author's calculations based on World Input-Output Database, April 2013.

Figure 5 Value added by regions in global production of manufactures, 1995-2011 (in billion 1995 US$).
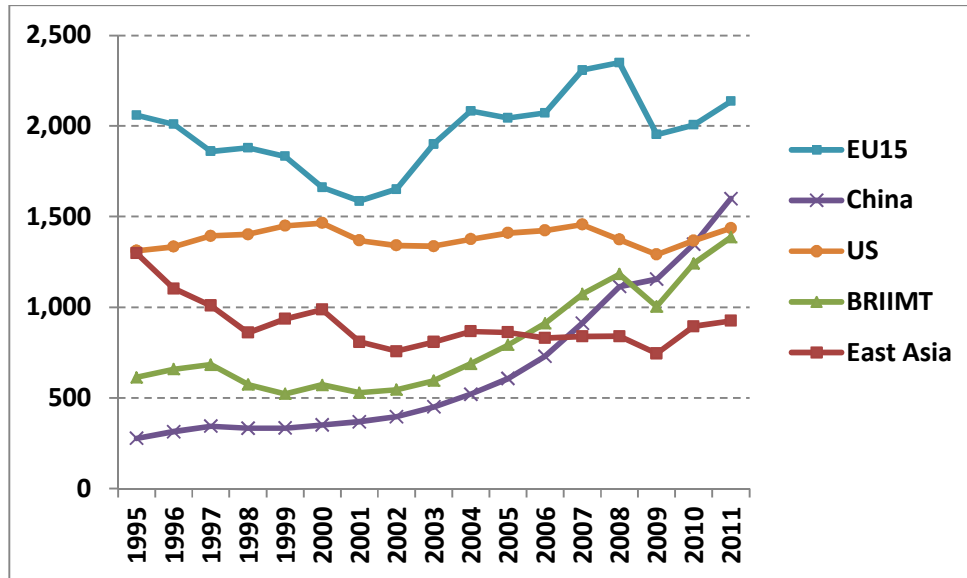
Notes: East Asia includes Japan, South Korea and Taiwan. BRIIMT includes Brazil, Russia, India, Indonesia, Mexico and Turkey. EU15 includes all European countries that joined the European Union before 2004. Value added in national currencies converted to US$ with official exchange rates and deflated to 1995 prices with the US CPI.
Source: Author's calculations based on World Input-Output Database, April 2013, with extrapolation for 2010 and 2011.

Figure 6 Increased specialization in high-skilled activities
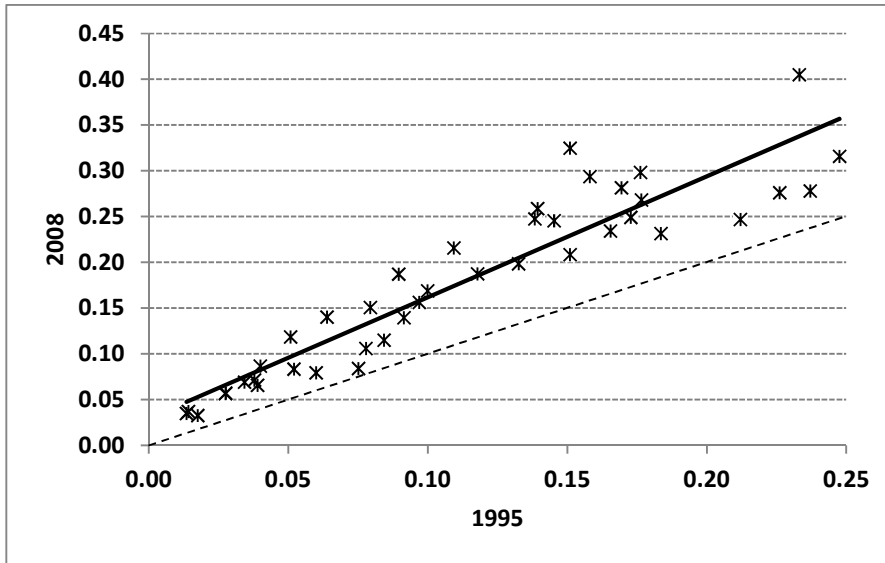
Note: Share of high skilled in all workers of a country employed in any manufactures GVCs in 1995 (x-axis) and in 2008 (y-axis). Observations for 40 countries covered in WIOD database. The dashed line is the 45 degree line. The solid line has been obtained by OLS regression and has a slope coefficient of 1.32 and intercept 0.029.
Source: Authors' calculations based on World Input-Output Database, April 2013.

Table 1 Slicing up global value chains (% of final output value)

| | Transport equipment from Germany | |
	1995	2008
Domestic value added	79	66
high-skilled labour	16	17
other labour	42	30
Capital	21	20
Foreign value added	21	34
Labour	13	19
Capital	8	15
Total final output	100	100

Note: breakdown of the value added to final output from German transport equipment manufacturing (ISIC rev 3 industries 34 and 35).

Source: Author's calculations based on World Input-Output Database, April 2013.

