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GLOBAL VALUE CHAINS: A SURVEY OF DRIVERS AND MEASURES

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Abstract. Global value chains (GVCs) emerged as the paradigm for the international organization of production. For most goods and services production is nowadays vertically fragmented across different countries and this reality gave rise to a significant new strand of research in international trade. This article starts by discussing the major driving forces of GVCs in recent decades. Next, it surveys the main measures of GVCs, accounting for their different scopes and required data sets. The article highlights the timing of the contributions to the literature, signalling their sequential nature and the trend toward more accurate and data-demanding indicators.

Keywords. Fragmentation; Global value chains; Globalization; International trade; Offshoring; Survey

1. Introduction

> *'The cross-border flows of goods, investment, services, know-how and people associated with international production networks – call it "supply chain trade" for short – has transformed the world.'* (Baldwin, 2012, p.1)

The rise of *Global Value Chains* (GVCs) has dramatically changed the organization of world production of goods and services in recent decades, making a deep and lasting impact on international trade and investment patterns and affecting competitiveness and macroeconomic developments. International production sharing has always been part of international trade as countries import manufactured goods to be incorporated in their exports. However, the reduction of transport and communication costs, the acceleration of technological progress and the removal of political and economic barriers to trade exponentiated the opportunities for the international fragmentation of production. Nowadays, GVCs are probably the most prominent feature of globalization.

The growth of GVCs brought a permanent reshuffling of global comparative advantages, which are now identified in terms of intermediate goods and services or specific tasks in the value chain, rather than only in terms of final products. Hence, GVCs cannot be perfectly understood with the traditional concepts of comparative advantage applied to countries and broad sectors. Instead, GVCs are mostly about the ability of firms to integrate value from different origins. Reaping the benefits from international trade implies

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adjusting the productive structure to this changing reality and, hence, it requires the ability to reallocate inputs between industries and to attract and sustain the operations of multinational firms. The analysis of GVCs is key to understand the international creation and distribution of value, as well as the capacity of countries to prosper in an increasingly interdependent world. The pervasiveness of GVCs impacts strongly on trade, productivity and labour market developments but also on topics like inequality, poverty and the environment. Gereffi (2014) discusses the growing importance of GVCs for economic and social welfare and how changes in the governance of GVCs are crucial for global development, highlighting the increasing role of emerging countries.

The expansion of GVCs has significant policy implications, changing the way policy-makers interpret trade policies and external competitiveness and strongly increasing the economic interdependence between countries. At present, even simple measures that usually inform the policy-debate, such as export market shares or effective exchange rates, need to be redefined in order to disentangle the domestic and foreign value-added embodied in trade flows. As discussed in Johnson (2014), taking into account GVCs is key to obtain better quantitative answers to several policy-relevant macroeconomic and trade questions, like the international transmission of shocks, the adjustment of trade imbalances, the evolution of specialization patterns and the analysis of trade policy.

In theoretical terms, a comprehensive framework encompassing the specificities of GVCs is still missing. Arndt and Kierzkowski (2001) and Antrás and Rossi-Hansberg (2009) review the contributions to the theory of international fragmentation of production using Ricardian and Heckscher-Ohlin type models. Spencer (2005) and Helpman (2006) provide reviews of another strand of the theoretical literature on fragmentation, which focuses on the organizational choices of individual firms, their boundaries and incomplete-contracting.

Baldwin (2006) frames the major transformations of international trade over the last century as a sequence of two unbundlings. Until the late 19th century, factories had an integrated production structure, where parts and components were produced either sequentially or in different contiguous units located near consumers. Afterwards, the spatial unbundling of production and consumption (the first unbundling) was made possible by the great reduction in transport costs originated by steam power. Although production was dispersed internationally, leading to trade in final products, it was still clustered locally to minimize coordination costs. This paradigm was replaced by international networks of individual and autonomous suppliers that specialize in specific phases of the production process and locate in different countries. The spatial unbundling of production stages previously clustered in factories and offices (the second unbundling) benefited from the sharp fall of communication and coordination costs and radically changed the nature of international trade and investment.

The networks that operate GVCs are very complex, involving firms in manufacturing, logistics, transportation and other services, as well as customs agents and other public authorities. Supply-chain trade is determined by international differences in production and unbundling costs, with technology shaping the way in which the different stages of production are linked. Baldwin and Venables (2013) introduce the concepts of 'spiders' (production processes where multiple parts and components are assembled in no particular order) and 'snakes' (processes whose sequencing is dictated by engineering and where goods move in a sequential way from upstream to downstream stages with value being added along the way) as organizational benchmarks, though most international production processes are an intricate mixture of the two. An extreme form of international fragmentation of production, designated as 'factoryless goods producers', was recently documented for the US economy (see Bernard and Fort, 2013). Such producers are formally classified in the wholesale sector by official statistics, but they perform pre-production activities, such as design and engineering, and exert control over the production of manufactured goods.

The high complexity and the different scales of analysis make it virtually impossible to define, measure and map GVCs in a single way. Therefore, the economic literature has evolved along different strands of research, using different concepts, methods and terminologies.[1] Sturgeon (2001) discusses in detail a set of terms and concepts associated with global economic integration in three dimensions

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(organizational scale, geographic scale and types of productive actors), distinguishing between value chains and production networks. However, following most of the literature, the various terms relating to GVCs are used interchangeably in this article.

The review of the vast empirical literature on the different dimensions of GVCs is beyond the scope of this article. Instead, this survey focuses on the drivers and empirical measures of GVCs, a subject that, as far as we know, has not been summarized yet. We aim to provide a conceptual framework and signal potential lines for future research. The remainder of the article is organized as follows. Section 2 discusses the main drivers behind the significant expansion of GVCs in recent decades. Section 3 surveys the different methodologies used in the literature to map and measure GVCs. Finally, Section 4 presents some concluding remarks.

2. Drivers of GVCs

As discussed in Hillberry (2011), it is difficult to separate the drivers of the increase in international trade from those with a specific impact on the fragmentation of production. The same is true for the expansion of foreign direct investment (FDI) flows, which are instrumental for the setting up of GVCs by multinational corporations. Nevertheless, declining transport, information and communication costs, the sharp increase in technological progress and lower political and economic barriers to trade and capital flows are pointed out as the main drivers of GVCs in the last two decades. In addition, the development of GVCs in the nineties coincided with a period of historically low oil prices. Although there is little empirical evidence linking these two factors, a low oil price scenario should impact positively on the costs of trade. Overall, the lack of data has limited the empirical assessment of the drivers of GVCs, while important inter-linkages make it difficult to disentangle their individual effects.

Hillberry (2011) points the increasingly available air transport and the integration in the world economy of new countries in Eastern Europe and East Asia as important sources of growth in the international production fragmentation. WTO (2008) highlights the importance of the decline of international trade costs (including tariff rates, transportation and communication costs and time required to exchange goods) and the lower managerial costs of offshoring (including searching costs and costs of monitoring and coordinating foreign activities), mostly reflecting advances in telecommunications technology. Nordas (2008) finds that good governance and an open trade policy impact on supply chains in electronics and that infrastructures, especially ports, have a strong effect on fragmentation in the clothing sector. Finally, Baldwin (2013) provides an interesting framework for the understanding of GVCs, putting them in historical perspective and discussing factors likely to affect their future evolution, namely the trade-off between specialization gains and coordination costs.

