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Banco de Portugal

18 July 2008

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Working Papers

10 | 2008

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Av. Almirante Reis, 71-6th floor
1150-012 Lisboa
www.bportugal.pt

Printed and distributed by
Administrative Services Department
Av. Almirante Reis, 71-2nd floor
1150-012 Lisboa

Number of copies printed
170 issues

Legal Deposit no. 3664/83
ISSN 0870-0117
ISBN 978-989-8061-42-3

Vertical Specialization Across the World: A Relative Measure*

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Abstract

This paper investigates a specific aspect of international production linkages that, following Hummels et al. (2001), is commonly designated as vertical specialization (VS) - the use of imported inputs to produce goods that are afterwards exported. We propose a relative measure of VS-based trade that combines information from Input-Output matrices and international trade data, producing results for a large sample of individual countries and geographical areas with a detailed product breakdown over the 1967-2005 period. This measure identifies a country's trade flow as associated with VS activities when the share of exports of a good relatively to the world average is above a given threshold and it is accompanied by a relative share of imports of a related intermediate product that is also above the threshold. The quantification of VS-based trade for each country/product pair in each period is made in a relative and conservative manner, since it includes only the value of intermediate imports that surpasses what is implied by the chosen international threshold. The detailed results can be subsequently added up to get any product or geographical breakdown desired. We illustrate this measure by showing the evolution of VS activities at the world level over the last four decades using a product breakdown by technological intensity and a geographical breakdown by main areas. The results point to a substantial increase of VS in high-technology products over the last two decades. There is also empirical evidence on the sharp increase of VS activities in East Asia.

Keywords: International Trade, International Fragmentation of Production, Vertical Specialization, Globalization

JEL Codes: F1, F14, F15, O50

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1 Introduction

Over the last decades, international trade has grown strongly and its pattern has evolved significantly. The international fragmentation of production, i.e. the cross-border dispersion of components' production/assembly within vertically integrated production processes, with countries specializing in particular stages of the production sequence, has been an important feature of the deepening structural interdependence of the world economy in recent decades (see Athukorala and Yamashita (2006)). This fact resulted in a growth of trade in parts and components (also called "middle products" or "fragments of final goods") at a rate exceeding that of trade in final goods. There are no comprehensive statistics to accurately measure the role of international production and trade networks across many countries, products and time. Although, some indirect evidence can be drawn from the analysis of different data sources (such as customs statistics, international trade flows, Input-Output tables and firm-level data), an integrated approach is still lacking. This paper investigates a specific aspect of international production linkages that, following Hummels et al. (2001), is commonly designated as vertical specialization (VS) - the use of imported inputs to produce goods that are afterwards exported. We propose a relative measure of VS-based trade that combines information from Input-Output matrices and international trade data, producing results for a large sample of individual countries and geographical areas with a detailed product breakdown over the 1967-2005 period.

The measure identifies a country's trade flow as associated with VS activities when the share of exports of a good relatively to the world average is above a given international threshold and it is accompanied by a relative share of imports of an interrelated intermediate product that is also above the threshold.[1] Next, a proxy of the level of VS-based trade for each country/product pair in each period is obtained by considering the value of intermediate imports that surpasses the one defined by the threshold. In other words, we argue that, for a country p, a simultaneous high export share of a specific product and a high import share of some intermediate product used in its production, relative to the world average, provides indirect evidence of VS. By quantifying this "excess" of intermediate imports we obtain a proxy of trade related to VS activities. The proposed measure has a relative nature because it bases the yearly identification and quantification of VS activities on trade flows whose relative dimension is above an international threshold that is also changing over time. The measure is also perceived as conservative because, in dynamic terms, it will only capture the cases where the

[1] In Amador et al. (2007), a simple product specialization index was introduced - the so-called $B^\star$. In this paper, the proposed measure of vertical specialization makes use of the $B^\star$ index, for both exports and imports, together with information from Input-Output matrices.

increase of real VS activities is strong enough to translate into a growth of intermediate imports above the one implied by the international threshold. Nonetheless, this proxy has adequate additive properties in the sense that, in each period, the results of each pair country/product can be summed to provide any upper-level product or geographical breakdown of VS-related trade.

The paper is organized as follows. Section 2 surveys the main approaches suggested in the literature to measure the international fragmentation of production. In Section 3, the relative measure of VS is presented and its general intuition is discussed. In addition, Section 3 formalizes the methodology and describes the data sources. Section 4 illustrates the evolution of VS activities in the world over the last four decades using a product breakdown by technological intensity and a geographical breakdown by main areas. A special focus is put on the evolution of VS-based trade in East-Asia and in high-tech goods. Over the last two decades, these are the cases where the most substantial increases have occurred. Section 5 presents some concluding remarks.

2 Measuring the international fragmentation of production

One of the factors underlying the high growth rate of international trade over the past two decades is the division of the production chain, with different stages of production located in different countries (see Yi (2003) and Jones et al. (2005)). This phenomenon has been labeled in the literature as "vertical specialization", "slicing up the value chain", "outsourcing", "offshoring", "international production sharing", "disintegration of production", "multi-stage production", "intra-product specialization", "production relocation", "international segmentation of production", etc.[2] International trade theorists tend to call it "fragmentation", a term proposed by Jones and Kierzkowski (1990). In parallel, the concept of middle products was introduced in the early eighties by Sanyal and Jones (1982) to incorporate the notion that all internationally traded goods incorporate some domestic value added either through manufacturing and assembly processes or just through local transportation and retailing services. More recently, important contributions to the theory of international fragmentation of production and trade in intermediate products using Ricardian and Heckscher-Ohlin type models include the works of Arndt (1997), Venables (1999), Yi (2003), Jones and Kierzkowski (2001, 2005), Deardorff (2001*a*,*b*, 2005) and Baldwin and Robert-Nicoud (2007), among others.[3] Grossman and Rossi-Hansberg (2006*a*,*b*) present a formal model of trade in tasks where offshoring acts as technological progress and originates a positive produc-

[2] See Hummels et al. (2001) for a discussion.

[3] See Arndt and Kierzkowski (2001) and Baldwin and Robert-Nicoud (2007) for a review of different models of fragmentation.

tivity effect that can generate gains for all domestic factors.

The extent of international fragmentation is difficult to measure accurately and assumes a variety of forms. The empirical trade literature suggests a range of different methods and data sources to quantify these activities.[4] Three main data sources have been used to document the international fragmentation of production at the sectoral level: customs statistics on processing trade, international trade statistics on parts and components, and Input-Output (I-O) tables.