Table 2 Value added shares by factor in all manufactures GVCs

	1995	2008	2008 minus 1995
Total value added (billion US$), by	**6,586**	**8,684**	**2,098**
capital (%)	40.9	47.4	6.5
high-skilled labor (%)	13.8	15.4	1.5
medium-skilled labor (%)	28.7	24.4	-4.2
low-skilled labor (%)	16.6	12.8	-3.8

Note: Breakdown of value added to global output of all final manufactures by factor of production. Value added is at basic prices (hence excluding net taxes, trade and transport margins on output). It is converted to US$ with official exchange rates and deflated to 1995 prices with the US CPI. Figures may not add due to rounding.

Source: Author's calculations based on World Input-Output Database, April 2013.

Table 3 Change in value added shares by factors in detailed manufactures GVCs

	Obser-vations > 0	First quartile	Median	Third quartile	Ave-rage	Weighted average
Value added by capital and high-skilled labor	**83%**	**2.1**	**6.5**	**10.5**	**6.3**	**8.0**
high-skilled	93%	2.3	4.0	5.4	3.9	1.5
capital in mining	96%	1.2	1.8	3.3	3.1	4.1
capital in non-mining	47%	-5.3	-0.6	3.8	-0.8	2.4
Value added by other labor	**17%**	**-10.5**	**-6.5**	**-2.1**	**-6.3**	**-8.0**
low-skilled	9%	-8.2	-4.7	-1.8	-5.4	-3.8
medium-skilled	44%	-4.2	-0.8	2.5	-1.0	-4.2

Note: Observations are the percentage change in the share of a production factor in total value added in a particular industry-country GVC between 1995 and 2008. The measures given in the table refer to distribution of the values for 560 value chains of manufacturing products. Value added by capital is split into value added by capital residing in the mining industry and in non-mining sectors. Value added by labor is split into value added by workers per level of educational attainment. The value chains are for 14 product groups with 40 countries of completion. The fourteen groups of products are defined as output of the following ISIC revision 3 manufacturing industries: 15t16; 17t18; 19; 20; 21t22; 23; 24; 25; 26; 27t28; 29; 30t33; 34t35; and 36t37. Weighted averages are based on GVC output weights.

Source: Author's calculations based on World Input-Output Database, April 2013

Table 4 Value added to global output of final manufactures, 1995 and 2008

	1995	2008	2008 minus 1995
Value added in North America, EU15 and East Asia (bil US$),	**4,863**	**4,864**	**1**
capital (%)	35.9	38.7	2.9
high-skilled labor (%)	16.8	21.8	5.0
medium-skilled labor (%)	33.3	30.3	-3.0
low-skilled labor (%)	14.0	9.1	-4.9
Value added in other countries (bil US$)	**1,723**	**3,820**	**2,097**
capital (%)	55.2	58.4	3.2
high-skilled labor (%)	5.4	7.1	1.7
medium-skilled labor (%)	15.6	17.0	1.4
low-skilled labor (%)	23.8	17.5	-6.3
World value added (bil US$)	**6,586**	**8,684**	**2,098**

Note: Breakdown of value added to global output of all final manufactures by factor of production. Value added by a region is sum of value added by labour and capital on the domestic territory. North America includes Canada and the United States; East Asia includes Japan, South Korea and Taiwan; EU15 includes all European countries that joined the European Union before 2004. Value added is at basic prices (hence excluding net taxes, trade and transport margins on output). It is converted to US$ with official exchange rates and deflated to 1995 prices with the US CPI. Figures may not add due to rounding.

Source: Author's calculations based on World Input-Output Database, April 2013

Table 5 Number of workers in global production of final manufactures, 1995 and 2008 (as percentage of total economy workers)

	1995	2008	change
United States	16.0	11.1	-4.9
Japan	22.6	19.4	-3.2
Germany	26.8	26.4	-0.4
France	22.0	18.7	-3.3
United Kingdom	20.1	12.6	-7.5
Italy	29.1	25.5	-3.6
Spain	23.2	17.5	-5.7
Canada	20.8	16.0	-4.7
Australia	18.2	14.5	-3.7
South Korea	29.7	22.8	-6.9
Netherlands	22.8	19.0	-3.8
Total eleven advanced countries	21.1	16.7	-4.4
China	31.7	33.3	1.6
Russian Federation	24.7	21.9	-2.8
Brazil	29.6	28.7	-0.9
India	27.9	27.3	-0.7
Mexico	30.3	24.4	-5.8
Turkey	27.1	30.4	3.3
Indonesia	32.1	25.6	-6.5
Poland	31.0	28.8	-2.1
Czech Republic	30.8	30.9	0.1
Total nine emerging countries	30.1	29.9	-0.2
Total twenty countries	28.2	27.2	-1.0

Notes: number of workers (including employees and self-employed) involved in global production of final manufactures. Eleven biggest advanced and nine biggest emerging countries covered in WIOD database, ranked on GDP in 2008 in US dollars in each group.

Source: Author's calculations based on World Input-Output Database, April 2013.