2.1 *Technological Progress and Trade Costs*

Technology is a key driver of GVCs. Only technological progress makes it possible that parts and components produced in factories in different parts of the world perfectly combine in sophisticated final products. In addition, improved information, telecommunications and transportation technologies are crucial in the coordination of dispersed production activities and in the management of highly complex GVCs. In fact, major past transformations in world production systems were mostly based on technological breakthroughs. As discussed in Blinder (2006), the available technology, especially in transportation, information and communications, largely determines what can be traded internationally and what cannot.

Deardorff (2001) discusses the important role of services in the emergence of GVCs. The operation of GVCs involves more services' inputs than trade in final goods only, thus these activities are highly dependent on the availability of the adequate services at low cost. Significant technological improvements

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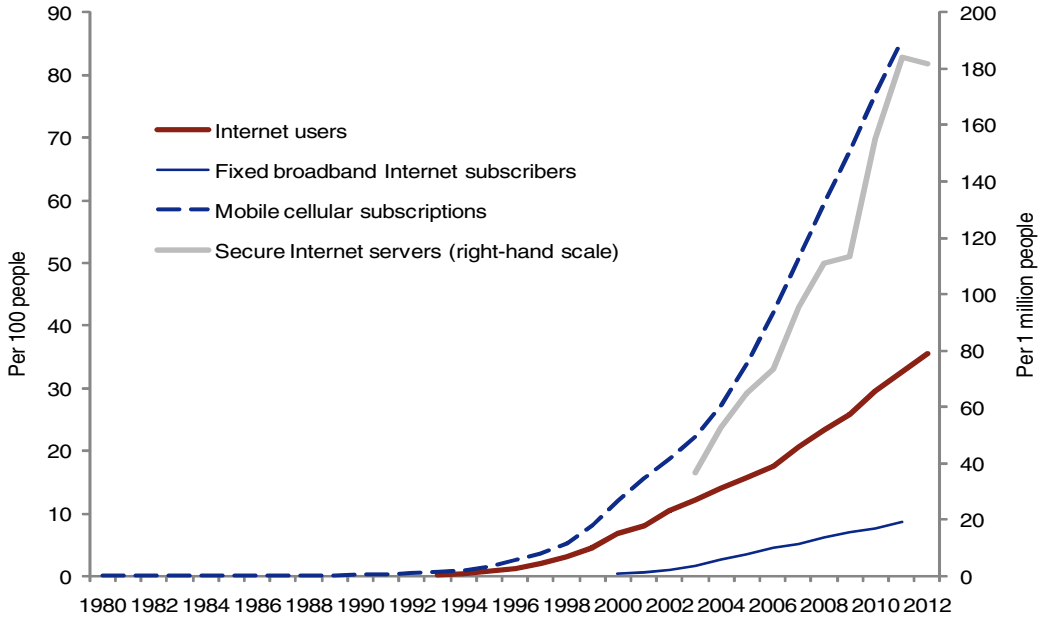

Figure 1. World Indicators of Information and Communication Technologies.

Source: World Bank – World Development Indicators (WDI).

and the liberalization of trade in services have contributed to lower their cost. Debaere *et al.* (2013) study the effect of services on offshoring in the manufacturing industry using firm-level data for Ireland. They find that the greater availability of local services increases the ratio of imported intermediates to sales.

In recent decades, there was a sharp progress in information and communication technologies (ICT) and a dramatic fall in telecommunication costs (Figure 1). These major transformations have enhanced the development of GVCs in the services sector itself. Amiti and Wei (2005) describe the main world trends in outsourcing of business services and computing and information services. The authors show that service outsourcing has been steadily increasing, though it is still at low levels. Abramovsky and Griffith (2006) examine how ICT affects the cost of offshoring services using firm-level data for the UK and find that it plays an important role in facilitating firms decision to purchase business services from abroad.

With the strong growth of exchanges of electronically transmitted business services, the importance of geographical distance as a barrier for international service transactions declines and sectors like financial services, computer and information services and other commercial and business services are increasingly traded internationally. In fact, the great technological advances in communication networks with the availability of global high-bandwidth network infrastructures led to new types of business services trade, which take advantage of time zone differences between countries. The development of the Indian software industry or the rise of the call-centre service industry in Ireland are commonly cited as examples. Dettmer (2014) provides empirical evidence that time zones are a driving force of business services trade by allowing for continuous operations when a proper division of labour is feasible and countries are connected to electronic communications infrastructures.

The important technical innovations in transportation technology in recent decades also play a key role in the development of GVCs. As discussed in DFAIT (2011), the growth of GVCs may be less influenced by the costs of transportation in a traditional sense, and more by the increased speed and reliability of

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transportation, as the maintenance of an efficient international supply of inputs puts a premium on the timeliness of deliveries. This argument is also supported by evidence that a growing share of trade in intermediate inputs is being transported by air, a fast but relatively expensive mode of transportation. As examined in Hummels (2007), there have been significant technological improvements in air shipping over the last decades, namely in avionics, wing design, materials, and most importantly the adoption of jet aircraft engines, which are faster, more fuel efficient and reliable. Hummels and Schaur (2013) study firms' transport choices between the use of air and ocean cargo and conclude that trade in parts and components is specially time-sensitive. These results suggests a link between the decline in the relative cost of rapid transportation and the growth in worldwide fragmentation of production.

Ocean shipping, which represents the major transportation mode in world trade, underwent also important technological changes in the last decades, which can be linked to the rise of GVCs. The growth of open registry shipping, the scale effects from increased trade volumes and the introduction of containerization contributed to shorter transportation time (see Hummels, 2007, for a discussion). An increasing amount of ocean shipping is done under flags of convenience with lower vessel operating cost than traditional flag shippers. In addition, the development of containerized transport allowed cost reductions in cargo handling, increasing cargo transshipment and inducing the creation of hub ports that take advantage of increasing returns to scale in maritime transport (see Clark *et al.*, 2004).

ICT also led to improved logistic services that facilitate the timely and efficient exchange of intermediate goods. Using the example stated in Hillberry (2011), global positioning systems, along with efficient telecommunications and information technology, allow firms to better track and schedule their shipments of goods. In this context, benefiting from their strategic geographical location and adequate infrastructures, some regions became core distribution and logistics hubs for GVCs. Feenstra and Hanson (2004) study the role of Hong Kong in the distribution of China's exports, providing a range of services, like packaging, testing, marketing and matching suppliers and customers, which lower information costs. Additionally, Kimura (2006) discusses the importance of service link costs for connecting production blocks in the development of efficient international production and distribution networks in East Asia. Young (1999) argues that the movement of goods through hubs like Hong Kong and the Netherlands is driven not only by transport considerations, but also by their role in the processing and marketing of the goods.