Customs statistics provide information from customs arrangements in which tariff exemptions or reductions are granted in accordance to the domestic input content of imported goods. The US Offshore Assembly Programme and the European Union (EU) Processing Trade data sets are examples of such data, which have been used in a number of empirical studies to obtain a narrow measure of the international fragmentation of production. This narrow measure captures only the cases where components or materials are exported (imported) for processing abroad (internally) and then reimported (reexported). Swenson (2005) examines the US offshore assembly program between 1980 and 2000 and concludes that these operations grew strongly in that period. Yeats (1998) uses data on offshore assembly processing as a second source of information on international production sharing. He shows that, outside the machinery and transport equipment group, production sharing seems to be also a key factor in the manufacture of textiles and clothing, leather goods, footwear and other labour intensive manufactures. In addition, Clark (2006) examines data on the use of offshore assembly provisions in the US tariff code and concludes that US firms tend to shift the simple assembly operations to unskilled labour abundant countries. Feenstra et al. (1998) also find that the US content of imports, made through the US offshore assembly program, of apparel and machinery and of transportation equipment from industrial countries is characterized by relatively intense use of skilled labour. Görg (2000) using Eurostat data shows that there was an increase of US inward processing trade in the EU countries, in particular in peripheral countries and in the leather and textiles sectors. Baldone et al. (2001) conclude that outward processing trade represents a significant share of trade between the EU15 and Central and Eastern European countries in the textile and apparel industry. According to Helg and Tajoli (2005), Germany has a higher propensity to use outward processing trade than Italy, especially towards Central and Eastern Europe, and it appears to be concentrated in a few specific sectors. Baldone et al. (2007) also observe that EU processing trade tends to be concentrated in a few industries and regions, while Egger and Egger (2001) find that outward processing trade in the EU is stronger in import-competing industries, which correspond

[4] See Molnar et al. (2007) and Baumann and di Mauro (2007) for a discussion.

to the EU low-skilled intensive industries. They also show that outward processing in EU manufacturing grew at the relatively rapid pace in the period 1995-1997. Similarly, Egger and Egger (2005) observe that outward processing trade in the EU grew significantly between 1988 and 1999, in particular with Central and Eastern European countries. Offshore assembly processing accounts also for a significant share of the total manufactured exports of some developing countries. Lemoine and Ünal Kesenci (2002, 2004) and Gaulier et al. (2005) use detailed data from China´s customs statistics on processing trade and conclude that the preferential treatment granted to international processing activities has fostered production sharing between China and its neighbours and strengthened regional economic integration in East Asia.

The classification of trade statistics has been used to measure fragmentation by comparing trade in parts and components with trade in final products. The share of trade in parts and components provides a proxy measure of fragmentation that has been widely used in the literature. Even if trade in intermediate goods as a whole has not risen much faster than trade in final goods, data show that trade in parts and components has exhibited a dynamism exceeding that of trade in final goods (see Athukorala and Yamashita (2006) and Jones et al. (2005) for a review). The main advantage of this approach is the accessibility of the data and its comparability across countries, allowing the identification of specific trading partner relationships. A drawback is that it relies heavily on the product classification of trade statistics. Typically, the parts and components aggregate is obtained from the Standard International Trade Classification (SITC) at the most detailed level and tends to include products belonging to SITC 7 (Machinery and transport equipment) and SITC 8 (Miscellaneous manufactured articles). This type of analysis was initiated with the works of Yeats (1998) and Ng and Yeats (1999) and used extensively afterwards. Yeats (1998) finds that trade in parts and components accounts for 30 per cent of total OECD exports of SITC 7 in 1995 and that this ratio had been rising in recent years. Several papers focus on specific regions or countries and make use of this type of detailed trade data to analyse the international fragmentation of production. Understandably, the focus is put on East Asia and China's recent experiences. This is the case of Lemoine and Ünal Kesenci (2002, 2004) and Gaulier et al. (2005) that use data on imports of parts and components to complement their analysis of the evolution of trade patterns in East Asia. Gaulier et al. (2006) use a detailed bilateral trade database with information on unit values and show that the emergence of the Chinese economy has intensified the international segmentation of production processes among Asian partners. Kaminski and Ng (2001) analyze the evolution of trade in parts and components of ten Central and Eastern European countries and conclude that all of them engage in this type of trade, especially Estonia, Hungary and Slovakia. Other authors have used this method to measure the importance of fragmentation in specific industries in particular countries or geographical areas, as Lall et al. (2004) study of the electronics and automotive sectors in East Asia and Latin America. They show that electronics is fragmenting faster worldwide than the car industry, in particular in East Asia where electronics networks are more advanced. Finally, Kimura et al. (2007) examine patterns of international trade in machinery parts and components in East Asia and Europe and conclude that the theory of fragmentation is well suited for explaining the mechanics of international networks in East Asia.

Most of the existing systematic evidence on the international fragmentation of production focuses on the imported input shares of gross output, total inputs or exports. Typically, such measures use information from I-O tables sometimes complemented with import penetration statistics computed from trade data. The accuracy of the measurement of fragmentation depends crucially on the product breakdown available. A very detailed product classification assures that the characteristics of the production chain are identified and tracked properly, i.e. that a given product is indeed an intermediate good used in the production of another product. However, such data is typically unavailable, making accurate cross-country and/or time-series analysis more difficult to implement. Therefore, the identification of countries with important offshoring activities and the assessment of its main trends has usually been carried out at a relatively aggregate product breakdown. However, in most cases, I-O tables provide the most appropriate source of information, as they allow the analysis across industries and time, even if they are available only for some countries on a comparable basis and are not updated regularly.

Two different types of measures based on I-O data have been implemented in the empirical trade literature (see Hijzen (2005) for a discussion). The first type of measure focuses on the foreign content of domestic production as it considers the share of (direct) imported inputs in production or in total inputs (see Feenstra and Hanson (1996)). As a result, this measure has been used to assess the potential impact of fragmentation on employment and wages of low-skilled workers of the domestic economy, as they are substituted by workers abroad (see Feenstra (2007) for a review). Horgos (2007) provides a detailed analysis of the design of this type of indices. Generally, these studies find a steady increase of the extent of international outsourcing of material inputs over time. Campa and Goldberg (1997) find an increase of the share of imported inputs in production in the US, UK and Canada, but not in Japan. Hijzen (2005) shows that international outsourcing has steadily increased since the early eighties in the United Kingdom, while significant differences persist across industries. In addition, Egger et al. (2001) and Egger and Egger (2003) provide evidence of a significant growth of Austrian outsourcing to Central and Eastern European countries from 1990 to 1998, reflecting the decline of trade barriers and the low wages prevailing there. Finally, Strauss-Kahn (2003) finds an increase of the share of imported inputs in production in France from 1977 to 1993, Geishecker (2006) identifies a significant growth of international outsourcing during the nineties in German manufacturing, while Geishecker et al. (2008) provide evidence of an increase of outsourcing in Germany, the UK and Denmark.