2.2 *Economic and Trade Liberalization*

The fall in political and economic barriers has been an important driver of trade, in general, and of GVCs, in particular (Figure 2). As discussed in Baldwin (2012), supply-chain trade is very regionalized, supported by a combination of deep regional trade agreements (RTAs), bilateral investment treaties (BITs) and unilateral reforms by developing countries, mostly accomplished outside the World Trade Organisation (WTO). In fact, the pervasiveness of GVCs poses substantial challenges to the WTO multilateral trading system, as its principles are based on the existence of localized production within nations and not on internationally fragmented production systems (see Baldwin, 2011). Nevertheless, WTO members recently reached a comprehensive trade agreement (the 'Bali Package') aimed at lowering global trade barriers. It involves an effort to simplify the procedures for doing business across borders, including an agreement on trade facilitation, and to improve market access for least-developed countries.

At present, the global production network is organized around three major regional blocks in Europe, Asia and North America. The political and economic liberalization in Europe is vividly illustrated by the successive enlargements of the European Union (EU) towards Central and Eastern European countries. This fact created an intense net of new international trade linkages, including important GVCs. Kaminski and Ng (2005) investigate network trade in ten Central and Eastern European countries until 2002, showing that it underwent important changes, namely a shift from simple assembly operations to processing and local production of parts and an expansion beyond EU markets. Marin (2006) uses survey data on

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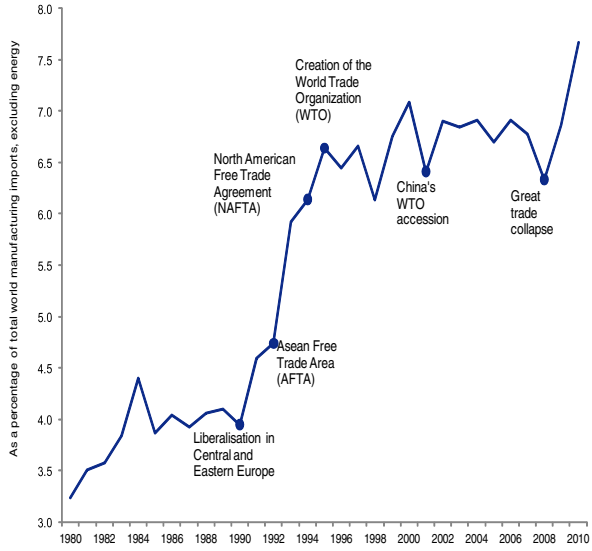
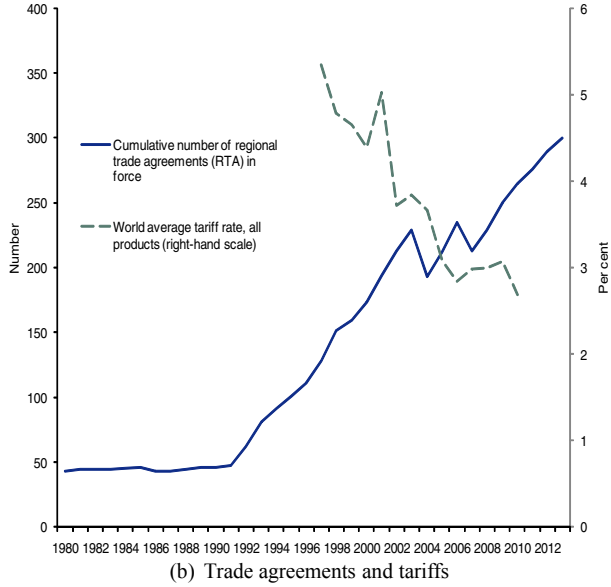


(a) A timeline of main trade events



(b) Trade agreements and tariffs

Figure 2. Global Economic and Trade Liberalization.

Notes: Measure of vertical specialization activities computed as the 'excess' imports of an intermediate good for a country with very high exports of a related output good (see Amador and Cabral, 2009). Cumulative number of regional trade agreements (RTA) in force by date of entry into force. Weighted mean applied tariff as the average of effectively applied rates weighted by the product import shares of each partner country.
Sources: World Trade Organization (WTO) for the RTA data, World Bank – World Development Indicators (WDI) for the tariff rate data and authors' calculations.

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investment projects by German and Austrian firms in Eastern Europe from 1990 to 2001 to document the pattern of intra-firm trade among these countries and the emergence of some of the Eastern European countries as new players in the international division of production.

An essential element of the movement towards trade liberalization was the accession of China to the WTO in 2001. Athukorala (2009) concludes that China's rapid integration into global production networks as a major assembly centre has created new opportunities for other East Asian countries to engage in various segments of the value chain in line with their comparative advantages. Kimura and Ando (2005) examine the mechanics of international networks in East Asia. The authors find evidence of active trade of parts and components in a complex combination of intra-firm and arm's-length transactions and suggest that the policy environment in East Asia was important in fostering these activities. Kimura and Obashi (2011) provide a recent and detailed review of production networks in East Asia, discussing their structure, the conditions of their existence and their implications. In addition, Escaith and Inomata (2011) examine the conjunction of technical, institutional and political changes that led to the emergence of production and trade networks in East Asia.

In general, tariffs in Asia are low and still decreasing but vary among sectors. The importance of trade on semi-processed products in Asian trade is reflected in the fact that tariffs on these products are the lowest. Additionally, several regional trading agreements among Asian countries have also contributed to accentuate regional integration and the development of GVCs in the region. One of the best known trade agreements is the Association of Southeast Asian Nations (ASEAN) Free Trade Area (AFTA).[2] The efforts of economic integration in the area were reinforced with the formation of the ASEAN Economic Community (AEC) in 2003, which aims at creating a single market and production base among ASEAN countries. As examined in Athukorala (2011), network trade strengthened economic interdependence in Asia, with China playing a key role as a centre of final assembly. Krapohl and Fink (2013) study different paths of regional integration and show, that for ASEAN countries, it worked as part of an export-promoting development strategy dependent on major economic partners outside the regional organization, namely the US, Japan and China.

One of the most debated RTAs is the North American Free Trade Agreement (NAFTA) between the United States, Canada and Mexico, which entered into force in 1994. As discussed in Gruben (2001), evidence on the direct causal impact of NAFTA on the substantial growth of plants operating under the Mexican's *maquiladora* program is difficult to disentangle from other non-NAFTA factors. However, under NAFTA there was a substantial increase in cross-border trade and FDI flows and a deepening of production sharing in North America.

Finally, Orefice and Rocha (2014) confirm the positive two-way relation between production networks trade and deeper trade agreements. On the one hand, signing deeper agreements stimulates the creation of production networks by facilitating trade among potential members of a supply chain. The impact of deep integration is higher for trade in automobile parts and information and technology products compared with textiles products. On the other hand, countries already involved in the international fragmentation of production are more willing to sign deeper preferential trade agreements with their partners. The probability of signing deeper agreements is higher for country pairs involved in North-South production sharing and for countries in the Asian region.

3. Mapping and Measuring GVCs

The empirical trade literature suggests a range of methods and data sources to map and measure GVCs at the sectoral level. Three main methodological approaches have been used: international trade statistics on parts and components; customs statistics on processing trade and international trade data combined with input-output (I-O) tables. Figure 3 presents a timeline of the main articles in each approach, which are detailed in the next subsections. The research on GVCs using firm-level data

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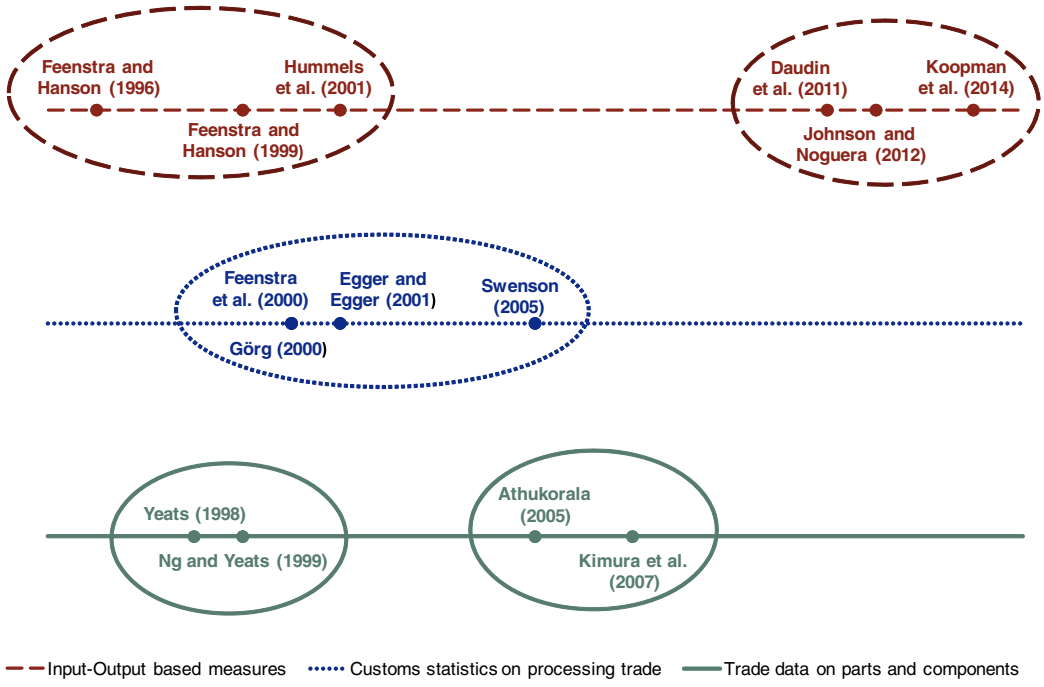

Figure 3. Measuring GVCs Using Sector-Level Data – Timeline of Main Research.

has emerged more recently, following different methodologies and using both qualitative surveys and international trade data. The major measures of GVCs obtained from micro-level data are outlined in Section 3.4.

Existing methodologies provide different angles on the quantification of GVCs, being to a large extent complementary. Figure 4 illustrates the strengths and caveats of the major strands of research that map and measure GVCs. The first dimension in the figure (x-axis) corresponds to the complexity of data required to compute the measure; the second dimension (y-axis) stands for the accuracy of the resulting quantification, i.e., to what extent the measure records with precision the aspects of GVCs that it aims to assess; the third dimension (size of the circle) represents the coverage of the measure, i.e., to what extent the information content of the measure encompasses the worldwide dimension of GVCs. For the purpose of ranking, each dimension is measured from 1 to 5, such that higher values mean more complex data needed, a more accurate final measure, and higher global coverage, respectively.

3.1 *International Trade Data on Parts and Components*

The first and simplest approach to measure fragmentation compares international trade statistics of parts and components with trade in final products. In fact, even if trade in intermediate goods as a whole has not risen much faster than trade in final goods, trade in parts and components has been more dynamic until mid-2000s (see Athukorala and Yamashita, 2006 and Jones *et al.*, 2005). The main advantage of this approach is the high coverage and low complexity of the data and its comparability across countries, allowing the identification of bilateral trading partner relations. A drawback is the low accuracy of the measure and the fact that it relies heavily on the product classifications of trade statistics. Typically, the

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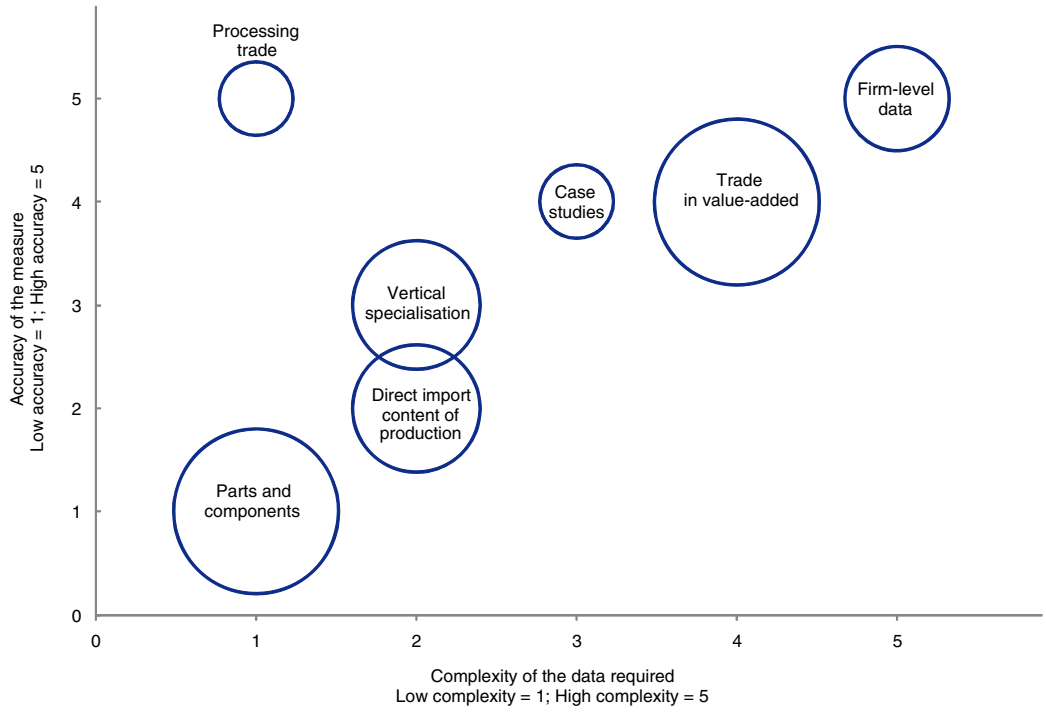

Figure 4. Summary of Main Strands of the Empirical Research on GVCs.