The second I-O based measure of fragmentation focuses on the (direct and indirect) import content of exports and it was initially formulated by Hummels et al. (1998) and Hummels et al. (2001), which labelled it vertical specialization (VS). This measure captures cases where the production is carried out in at least two countries and that the goods cross at least twice the international borders. In comparison with the first I-O based measure, which refers to the direct imported input share of gross output, this measure is narrower as it adds the condition that some of the resulting output must be exported. Conversely, the VS measure proposed by Hummels et al. (2001) is broader as it considers also the imported inputs used indirectly in the production of the goods exported. Hummels et al. (2001) found that VS activities accounted for 21 per cent of the exports of ten OECD and four emerging market countries in 1990 and grew almost 30 per cent between 1970 and 1990. Chen et al. (2005) updates the analysis presented in Hummels et al. (2001) by using more recent I-O tables, finding also that trade in vertical specialized goods has increased over time. Other studies have applied this methodology, in some cases with minor changes from the original formulation, and found an increase of VS activities. Some examples are Amador and Cabral (2008) for Portugal, Minondo and Rubert (2002) for Spain, Breda et al. (2007) for Italy and six other EU countries, Cadarso et al. (2007) for nine EU countries, Dean et al. (2007) and Xiaodi and Jingwei (2007) for China and Chen and Chang (2006) for Taiwan and South Korea.

The phenomenon of VS, as defined by Hummels et al. (2001), has always been part of international trade as countries import manufactured goods to be incorporated in their exports (see Yeats (1998) for a discussion). Nevertheless, the reduction of transport costs, the sharp increase in technical progress and the removal of political and economic barriers to trade exponentiated the opportunities for the international fragmentation of production. Therefore, firms began to offshore many tasks that were previously considered as non-tradable. As stated by Baldwin (2006), fragmentation is now occurring at a much finer level of disaggregation and international competition – which used to be primarily between firms and sectors in different nations – now occurs between individual workers performing similar tasks in different nations. Overall, this new globalization process, named by Baldwin (2006) "*the second unbundling*", led to the surge of new countries in world trade depending heavily on outsourced tasks in industries where potential gains of specialization are higher. In geographical terms, this phenomenon has been largely reported in emerging economies in East Asia, where regional integration seems well advanced. In parallel, international fragmentation has been associated with vertical foreign direct investment (FDI) operations, as multinational firms become prominent players in international trade, now mediating a large fraction of world trade. In this case, trade in intermediate goods takes the form of intra-firm transactions when production stages in different countries are performed by vertically integrated units of the multinational company, i.e. vertical production networks in multinationals. For instance, Hanson et al. (2005) use firm-level data on US multinationals to examine trade in intermediate goods between parent firms and foreign affiliates, concluding that imports of inputs by the affiliates are higher in host countries with lower trade costs, lower wages for less-skilled labour and lower corporate income tax rates. In the same vein, Borga and Zeile (2004) examine intra-firm trade in terms of the propensity of foreign affiliates to import intermediate goods from their US parent companies. Kimura and Ando (2005) examine the mechanics of international networks in East Asia using highly disaggregated international trade data and micro-data for Japanese firms, finding evidence of active trade of parts and components in a combination of intra-firm and arm's length transactions.

3 Methodology and data

This section proposes a relative measure of VS-based trade in the spirit of Hummels et al. (2001), *i.e.* the use of imported inputs to produce goods that are afterwards exported. The new measure combines information from I-O matrices and from international trade data. The information from I-O matrices with a detailed product breakdown is essential to properly identify the characteristics of the production chain, i.e. that a given product is indeed an interrelated intermediate good used in the production of another product. The international trade data is used in both the identification and the quantification of VS activities over time. The basic argument goes along the following lines. For a given country p, a high export share of a specific product together with a high import share of some interrelated intermediate product, evaluated in terms of an international product specialization index, points to the existence of VS. Then, once potential VS situations are labelled, it is necessary to choose a metric to evaluate its intensity. In this case, the option was to set a restrictive threshold based on the cross-country distribution of the product specialization index, evaluating intermediate imports above the value defined by the threshold as a percentage of total imports. In order to proceed, it is first necessary to choose a suitable international product specialization index.

The international product specialization index used in the analysis is the one introduced in Amador et al. (2007) - the $B^{\star}$ -, with good cardinal properties for a cross-country analysis within one single sector. The $B^{\star}$ index draws from the Balassa (1965) index and simply uses a different "normalization", i.e. a different denominator. To evaluate the relative export specialization of country p in sector j, the $B^{\star}$ is defined as:

$$B^{\star}_{Xpj} = \frac{\frac{x_{pj}}{X_p}}{\left(\overline{\mu_p}\right)_j} \qquad \text{country } p = 1, 2 \ldots N; \text{ product } i, j = 1, 2 \ldots S \tag{1}$$

Where $\left(\overline{\mu_p}\right)_j = \frac{1}{N}\sum_{p=1}^{N}\left(\frac{x_{pj}}{X_p}\right)_j$ is the *average* export share of sector j across the different p countries. Each country $p = 1, 2 \ldots N$ has a particular share of product j in total exports, $\frac{x_{pj}}{X_p}$, and $\left(\overline{\mu_p}\right)_j$ is just the *unweighted* average of this export share in all countries.[5] The index can also be computed for imports, bearing similar characteristics and similar interpretations. The index for imports will be designated by $B^{\star}_{Mpi}$ and when it reaches a value higher than one it means that country p is classified as being a relatively stronger importer in sector i.

Our definition of what are *high* export and import shares is dependent on the distribution of each $B^{\star}_{Xj}$ and $B^{\star}_{Mi}$. In a given period, if the $B^{\star}_{Xpj}$ is higher than the $B^{\star}_{Xj}$ of a given percentile, i.e. $B^{\star}_{Xpj} > B^{\star PRC}_{Xj}$, then the export share is considered to be relatively high. The same applies to the import side. Although we acknowledge that intra-industry trade may explain relatively high values of both $B^{\star}$ indicators, it is hard to accept that such trade justifies import shares that are, for instance, twice the world average. We estimated the kernel distributions for each of the 121 products both on the import and on the export side at the beginning and at the end of the sample period. In general, the density functions estimated for exports are markedly more right skewed than those obtained on the import side, indicating a higher overall degree of specialization. On the contrary, the density functions of imports are more symmetric, pointing to more similar product import shares across all countries, especially in the last period. The main exceptions are some intermediate goods, mainly food products and some processed industry supplies, where evidence of a strong specialization was found on the import side.[6]

The international trade data used in this paper comes from the CEPII - CHELEM

[5] In every period t, the sum of all indices across countries within each product j yields, by construction, the upper bound N - thus neither dependent on the relative dimension of country p, nor variable across time.

[6] The estimated kernel densities of each product are omitted for presentation reasons but are available from the authors upon request.

database, which reports bilateral trade flows for goods in value terms (the unit being the US dollar).[7] The sample period starts in 1967 and ends in 2005. Our database comprises 79 countries or country groups (N=79) and 121 different manufacturing products (S=121), with a product breakdown at the 4-digit level of the International Standard Industrial Classification of All Economic Activities (ISIC), rev.3.1. These 121 manufactured goods can be grouped in accordance with their technological intensity, following the OECD classification of R&D intensities. This widely used technological classification includes four main sectors: high-technology, medium-high-technology, medium-low-technology and low-technology; and a second breakdown level contains twenty sub-sectors. Appendix A displays the list of countries and country groups included in our sample and Appendix B reports the product technological breakdown with the respective ISIC code.