Notes: The size of the circles represents the coverage of each measure relatively to the size of the GVCs in the world economy, with larger circles standing for higher coverage. The *x*-axis corresponds to the complexity of data required to compute the measure and the *y*-axis stands for the accuracy of the resulting quantification, i.e., to what extent the measure records with precision the aspects of GVCs that it aims to assess.

parts and components aggregate is obtained from the Standard International Trade Classification (SITC) at the most detailed level and tends to include products of SITC 7 (Machinery and transport equipment) and SITC 8 (miscellaneous manufactured articles). In addition, the United Nations classification by Broad Economic Categories (BEC), which categorizes trade into large economic classes of goods on the basis of their principal use, has also been used to measure fragmentation, namely through the class of intermediate goods.

This type of analysis was initiated with the works of Yeats (1998) and Ng and Yeats (1999) and has been used extensively afterwards. Several papers focus on specific countries or regions. Athukorala (2005) use trade data on parts and components to examine the international product fragmentation and its implications for global and regional trade patterns in East Asia. He finds that the degree of dependence of East Asia on this new form of international specialization is proportionately larger than that of North America and Europe. Gaulier *et al.* (2007) use a detailed bilateral trade database and also conclude that the emergence of the Chinese economy has intensified the international segmentation of production processes among Asian partners.

Other authors have used this method to measure the importance of fragmentation in specific industries. Lall *et al.* (2004) study the electronics and automotive sectors in East Asia and Latin America. They show

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that electronics is fragmenting faster worldwide than the car industry, in particular in East Asia where electronics networks are more advanced. 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. Sturgeon and Memedovic (2010) trace the evolution of GVCs in the three industries (electronics, automobiles and motorcycles, and apparel and footwear) and find evidence of deepening economic integration overall, especially since 2001, but with strong differences across industries. The electronics industry has driven intermediate goods trade the most, being the only of the three industries where it rose more than trade in final goods.

3.2 *Customs Statistics on Processing Trade*

The second methodological approach relies on the analysis of customs statistics on processing trade. These statistics include information on trade associated with customs arrangements in which tariff exemptions or reductions are granted in accordance to the domestic input content of imported goods. For instance, the US Offshore Assembly Programme and the EU Processing Trade data sets have been used in a number of empirical studies to obtain a measure of international fragmentation. Outward (inward) processing trade is considered a narrow measure of fragmentation because it captures only the cases where components or materials are exported (imported) for processing abroad (internally) and then reimported (reexported). However, given that this data is administered by customs authorities, trade in these goods is recorded accurately at a highly disaggregated level.

Feenstra *et al.* (2000) find that the US content of imports of apparel and machinery and of transportation equipment from industrial countries, made through the US offshore assembly program, is characterized by relatively intense use of skilled-labour. Clark (2006) examines data on the use of offshore assembly provisions and concludes that US firms tend to shift the simple assembly operations to unskilled-labour abundant countries. Swenson (2005) analyses the US offshore assembly program between 1980 and 2000 and concludes that these operations grew strongly in that period. Swenson (2007) uses the same data set to examine how competition and production persistence influence outsourcing decisions and finds that sunk costs have a large effect on assembly location choices.

Görg (2000) uses Eurostat data to show that there was an increase in US inward processing trade in EU countries, in particular in the periphery and in the leather and textiles sectors. Moreover, Baldone *et al.* (2001) conclude that outward processing trade represents a significant share of trade between the EU15 and Central Europe 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 and that it increased rapidly 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.

Processing trade accounts also for a significant share of the total manufactured exports of some developing countries. Lemoine and Ünal Kesenci (2004) use detailed data from China's customs statistics on processing trade and conclude that these activities fostered production sharing between China and its neighbours, strengthened regional economic integration in East Asia and allowed a rapid diversification of Chinese manufacturing exports. Xing (2012) shows that China's processing trade has a marked geographic

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pattern as most of processing imports from East Asia are intermediate inputs for finished products exported to third markets.

3.3 *Input-Output Based Measures*

3.3.1 *Classical I-O Matrices and the Import Content of Production and Exports*

Most of the initial systematic evidence on the international fragmentation of production focuses on the imported input shares of gross output, total inputs or exports. Typically, these measures use information from classical I-O tables, sometimes complemented with import penetration statistics computed from trade data and their accuracy depends crucially on the product breakdown available. A very detailed 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 difficult to implement. Therefore, the identification of countries with important fragmentation activities and the assessment of their main trends has usually been carried out at a relatively aggregate product breakdown. I-O tables tend to provide the most appropriate source of sectoral information, as they allow a cross-industry and time analysis, even if they are available only for some countries on a comparable basis and are not updated regularly.

Traditionally, two different types of measures based on classical I-O data have been implemented in the literature (see Hijzen (2005) for a discussion). The first focuses on the foreign content of domestic production as it considers the share of (direct) imported inputs in production or in total inputs. This measure is originally due to Feenstra and Hanson (1996) and has been used widely afterwards in different formats (see Horgos (2009) for a detailed analysis of the design of this type of indices). Feenstra and Hanson (1999) distinguish between broad and narrow definitions of outsourcing. The broad definition considers the value of intermediate goods that each manufacturing industry purchases from all the remaining ones. The narrow definition of outsourcing is obtained by considering only the inputs that are purchased from the same industry of the good being produced. More recently, Feenstra and Jensen (2012) use US firm-level data on imports and production to improve the classical I-O sectoral estimates of imported inputs. In fact, because I-O data on imported inputs at the sectoral level are not available for the US, the empirical research has mostly relied on the 'proportionality' or 'import comparability, assumption, i.e., each sector is assumed to import each input in the same proportion as its economy-wide use (see Winkler and Milberg (2012) for a discussion).

Most of the studies using this measure find a steady increase of international outsourcing of material inputs over time. Campa and Goldberg (1997) show an increase of the share of imported inputs in production in the US, UK and Canada, but not in Japan. Hijzen (2005) concludes that international outsourcing has steadily increased since the early eighties in the UK, while significant differences persist across industries. Egger *et al.* (2001) and Egger and Egger (2003) provide evidence of a significant growth of Austrian outsourcing to Central and Eastern European countries in the nineties, reflecting the decline of trade barriers and the low wages prevailing there.

The second I-O based measure of fragmentation focuses on the (direct and indirect) import content of exports and it was formulated by Hummels *et al.* (2001), which labelled it 'vertical specialization'. This measure captures situations where the production is carried out in at least two countries and 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, it can be argued that the 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) find that vertical specialization activities accounted for

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21 per cent of the exports of ten OECD and four emerging market countries in 1990 and grew almost 30% between 1970 and 1990.

Chen *et al.* (2005) update the analysis of Hummels *et al.* (2001) using more recent I-O tables and conclude 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 vertical specialization activities. Some examples are Amador and Cabral (2008) for Portugal, Breda *et al.* (2007) for seven EU countries, Zhang and Sun (2007) for China, and Chen and Chang (2006) for Taiwan and South Korea.