The Input-Output (I-O) matrices come from Bureau of Economic Analysis (BEA) 1997 Benchmark Input-Output Accounts for the United States (US).[8] The estimates from the 1997 benchmark I-O accounts at the detailed level report the flows of 498 commodities to 504 industries, according to the I-O classification system. Some adjustments had to be made to turn the I-O classification compatible with the ISIC classification available for the international trade data. Firstly, the US I-O classification system is based on the North American Industry Classification System (NAICS) and a table with the detailed I-O codes and the related NAICS codes is available on-line from the BEA. Secondly, the correspondence table between the ISIC rev.3.1 and the NAICS US 2002, available from the United Nations Statistics Division, was used. For 1997 (benchmark year) the manufacturing industry includes 344 detailed commodities (inputs) of the I-O classification, which were aggregated into the 121 sectors of the ISIC classification. The same procedure was followed for the available 344 manufacturing industries (outputs). The aggregation process is not straightforward as the correspondence between ISIC rev.3.1 and NAICS 2002 is not direct. Therefore, some hypothesis had to be made and some ISIC products were computed together and later broken down. As a result, a 121 by 121 I-O matrix following the ISIC is obtained, establishing the amount of each input used in the production of each of the 121 products. Afterwards, this I-O matrix was turned into a 1/0 pseudo I-O matrix, according to the following rule: if a product represents more than 1 percent of total inputs of an industry, then the pseudo I-O matrix takes the value 1; otherwise it takes the value zero.[9] This pseudo I-O matrix, designated by IO_{ij}, is a crucial component in the detection of VS activities, as

[7] See De Saint-Vaulry (2008) for a detailed description of this database.

[8] The table "The Use of Commodities by Industries after Redefinitions" available on-line in Interactive Access To Input-Output Accounts Data was used. For more details on the concepts and methods of the US Input-Output Accounts, see Lawson et al. (2002).

[9] Several other limits were tested and no major changes were detected.

it allows the identification of the products i that are inputs used in the production of each good j. The same pseudo IO_{ij} matrix is used for every country of our sample in each period, thus assuming that the main characteristics of the production chain do not change overtime and from one country to the other.[10]

Three other pseudo IO_{ij} matrices were computed with different product compositions. Firstly, energy-related items as coke, refined oil products and nuclear fuel were excluded from the analysis by zeroing the respective input and output elements of the matrix, resulting in 118 active products on both sides. Secondly, the values of some inputs i were also set to zero to approximate the definition of parts and components that is used in several studies.[11] All inputs not included in the parts and components aggregate were set to zero, resulting in a new pseudo IO_{ij} matrix with 45 active products as inputs. Thirdly, a more restrictive definition of parts and components was applied, by zeroing additional products on the input side, leaving 33 active products as inputs.[12] The description of the products included in each of the two proxies of parts and components is included in Appendix C.

At this point let us be more precise in defining the two steps underlying the proposed methodology for a relative measure of VS:

Step 1: Labelling VS activities

The identification of relevant VS activities combines the different elements mentioned above. In every period t, for each pair of products (i, j) and a given threshold percentile PRC, if $IO_{ij} = 1$ *and* $B^{\star}_{Xpj} > B^{\star PRC}_{Xj}$ *and* $B^{\star}_{Mpi} > B^{\star PRC}_{Mi}$, then the element i, j, p of the matrix VS_t takes the value one; otherwise it takes the value zero. This procedure was first followed considering all 121 products for every country $p = 1, 2 \ldots 79$ in every period $t = 1, 2 \ldots 47$. The same procedure was replicated with the different I-O matrices described above, corresponding to the other three product compositions. The detection of relevant VS activities using this procedure depends heavily on the percentile

[10] This can possibly be a strong assumption, but the inputs used in the production of each good probably depend more on technology than on cross-country differences. Additionally, the fact that US produces most existing goods ensures a broad production coverage. Moreover, the pseudo I-O matrix is only one of three components that are used in the identification of VS activities.

[11] The United Nations classification by Broad Economic Categories (BEC) rev.3 categorizes trade statistics into large economic economic classes of goods on the basis of the principal use of the products. The BEC sub-categories "42 - Parts and accessories of capital goods" and "53 - Parts and accessories of transport equipment" are used as the starting point of the proxy of "parts and components" (see, for instance, Gaulier et al. (2006) for a similar definition). As the BEC rev.3 is defined in terms of Standard International Trade Classification (SITC) rev.3, there is an exact correspondence between the two classifications. However, our data is classified at the four digits level of the ISIC rev.3.1 and no direct correspondence with the BEC is available at this breakdown level. As a result, the correspondence between BEC and ISIC was constructed starting from a correspondence between ISIC rev.3 and SITC rev.3, though some approximations had to be made as the matches are not exact.

[12] Since the correspondence with BEC is not exact, some ISIC products were considered as parts and components in the 45 inputs definition even if only one of its several SITC elements was included in that BEC classification. In this more restrictive proxy of parts and components, these inputs were set to zero.

that defines the VS threshold. For this reason, the selection process was implemented considering 5 different threshold percentiles: $PRC = 75, 80, 85, 90, 95$. The percentiles chosen were high-order, to abstract, as much as possible, from intra-industry trade or country characteristics that would justify trade flows somewhat higher than the world average. For each country p, if the result of the sum of all columns of each VS_t for each i product is positive, then product i is being identified as an intermediate good in VS activities and its imports should be considered in the measurement of VS in period t.

Step 2: Quantifying VS activities

In each country and for each product i, the value of intermediate imports that surpasses the value implied by the threshold percentile will be considered as trade due to VS activities in period t. The use of different threshold percentiles provides an interval for the dimension of estimated VS activities.

Firstly, we obtain, for each country in each period, the level of imports that would make $B^{\star}_{Mpi} = B^{\star PRC}_{Mi}$. Starting from:

$$B^{\star}_{Mpi} = B^{\star PRC}_{Mi} \Leftrightarrow \frac{\left(\dfrac{m_{pi}}{M_p}\right)}{\frac{1}{N}\sum_{p=1}^{N}\left(\frac{m_{pi}}{M_p}\right)} = \frac{\left(\dfrac{m_{pi}^{PRC}}{M_p^{PRC}}\right)}{\frac{1}{N}\sum_{p=1}^{N}\left(\frac{m_{pi}^{PRC}}{M_p^{PRC}}\right)} \Leftrightarrow$$

$$\frac{\left(\dfrac{m_{pi}}{m_{pi}+\sum_{z\neq i}^{S} m_{pz}}\right)}{\frac{1}{N}\left(\dfrac{m_{pi}}{m_{pi}+\sum_{z\neq i}^{S} m_{pz}}\right)+\frac{1}{N}\sum_{c\neq p}^{N}\left(\frac{m_{ci}}{M_c}\right)} = \frac{\left(\dfrac{m_{pi}^{PRC}}{m_{pi}^{PRC}+\sum_{z\neq i}^{S} m_{pz}}\right)}{\frac{1}{N}\left(\dfrac{m_{pi}^{PRC}}{m_{pi}^{PRC}+\sum_{z\neq i}^{S} m_{pz}}\right)+\frac{1}{N}\sum_{c\neq p}^{N}\left(\frac{m_{ci}}{M_c}\right)} \tag{2}$$

Solving (2) in order of m_{pi}^{PRC}, the value of the imports of product i by country p in period t that would make $B^{\star}_{Mpi} = B^{\star PRC}_{Mi}$ is:

$$m_{pi}^{PRC} = \frac{\frac{B^{\star PRC}_{Mi}}{N}\left(\sum_{c\neq p}^{N}\frac{m_{ci}}{M_c}\right)\left(\sum_{z\neq i}^{S} m_{pz}\right)}{1-\frac{B^{\star PRC}_{Mi}}{N}\left(1+\sum_{c\neq p}^{N}\frac{m_{ci}}{M_c}\right)} \tag{3}$$

In each period t, the value of intermediate imports above the one implied by threshold is used as a relative measure of VS activities for each country/product pair:

$$VSM_{pi}^{PRC} = m_{pi} - m_{pi}^{PRC} \qquad \text{country } p = 1, 2 \ldots N;\ \text{product } i, j = 1, 2 \ldots S \tag{4}$$

As previously mentioned, this computation is applied conditional on the prior identification of VS activities, hence equation 4 always takes a positive value. However, if the growth of real VS activities from one period to the next translates into an increase of m_{pi} that is smaller than the increase of m_{pi}^{PRC}, then VSM_{pi}^{PRC} will decline. In this sense, the measure has a relative nature because it bases the identification and quantification of VS activities on trade flows whose relative dimension in the country is above an international threshold that is also changing over time. In fact, in dynamic terms, this measure will only capture the cases where the increase of real VS activities is strong enough to translate into a growth of intermediate imports above the one implied by the international threshold. Hence, the measure is perceived as conservative because it underestimates true VS activities in situations where the international threshold is increasing.

This proposed metric has adequate additive properties in the sense that, in each period, VSM_{pi}^{PRC} can be summed for each country p and/or for each product i, providing a breakdown of VS-related trade by country or by product over time. In fact, given that we obtain a proxy for the level of VS activities for each pair country/product in each period, the detailed results can be added up to get any other upper-level breakdown. For instance, the 121 initial products can be grouped in accordance with their technological intensity or any other upper-level classification with a correspondence to the ISIC rev.3.1. The same is true at the country-level as the different countries can be grouped to get some geographical area of interest. Additionally, the analysis of VS-based trade can be made both from a cross-sector perspective (different products within one geographical area) and from a cross-country view (different countries within one sector). To facilitate comparisons between countries (or products) and over time, the final measure is computed as a percentage of total imports for each country/geograpical area or for each product. That is:

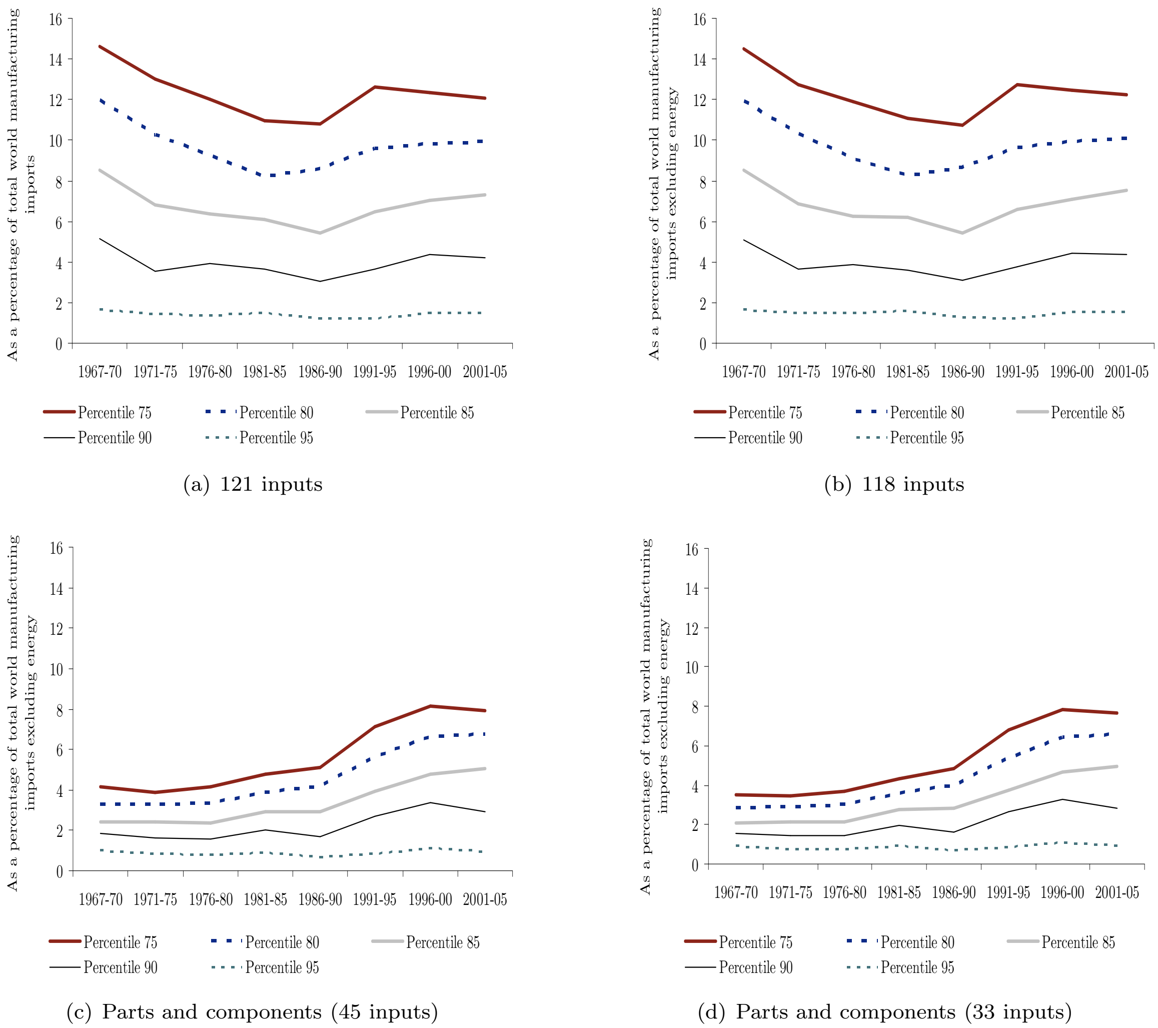
$$VSM_{p}^{PRC} = \frac{\sum_i VSM_{pi}^{PRC}}{\sum_i m_{pi}} \qquad \text{or} \qquad VSM_{i}^{PRC} = \frac{\sum_p VSM_{pi}^{PRC}}{\sum_p m_{pi}}$$

4 Measuring vertical specialization across the world

This section provides an illustration of the main results at the world level over the last four decades, using both a product and a geographical breakdown. In order to facilitate the analysis, VS-based trade is presented as a percentage of total world imports. The detailed analysis of the results both at the country and at the product levels is notoriously beyond the scope of this paper and will be selectively developed in future work.