China's processing trade regime raises additional challenges to the measurement of the foreign content of exports, because it invalidates the Hummels *et al.* (2001) assumption that imported inputs are used evenly in production for domestic sales and for exports. Koopman *et al.* (2012) start from the Hummels *et al.* (2001) formulation and develop a general framework for estimating the foreign and domestic content in exports when processing exports are pervasive, applying it to Chinese data. Chen *et al.* (2012) measure the domestic value-added generated by Chinese exports estimating distinct I-O coefficients for processing exports, non-processing exports and products for domestic use. Finally, Upward *et al.* (2013) use imports of intermediate inputs and exports at the firm-transaction level to estimate foreign and domestic value-added of Chinese exports, taking into account processing trade. As imported inputs are used more intensively in the production of processing exports, accounting for processing trade leads to a higher estimate of the foreign content of exports.

Amador and Cabral (2009) propose a relative measure of vertical specialization that combines information from international trade with a product detailed and country generic I-O matrix. If a country has a simultaneous high export share of a product and a high import share of an intermediate good used in its production, then this 'excess' of intermediate imports is used as a proxy of vertical specialization-based trade. The strength of this measure is its ability to produce results for a large sample of countries with a detailed product breakdown over more than four decades. However, the estimated measures of vertical specialization must be interpreted in relative terms and as proxies. The article finds a substantial increase of vertical specialization in high-tech goods in East Asia over the last two decades.

In a different framework, recent studies use classical I-O data to measure the average position of an industry in the production chain. Using US I-O tables, Antràs *et al.* (2012) measure the average distance of an industry from final use (upstreamness). They also compute a summary measure of the average upstreamness of exports at the country-level as a weighted average of industry values. Complementarily, Antràs and Chor (2013) propose two related measures of the average position of an industry in the value chain to capture its downstreamness in production processes. The authors show that the optimal pattern of ownership along an international value chain depends on the relative position (upstream versus downstream) of each supplier and on whether production stages are sequential complements or substitutes.

3.3.2 *Global I-O Matrices and Trade in Value-Added*

As GVCs spread worldwide, the concept of 'country of origin' becomes increasingly difficult to apply. A country may stand as a large exporter of a specific good without adding much value to it (see, for instance, Dedrick *et al.* (2010) for a case study of Apple's iPod value chain). Nowadays, the study of an industry export potential and competitiveness needs to take into account its integration in a GVC and the role of trade in intermediate inputs. Hence, the analysis of gross trade flows has to be complemented with the analysis of trade in value-added, tracking down the original source country of the value-added.

The measurement of trade in value-added requires world I-O tables with information on all bilateral exchanges of intermediate and final goods to allocate the value-added along the GVC to each producer. A recent special issue of the *Economic Systems Research* provides a detailed description of several global

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multi-regional I-O databases currently available (see Tukker and Dietzenbacher (2013) for an introduction to this special issue and the papers therein). Table 1 summarizes some features of the main global I-O matrices that have been used in the empirical research on GVCs.

The availability of global I-O matrices led to methodological contributions on new metrics for GVCs. Several recent articles generalize the vertical specialization concept of Hummels *et al.* (2001) and capture different dimensions of international flows of value-added. The initial studies were those of Johnson and Noguera (2012), Daudin *et al.* (2011) and Koopman *et al.* (2014), using the Global Trade Analysis Project (GTAP) database.

Johnson and Noguera (2012) define value-added exports as income generated in a given source country that is embodied in final goods absorbed in a particular destination and compute the ratio to gross exports in 2004. They find that this ratio varies substantially across countries and sectors, being lower in manufacturing than in services. Across bilateral trade partners, the ratios of value-added exports are very heterogeneous and imbalances measured in value-added differ significantly from gross trade imbalances.

In a similar conceptual framework, Daudin *et al.* (2011) reallocate the value-added contained in trade in final goods to each country that has participated in its production. They compute the share of imported inputs in exports as in Hummels *et al.* (2001), the share of exports used as inputs in exports of other countries and the domestic content of imports in 1997, 2001, and 2004. They also find that the sectoral and geographic patterns of value-added trade are very different from those of gross trade.

Finally, Koopman *et al.* (2014) provide an unified framework that integrates the several existing measures in the literature in block matrix formulation. They fully decompose gross exports into value-added components and connect official gross statistics to value-added measures of trade. Using this framework, it is possible to completely breakdown gross exports into its domestic and foreign content and further decompose domestic value-added into exports that end up in the direct importer, return from abroad to the exporting country, and indirect exports sent to third countries. They also present several applications to illustrate how this full-decomposition methodology affects a variety of research and policy questions, like revealed comparative advantages, bilateral trade balances, effective exchange rates and trade costs.

In parallel, Foster-McGregor and Stehrer (2013) and Dietzenbacher *et al.* (2014) describe the contents of the World Input-Output Database (WIOD), which includes also data on labour and capital inputs, discuss the different concepts associated with trade in value-added and illustrate the potential of this database to improve the understanding of GVCs in several ways. Since its release, the WIOD has been used by various researchers to examine different aspects of the international fragmentation of production. Timmer *et al.* (2013) derive a new measure of competitiveness that takes into account the value-added content of trade in each stage of production, concluding that gross exports overestimate the competitiveness of countries that rely heavily on imported intermediates. Foster-McGregor *et al.* (2013) study the link between offshoring and skill composition, finding the largest negative effects of offshoring for medium-skilled workers. Timmer *et al.* (2014) decompose the value of final manufacturing goods into income for capital and for different skill levels of labour. They show that the foreign value-added content of production increased strongly since the nineties and that there was a shift towards more value being added by capital and high-skilled labour.

The OECD-WTO Trade in Value Added (TiVA) database was made public more recently and has been mostly used in policy-oriented studies. OECD (2013) summarizes the main evidence and policy implications of the OECD's work, including trade and investment policies targeted at GVCs. In addition, the OECD produced several comparable country notes, including indicators on the relevance of value-added trade and the participation in GVCs. Other recent exploratory analysis with this database include Newby (2013) for Finland and Duprez and Dresse (2013) for Belgium. Baldwin and Lopez-Gonzalez (2015) use both the WIOD and the OECD-WTO TiVA database to provide a detailed portrait of the rise of supply-chain trade and its regional evolution between 1995 and 2009.

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Table 1. Summary of the Main Global Input-Output Databases Used in GVCs Analysis

	Geographical coverage	Sector breakdown	Time span	Methodological reference
GTAP (Global Trade Analysis Project)	129 countries	57 sectors	1997, 2001, 2004, 2007	Aguiar and Walmsley (2012)
WIOD (World Input-Output Database)	40 countries	35 sectors	1995-2011	Dietzenbacher *et al.* (2013)
OECD-WTO TiVA (Trade in Value Added)	57 countries	18 sectors	1995, 2000, 2005, 2008, 2009	OECD and WTO (2012)
UNCTAD-Eora GVC Database	187 countries	25 to 500 sectors	1990–2010	Lenzen *et al.* (2013)
IDE-JETRO (Institute of Developing Economies -Japan External Trade Organisation)	10 countries	76 industries	1975, 1980, 1985, 1990, 1995, 2000	Meng *et al.* (2013)

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Finally, a recent collaborative effort between the United Nations Conference on Trade and Development (UNCTAD) and the Eora project[3] resulted in an I-O data set of trade in value-added for the period 1990-2010 with expanded country-coverage (the UNCTAD-Eora GVC database). This database is used in the 2013 World Investment Report (UNCTAD, 2013), which offers a general picture of GVCs in the global economy, examines the crossed links between world investment and trade through international production networks and analyses their contributions and risks for global and sustainable development.

3.4 *Firm-Level Data*

Empirical studies on GVCs using firm-level data are still relatively scarce but are expanding rapidly. The available research follows different approaches to measuring GVCs. Some articles rely on qualitative survey data (typically answers pertaining to the international relocation of some activities), while others make use of international trade data to quantify the relevance of offshoring in the firm.

A related strand of literature examines the international transfer of production activities within multinational firms. Several of these studies use the relative importance of activities in the affiliates as a measure of offshoring. The share of affiliate employment in total multinational's employment is used, for instance, by Head and Ries (2002) for Japan, by Hansson (2005) for Sweden, by Ebenstein *et al.* (2014) and Ottaviano *et al.* (2013) for the US, and by Becker *et al.* (2013) for Germany. However, these measures capture only partially the offshoring activities of multinational firms, as they exclude all their arm's-length relations.

3.4.1 *International Trade Data*

In most micro-level studies, data on imports of intermediates is used to obtain a quantification of the relevance of foreign inputs in the productive process of each firm. The literature presents several alternatives for the computation of these ratios, with differences in terms of the specific variables used in the numerator and the denominator, as well as on the denomination, type of transactions and products considered.

In the numerator, most studies use a measure of imports of inputs in real terms but with different deflating options. Imports of intermediate goods can be deflated using industry-level price deflators, as in Hijzen *et al.* (2010) for Japan, official import price deflators, as in Amiti and Konings (2007) for Indonesia and Kasahara and Rodrigue (2008) for Chile, or standard consumer price indices, as in Görg *et al.* (2008) for Ireland. On the contrary, McCann (2011) uses the euro amount of inputs sourced from abroad to measure foreign outsourcing intensity of Irish manufacturing firms.

In general, studies use total imports of inputs, including both intra-firm and arm's-length. However, some studies differentiate these two types of transactions as they are expected to have distinct causes and consequences. For instance, Hijzen *et al.* (2010) consider two different measures of offshoring for Japanese firms, one for total offshoring and another for intra-firm offshoring.

The greater difference between the measures computed in the various studies relates to the types of products that are considered as imported inputs. The first distinction is to include only materials or also services inputs. Görg and Hanley (2005) and Görg *et al.* (2008) use data on Irish firms and break down intermediate inputs into two groups: raw materials and components, and services inputs. Even considering only studies on materials' offshoring, distinct options still exist: to include only parts and components or imports of all materials (including raw materials). Lo Turco and Maggioni (2012) use imports of non-energy material intermediates from all sectors together with imports of finished goods from the firm's own sector. Biscourp and Kramarz (2007) for France and Mion and Zhu (2013) for Belgium compute two measures of offshoring using detailed firm-level import data for the manufacturing industry: offshoring of finished goods and offshoring of intermediate goods. Finished goods are defined as products that

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correspond to the same 3-digit code of the main activity of the firm, while other imports of the firm are defined as imports of intermediate goods.

A related aspect on the measurement of outsourcing at the firm-level was introduced by Hummels *et al.* (2014) based on the notions of 'broad and narrow offshoring', as previously defined by Feenstra and Hanson (1999). The point is to guarantee that observed firm's imports are inputs into production and also that they are potential substitutes for labour within the firm. Broad offshoring is the total value of imports of goods by a given manufacturing firm and narrow offshoring stands for the imports in the same Harmonised System 4-digit category as goods sold by the firm.

As for the denominator of the offshoring intensity of a firm, variables used comprise total inputs, material purchases, sales, wage bill, value-added and gross output. The indicators of international outsourcing intensity of Irish electronics firms are computed by Görg and Hanley (2005) as ratios of imported inputs to total inputs. Amiti and Konings (2007) also use the share of imported inputs to total inputs in some specifications of their study. Hummels *et al.* (2014) use both total material purchases and gross output as denominators in their measures of offshoring for Danish firms. McCann (2011) computes the foreign outsourcing intensity relative to the firm's wage bill, as outsourcing can be seen as a substitute for inhouse production. Görg *et al.* (2008) also calculate their international outsourcing indicator relative to the plant's total wage bill, using total inputs as a robustness check. Finally, Hijzen *et al.* (2010) use real value-added in the denominator of their measures of offshoring intensity of Japanese firms, while Biscourp and Kramarz (2007) and Mion and Zhu (2013) use total sales.

3.4.2 *Survey Data*

The existence of cross-country firm-level survey data covering several years is very rare. One reason for the unavailability of such data relates with domestic regulations on statistical confidentiality, as well as different national criteria for collecting and recording the information. Nevertheless, such data is vital to obtain solid and comparable empirical evidence.

A promising avenue is the indirect use of micro data, where different national authorities provide in-house estimates derived from comparable econometric code designed by external researchers. One example of these efforts is the International Study Group on Exports and Productivity (ISGEP) that used comparable micro-level panel data for 14 countries and a set of identically specified empirical models to investigate the relationship between exports and productivity (ISGEP, 2008). Another example is the Competitiveness Research Network (CompNet) established in 2011 with participants from European central banks, as well as from a number of international organizations.[4] In parallel, the European statistical authorities are building sample-based comparable firm-level databases that can also help fill this information gap.

Additionally, some surveys have been conducted recently with a special focus on the internationalization of production. In most of these surveys, only qualitative information on the offshoring status of each firm is available. Furthermore, these surveys are typically one-shot, thus not allowing an analysis of the dynamics of offshoring. However, they still offer a potential avenue for empirically validating the predictions of different theories associated with the international fragmentation of production. For example, Antrás (2014) discusses in detail four firm-level data sets that have been used to test the empirical relevance of the property-rights theory in the context of the international organization of production. In the remaining of this section, we briefly refer some of the main firm-level survey databases that have been used to empirically study GVCs.

Altomonte and Aquilante (2012) describe the EU-EFIGE/Bruegel-UniCredit data set (in short the EFIGE data set), a database collected within the EFIGE project (European Firms in a Global Economy) that consists of a representative sample for the manufacturing industry in seven European countries (Germany, France, Italy, Spain, United Kingdom, Austria, Hungary). It contains both qualitative and

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quantitative data on firms' characteristics and activities. Using this database, Veugelers *et al.* (2013) examine GVCs in Europe, defining GVC-involved firms as those that simultaneously import components, maintain production activities located abroad and export their goods. They find that only a few firms are intensively involved in GVCs, but these firms tend to be larger, more trade-intensive, more innovative and more productive.