This section also includes a sensitivity analysis, at the world level, of the VS measure proposed because this empirical approach allows for different options on crucial aspects as the classification of intermediate goods and the percentile that defines the VS threshold. Figure 1 shows the aggregated results for VS trade at the world level, as a percentage of total world imports, considering different alternatives in each dimension, i.e. total sample (121 products), excluding energy-related items (118 active products), broad definition of parts and components (with 45 active inputs), strict definition of parts and components (with 33 active inputs); and different threshold percentiles ($PRC = 75, 80, 85, 90, 95$).[13] All computations were made on a yearly basis, but for presentation purposes the results were aggregated in eight reference periods (1967-70, 1971-75, 1976-80, 1981-85, 1986-90, 1991-95, 1996-00 and 2001-05).

Figure 1: World - Vertical specialization activities



(a) 121 inputs

(b) 118 inputs

(c) Parts and components (45 inputs)

(d) Parts and components (33 inputs)

[13]The sensitivity analysis was performed for each for the 79 countries and geographical areas of the database. Given the obvious space limitations, only the aggregated results at the world level are included, but the detailed information for each country is available from the authors upon request.

The evolution of the share of VS in total world imports is very different when comparing the broad range of intermediate products (121 and 118 products) with the two narrower definitions of parts and components (45 and 33 products). In the latter group, the results are similar, pointing to an increase of the share of VS-related trade in the last decades. However, this trend is not visible taking the broad ranges of products, showing instead a slight decline of the VS share in total imports since the sixties. Several situations may justify this outcome. Firstly, as stated previously, our measure has a relative nature, meaning that it only detects VS in the interrelated sectors whose relative shares in the country's exports and imports are higher than an international threshold, which can also be growing over time. In this sense, the proposed measure is conservative. Secondly, total world imports are increasing for reasons other than VS activities, leading to a strong increase of the denominator of the ratio. Thirdly, changes in the relative prices of intermediate goods can also affect the result. If prices of intermediates grow slower than prices of other goods, the indicator may decrease. Unfortunately, there is very little empirical evidence on the path of relative prices of intermediate goods in the last decades. Gaulier et al. (2008) report results for the period 1997-2004 and show that relative prices between intermediate and final goods were broadly stable.

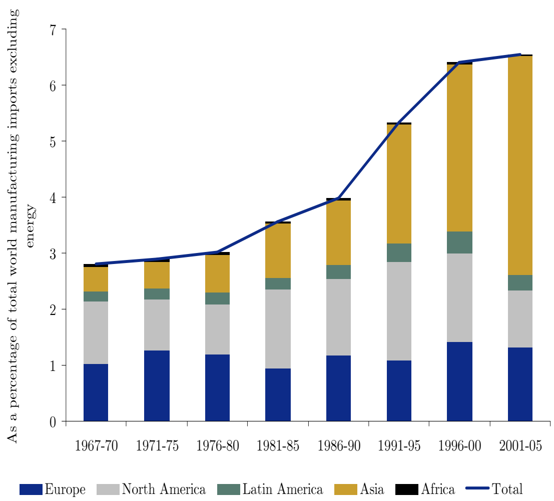
At this point it is important to note that the very high threshold percentiles ($PRC = 90, 95$) produce low and irregular values at the country level, though this latter aspect is offset when the world aggregate is calculated. This is due to an overdemanding criterium for labelling VS activities, leaving out many sectors where it actually exists and capturing primarily situations of very high imports and exports that occur just in one year, probably reflecting outliers or statistical problems. Thus, the analysis is focused in percentiles $PRC = 75, 80, 85$, which provide broadly similar results, specially with the parts and components definition of inputs (also at the country level).

For the sake of additional illustration, we chose the most restrictive definition of parts and components (33 inputs) and the percentile 80 as the threshold. The results for the available 79 countries were aggregated in broad geographical areas, including a world total. At the product level, the products were grouped by technological content (high technology, medium-high technology, medium-low technology and low technology) following the OECD classification of R&D intensities. Figure 2 depicts the evolution of the worldwide VS measure, as a percentage of total world manufacturing imports excluding energy, over the last forty years. Figure 2(a) presents the geographical breakdown of total world VS over time. The first strong result is that the share of Asia in total VS has increased sharply over the last twenty years, representing 60 per cent of total in the 2001-2005 period (from 16 per cent at the beginning of the sample period).

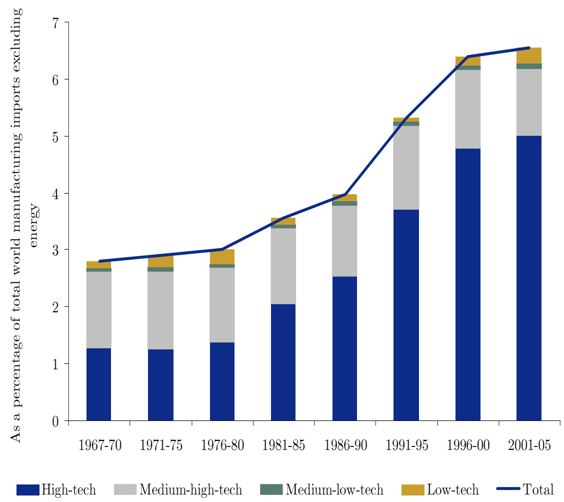
This result is in line with evidence found in several other studies referring that the segmentation of production processes is a major force driving regional trade in Asia (see Kimura (2006) for a comprehensive analysis of East Asian production and distribution networks). On the contrary, the relative importance of North-America in world VS declined markedly, in particular since mid-eighties. Our results point also to a substantial increase of the relevance of high-tech goods in VS activities, in particular over the last twenty years (Figure 2(b)). VS activities in the high-tech sector increased from 1.3 per cent in 1967-70 to 5.0 per cent of world non-energy imports in 2001-05, representing 76.5 per cent of total VS-based trade in the most recent period. On the contrary, the share of medium-high-tech goods in VS activities at the world level declined to 18 per cent of total in 2001-05, from almost 48 per cent in the first period, reflecting mainly the evolution of "Motor vehicles, trailers and semi-trailers".

Figures 2(c) and (d) give additional detail on the areas/sectors that exhibited the higher increase of VS-based trade. Figure 2(c) shows a breakdown of Asian countries, including two groups of emerging market economies located in South East Asia aggregated according to their level of economic development: the Dragons, i.e. the first tier of new industrialized economies (Hong Kong, Singapore, South Korea and Taiwan), and the Tigers, i.e. the second tier of new industrialized economies (Malaysia, Philippines and Thailand) (see Gaulier et al. (2006) for a similar geographical breakdown). The growth of VS activities was specially strong in the Dragons that almost doubled their share in world VS trade since mid-eighties, accounting for 24.5 per cent of the total in 2001-05. In the most recent period, the most impressive increase took place in China that now represents 15 per cent of total world VS from 1.7 per cent twenty years ago. Figure 2(d) displays the main products that compose the high-tech aggregate. Substantial VS trade is found in "Office, accounting and computing machinery" and, specially, in "Radio, TV and communications equipment", which accounts for around 60 per cent of VS activities in the high-tech sector.