For Japan, the Research Institute of Economy, Trade and Industry (RIETI) survey covers offshoring of both production activities and services by manufacturing firms and distinguishes different types of suppliers. However, it includes only qualitative data on the status of offshoring (see Ito *et al.* (2007) for details of the survey). Using data from this survey, Ito *et al.* (2011) find productivity gains in the firms offshoring both manufacturing and service tasks, but not in the firms offshoring only one type. These results suggest that the level of engagement in offshoring is important for firms' productivity. Tomiura *et al.* (2013) link the RIETI survey with firm-level data to examine the impact of offshoring on skill composition. They find that offshoring is related with a shift in the composition of employment towards high skills, even within non-production workers.

Another survey with qualitative data on offshoring is the Survey on Manufacturing Firms (*Indagine sulle Imprese Manifatturiere*) for Italy. This survey is run every three years and includes information on internationalization activities, investment, R&D and characteristics of the workforce. Antonietti and Antonioli (2011) use data from this survey to study the effects of cross-border relocation of production on the skill structure of firms. Their results point to a potential skill-bias effect of production offshoring, driven by a fall in the demand for unskilled workers. Crinó (2010) also uses this survey to examine the effects of service offshoring on the level and skill structure of domestic employment. He concludes that service offshoring has no effect on the level of employment but changes its composition in favour of high skilled workers.

Some recent studies on the mode of internationalization of firms, like Defever and Toubal (2013), Jabbour (2012) and Corcos *et al.* (2013), use data from the survey on the foreign activities of French industrial multinationals carried out in 1999 (*Enquête sur les Échanges Internationaux Intra-Groupe*). For each import transaction, there is information on the value, the classification of the imported product, the country of origin as well as the mode of governance of the transaction. The modes of governance in this database include vertical FDI, partnership and international outsourcing from a independent party. Corcos *et al.* (2013) find that intra-firm trade is more likely in capital- and skill-intensive firms, in more productive firms and from countries with well-functioning judicial institutions. On the contrary, Jabbour (2012) finds that more productive firms tend to outsource through arm's-length transactions, while less productive firms integrate vertically. Defever and Toubal (2013) also find that the most productive multinationals import through an unrelated supplier, while the least productive import their intermediate inputs from a related party.

4. Concluding Remarks

GVCs have deeply changed the paradigm of world production, affecting international trade and investment, labour market developments and the way policy-makers interpret trade policies and external competitiveness. The significant expansion of GVCs and the development of multinational corporations has been rooting on technological progress and the fall of political and economic barriers. These drivers are not expected to reverse in the near future. The global financial crisis caused a major decline in trade associated with GVCs in 2008 and 2009, but Los *et al.* (2015) show that international fragmentation trends have resumed afterwards, with a growing role of emerging economies as suppliers of intermediate goods.

The probability of a technological reversal that would limit the scope of GVCs looks minimal. In addition, although a major increase in economic barriers cannot be ruled out, such event seems

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unlikely. Given the strong interconnections between multinational corporations, domestic firms and capital markets, policies targeted at hampering GVCs would have major disruptive effects in the economy. The significant disturbances in the global economy that resulted from temporary breaks in GVCs following natural disasters provide a vivid illustration. Furthermore, multinational corporations and business groups represent an important share of economic activity worldwide, posting high productivity levels and holding strong political influence.

In this context, the return to a pre-GVCs world looks like a low probability event. On the contrary, there is scope for further growth and deepening of GVCs, especially through an expansion of trade in services. Moreover, there is potential for further international trade liberalization, especially in a multilateral dimension. Finally, developing countries are increasingly participating in different stages of GVCs and these links can play an important role in their economic development. GVCs can facilitate technology dissemination, skill building and industrial upgrading, thus enhancing their productive capacity (see Gereffi (1999) and Baldwin (2014) for a discussion).

Notwithstanding the substantial work done in recent decades, there are still important research gaps in the empirical literature on GVCs. As for the main drivers of GVCs, little systematic work has been undertaken to estimate the actual contributions of transport and communication costs, technological progress and economic barriers to the development of GVCs, as well as their potential complementarities. In addition, the role of geographic and gravitational variables on GVCs has not been explored in depth. Trade literature has identified gravity as a key driver for international trade, thus a similar pattern can be expected to emerge for GVCs. The proper understanding of its drivers is crucial to predict shifts in the dynamics of GVCs, which, in turn, are important to forecast macroeconomic developments and to assess the role, if any, that policy can play in shaping GVCs.

In spite of the intense research over the last decades, the mapping and measurement of GVCs is still incomplete and several research strands may bring further valuable results. A large part of the empirical literature has based on I-O matrices and aggregate trade data to map and measure GVCs across the world. The computation of global I-O matrices constitutes a big progress relatively to the use of national matrices but their time, sectoral and country coverage remains limited. In addition, although almost impossible to avoid, proportionality assumptions still hamper the accuracy of global I-O matrices. Therefore, a detailed historical mapping of GVCs covering a large number of countries and sectors is still missing. This research would be useful to understand the nature and dynamics of GVCs, also interlinking with its drivers and impacts.

A major strand of research that is still underdeveloped is the use of firm-level data to examine GVCs. Micro-level measurement and analysis of GVCs allows for the control of firm heterogeneity and can give important insights on the impacts of GVCs. Although several measures could be computed using micro databases, basic results, such as the assessment of the foreign value-added of exports at the firm level, are still not available. In addition, it is not possible to trace trade flows along GVCs at the micro-level, establishing links between firms in different countries and in different stages of the production process. The empirical research of GVCs at the firm-level is strongly determined by the availability of information, thus further data disclosure and sharing would allow for some progress in this front. A set of stylized facts on GVCs for several countries could be obtained using comparable micro databases and a common methodology.

Such developments would set the stage for important policy results and facilitate the integration of GVCs in macroeconomic general equilibrium models. Although GVCs are complex, it is essential that policy-analysis takes on board their impacts on the quantification and interpretation of traditional trade and competitiveness indicators and on the forecasting of macroeconomic developments. In microeconomic terms, the correct response of policy-makers to the challenges posed by GVCs requires an accurate knowledge on the characteristics of the firms, sectors and countries involved, as well as on the channels through which these networks operate.

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Notes

1. A wide range of terms has been used in the literature to label this phenomenon: international fragmentation of production, vertical specialization, outsourcing, offshoring, internationalization of production, international production sharing, disintegration of production, multi-stage production, intra-product specialization, production relocation, slicing up the value chain, etc.
2. The AFTA agreement was signed in 1992 and now comprises the 10 countries of the ASEAN (Indonesia, Malaysia, Philippines, Singapore, Thailand, Brunei, Myanmar, Cambodia, Laos and Vietnam).
3. See http://www.worldmrio.com/ for further information and access to the Eora MRIO Database and Lenzen *et al.* (2013) for a methodological description.
4. See http://www.ecb.europa.eu/home/html/researcher_compnet.en.html for further details and access to the research conducted within the network and ECB (2013) for a summary the main findings of the CompNet after one year of existence.

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