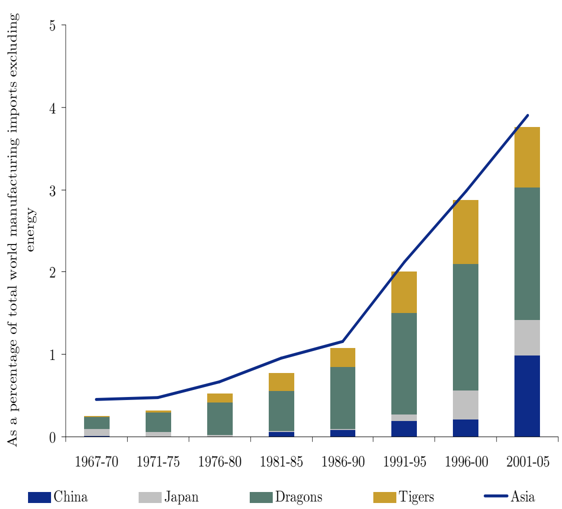
Figure 2: World - Vertical specialization activities
Parts and components (33 inputs) and Threshold percentile 80



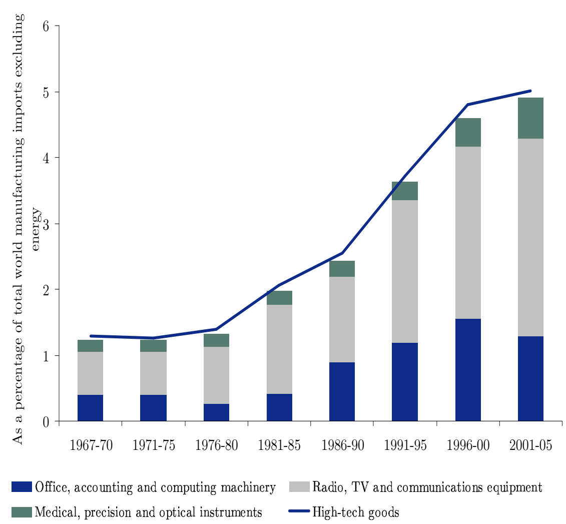
(a) By main geographical areas



(b) By technological intensity



(c) Asian geographical breakdown



(d) High-tech product breakdown

Note:
Dragons and Tigers refer to 7 emerging market economies located in South East Asia grouped according to their level of economic development: the Dragons, i.e. the first tier of new industrialised economies (Hong Kong, Singapore, South Korea and Taiwan), and the Tigers, i.e. the second tier of new industrialised economies (Malaysia, Philippines and Thailand).

5 Conclusions

Vertical specialization (VS) activities, as defined by Hummels et al. (2001), stand as a new paradigm in the organization of world production and represent an important element of international trade. Therefore, it is important to date its evolution and map its distribution across countries and products in a comparable and flexible way. This paper introduces a new relative measure that uses simultaneously information from Input-Output (I-O) matrices and from international trade statistics to compute a proxy of VS-based trade for a large sample of individual countries and geographical areas, including a world aggregate, with a detailed product breakdown. Our database comprises 79 countries or country groups with a sectoral breakdown that includes 121 different products from 1967 to 2005.

In the first step of the methodology, information from the I-O tables of the United States is used to identify the intermediate products used in the production of each good. Next, conditional on this information, the identification of relevant vertical specialization activities is accomplished by computing an international trade specialization indicator - the $B^{\star}$ index introduced in Amador et al. (2007) - for both exports and imports in the 121 different sectors, for the 79 sample countries, and by setting a restrictive threshold defined as a high percentile of the cross-country distribution of the index. The basic intuition is that if a country simultaneously exports a product and imports a related intermediate good in such a way that their relative shares are much higher than the average of the other countries, then international vertical linkages must play a role. In the second step of the methodology, the proxy of VS-based trade for each country/product pair in period t is defined as the value of intermediate imports that surpasses the value implied by the threshold percentile. Hence, the measure has a relative nature because it bases the identification and quantification of VS activities on trade flows whose relative dimension in the country is above an international threshold that is also changing over time. In dynamic terms, this measure only captures the cases where the increase of true VS activities is strong enough to translate into a growth of intermediate imports above the one implied by the international threshold. As a result, our proxy should be taken as conservative because it underestimates true VS activities in situations where the international threshold is increasing.

Using this methodology, we identify both countries and products where VS activities are relevant and quantify its evolution over time. Given that we obtain a proxy for the level of VS activities for each pair country/product in each period, the detailed results can be added up to get different breakdowns. For instance, a proxy of VS activities in hight-tech goods can be calculated by adding all products that compose this sector or a measure of VS-based trade in a specific geographical area can be obtained by summing all the results at the country level. Additionally, the analysis of VS-based trade using this proxy can be made both from a cross-sector perspective (different products within one geographical area) and from a cross-country view (different countries within one sector). This paper is mainly methodological, thus the detailed analysis of VS activities using this measure is not fully explored. This will be the object of further research. Notwithstanding, we provide an illustration of the main results by examining the evolution of VS activities at the world level over the last four decades using a product breakdown by technological intensity and a geographical breakdown by main country areas. Our results point to a substantial and continuous increase of VS processes in high-tech products since the eighties, in particular in "Radio, TV and communications equipment". In geographical terms, significant and growing VS activities are identified in East Asia over the last two decades, specially in the first tier of new industrialized economies (Hong Kong, Singapore, South Korea and Taiwan). In the last period, China stands out by the striking increase of VS-based trade.

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Appendices

A Geographical breakdown

The 79 countries or country groups included in our sample are the following:

United States; Canada; France; BLEU; Germany; Italy; Netherlands; United Kingdom; Ireland; Denmark; Finland; Norway; Sweden; Iceland; Austria; Switzerland; Spain; Greece; Portugal; Turkey; Israel; Former Yugoslavia; Others in South Europe; Japan; Australia; New Zealand; South African Union; Venezuela; Ecuador; Mexico; Brazil; Argentina; Chile; Colombia; Peru; Bolivia; Paraguay; Uruguay; Others in America; Algeria; Morocco; Tunisia; Egypt; Libya; Saudi Arabia; Gulf; Middle East (no OPEC); Nigeria; Gabon; Cameroon; Cote d'Ivoire; Kenya; Others in Africa; African LDCs; Indonesia; India; South Korea; Hong Kong; Singapore; Taiwan; Malaysia; Philippines; Thailand; Pakistan; Brunei; Bangladesh; Sri Lanka; Others in East Asia; East Asian LDCs; Former USSR; Bulgaria; Former Czechoslovakia; Hungary; Poland; Romania; Albania; China, People's Rep.; Vietnam; Cambodia, Laos.

The composition of the different areas/country groups is the following:

a. BLEU includes Belgium, Luxembourg.

b. Germany includes the former German Democratic Republic until 1990.

c. Former Yugoslavia includes Serbia and Montenegro, Bosnia and Herzegovina, Croatia, Macedonia, Republic of Slovenia.

d. Others in South Europe includes Andorra, Cyprus, Gibraltar, Malta.

e. South African Union includes Botswana, Lesotho, Namibia, South Africa, Swaziland.

f. Others in America includes Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Costa Rica, Cuba, Dominica, Dominican Republic, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Montserrat, Netherland Antilles, Nicaragua, Panama, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Suriname, Trinidad and Tobago, and all others in America nes.

g. Gulf includes Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, United Arab Emirates.

h. Middle East, (no OPEC) includes Jordan, Lebanon, Syria, Yemen.

i. African LDCs includes Angola, Benin, Burkina Faso, Burundi, Cape Verde, Central African Republic, Chad, Comoros, Democratic Republic of Congo (formerly Zaire), Djibouti, Equatorial Guinea, Eritrea, Ethiopia, Gambia, Guinea, Guinea-Bissau, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Rwanda, Sao Tome and Principe, Senegal, Sierra Leone, Somalia, Sudan, Tanzania, Togo, Uganda, Zambia.

j. Others in Africa includes Congo, Ghana, Mauritius, Seychelles, Western Sahara, Zimbabwe, and all others in Africa nes.

k. East Asian LDCs includes Afghanistan, Bhutan, Kiribati, Maldives, Myanmar, Nepal, Solomon Islands, Vanuatu, Western Samoa.

l. Others in East Asia includes Fiji, French Polynesia, Guam, Macao, Mongolia, New Caledonia, North Korea, Pacific Islands, Papua New Guinea, Tonga, US Samoa, Vanuatu, Western Samoa, and all others in Asia and Oceania nes.

m. Former USSR includes the Commonwealth of Independent States (Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine, Uzbekistan), Baltic States (Estonia, Latvia Lithuania).

n. Former Czechoslovakia includes Czech Republic, Slovakia.

Source: Chelem database.

B Product classification by technological intensity

		ISIC rev.3
High-technology products	**HT**	
Aircraft and spacecraft	HT1	353
Pharmaceuticals	HT2	2423
Office, accounting and computing machinery	HT3	30
Radio, TV and communications equipment	HT4	32
Medical, precision and optical instruments	HT5	33
Medium-high-technology products	**MHT**	
Other electrical machinery and apparatus	MHT1	31
Motor vehicles, trailers and semi-trailers	MHT2	34
Chemicals excl. pharmaceuticals	MHT3	24 excl. 2423
Railroad equipment and other transport equip.	MHT4	352 + 359
Other machinery and equipment	MHT5	29
Medium-low-technology products	**MLT**	
Coke, refined petroleum prod. and nuclear fuel	MLT1	23
Rubber and plastics products	MLT2	25
Other non-metallic mineral products	MLT3	26
Building and repairing of ships and boats	MLT4	351
Basic metals	MLT5	27
Fabricated metal products, excl. machinery	MLT6	28
Low-technology products	**LT**	
Other manufacturing and recycling	LT1	36-37
Wood, pulp, paper and printed products	LT2	20-22
Food products, beverages and tobacco	LT3	15-16
Textiles, textile products, leather and footwear	LT4	17-19
Total manufacturing		15-37

Source: Chelem database.

The product breakdown used here and available in the CEPII - CHELEM database follows the OECD classification of manufacturing industries according to technological intensity using the ISIC rev. 3 breakdown. This classification was based on the analysis of R&D expenditure and output of 12 OECD countries in the period 1991-99. For more information, see OECD (2005).

C Breakdown of the proxies of Parts and Components

	Parts and Components (45 products) ISIC rev.3 code and description			Parts and Components (33 products) ISIC rev.3 code and description
1	1729 Other textiles n.e.c.			
2	2511 Rubber tyres and tubes		1	2511 Rubber tyres and tubes
3	2519 Other rubber products			
4	2610 Glass and glass products			
5	2691 N-struct. n-refract. ceramic			
6	2813 Steam generators		2	2813 Steam generators
7	2893 Cutlery, hand tools & hardware		3	2893 Cutlery, hand tools & hardware
8	2899 Other fabricated metal prod.		4	2899 Other fabricated metal prod.
9	2911 Engines, exc. vehicle engines		5	2911 Engines, exc. vehicle engines
10	2912 Pumps, taps and valves		6	2912 Pumps, taps and valves
11	2913 Bearings, gears		7	2913 Bearings, gears
12	2914 Ovens, furnaces and burners		8	2914 Ovens, furnaces and burners
13	2915 Lifting and handling equipment		9	2915 Lifting and handling equipment
14	2919 Oth. general purpose machinery			
15	2921 Agric. and forestry machinery			
16	2922 Machine-tools		10	2922 Machine-tools
17	2923 Machinery for metallurgy			
18	2924 Machinery for mining & constr.			
19	2925 Machinery for food processing			
20	2926 Machinery for textile prod.			
21	2927 Weapons and ammunition			
22	2929 Oth. special purpose machinery		11	2929 Oth. special purpose machinery
23	2930 Domestic appliances n.e.c.			
24	3000 Office and computing machinery		12	3000 Office and computing machinery
25	3110 Electric motors and generators		13	3110 Electric motors and generators
26	3120 Electricity distrib. apparatus		14	3120 Electricity distrib. apparatus
27	3140 Accumulators and primary cells		15	3140 Accumulators and primary cells
28	3150 Electric lamps & lighting eq.		16	3150 Electric lamps & lighting eq.
29	3190 Other electrical equipment		17	3190 Other electrical equipment
30	3210 Electronic valves and tubes		18	3210 Electronic valves and tubes
31	3220 TV & radio transmitters & tel.		19	3220 TV & radio transmitters & tel.
32	3230 TV & radio receivers, record.		20	3230 TV & radio receivers, record.
33	3311 Medical & surgical equip.		21	3311 Medical & surgical equip.
34	3312 Instruments for measuring		22	3312 Instruments for measuring
35	3313 Indust. process control equip.		23	3313 Indust. process control equip.
36	3320 Optical instr. & photo equip.		24	3320 Optical instr. & photo equip.
37	3330 Watches and clocks		25	3330 Watches and clocks
38	3410 Motor vehicles		26	3410 Motor vehicles
39	3420 Bodies for motor vehicles		27	3420 Bodies for motor vehicles
40	3430 Parts for motor vehicles		28	3430 Parts for motor vehicles
41	3520 Railway & tramway locomotives		29	3520 Railway & tramway locomotives
42	3530 Aircraft and spacecraft		30	3530 Aircraft and spacecraft
43	3591 Motorcycles		31	3591 Motorcycles
44	3592 Bicycles and invalid carriages		32	3592 Bicycles and invalid carriages
45	3610 Furniture		33	3610 Furniture

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