GLOBAL VALUE CHAINS SURVEYING DRIVERS AND MEASURES

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Abstract

The production of most goods and services is nowadays vertically fragmented across different countries, as global value chains (GVCs) emerged as the current paradigm for the international organisation of production. This paper surveys part of the growing empirical literature on GVCs, starting by discussing the main driving forces of GVCs in recent decades. Next, it surveys the indicators used to map and measure this phenomenon, accounting for their different scopes and required datasets.

Non-technical summary

In the last decades, global value chains (GVCs) emerged as the paradigm for the international organisation of production. Nowadays, most production processes are vertically fragmented worldwide, i.e., goods and services are produced in separate stages located in different countries and are assembled either sequentially along the supply chain or in a final location. The rise of GVCs interlinks with the strong expansion of international trade, especially of parts and components, and foreign direct investment flows, mostly by multinational corporations, which are the key players in the operation of these networks. As a consequence, GVCs produced a deep and lasting impact on the world economy, affecting competitiveness and macroeconomic developments and strongly increasing the economic interdependence between countries.

Unsurprisingly, GVCs gave rise to a significant new strand of both theoretical and empirical research in international trade. This paper surveys part of the vast empirical literature on this topic, focusing on their main drivers and empirical measures. The paper starts with a broad discussion of the major driving forces of GVCs, highlighting the contributions of technological progress, reduction of transport and communication costs and removal of political and economic barriers. Next, it surveys the different methodologies used in the literature to map and measure GVCs, accounting for their different scopes and required datasets. Given the nature of the phenomenon, the scale at which GVCs' mapping and measuring is made is very diverse. Mapping ranges from specific case studies to worldwide analysis and measuring ranges from broad measures to those capturing just specific processing trade activities. All in all, the paper provides a guide on the different ways of mapping and measuring GVCs found in the literature.

The major drivers of international trade also apply to GVCs. Nevertheless, GVCs are more than just trade in parts and components as they imply a different organisation of worldwide production with significant international flows of investment, people and technology. So what changed since the nineties so that this new paradigm for the international organisation of production emerged?

In short, there was an acceleration of technological progress, a reduction of transport and communication costs and a strong economic and trade liberalisation. Technological progress enables the international fragmentation of production because it makes it possible to separately produce parts and components that are perfectly compatible, instead of forcing production as one piece. Furthermore, there were sharp progresses in information and communication technologies and important technical innovations in transportation technology, both in air and ocean shipping. In fact, improved information, communications and transportation technologies are crucial in the coordination of geographically dispersed production activities

and in the management of highly complex GVCs. Finally, the removal of political and economic barriers to international trade and investment, with the participation of new countries in international trade, exponentiated the opportunities for the international fragmentation of production.

The empirical trade literature suggests a wide 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. 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, in particular those basing on recently available global I-O matrices. In addition, empirical studies on GVCs using firm-level data are still scarce but expanding rapidly.

GVCs cannot be perfectly understood under the classical concept of comparative advantages applied to countries and broad sectors. Instead, GVCs are mostly about combining value-added from different sources. Their effects span over multiple dimensions, namely trade flows, productivity and labour market developments. GVCs also have significant policy implications, changing the way policy-makers interpret trade policies, exchange rate fluctuations and external competitiveness. Reaping the benefits from international trade in this environment implies adjusting the productive structure to this changing reality and, hence, capacity to reallocate inputs between industries and to attract and sustain the operations of multinational firms. The correct understanding of GVCs is crucial to predict shifts in their future dynamics, which, in turn, are important to forecast macroeconomic developments and to assess the role, if any, that policy can play in shaping GVCs.

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." Richard Baldwin (in Baldwin, 2012).

The rise of *Global Value Chains* (GVCs) has dramatically changed the organisation 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 (see Yeats (1998) for a discussion). 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 globalisation.

Baldwin (2006) frames the major transformations of international trade over the last century as a sequence of two unbundlings. Until the late XIX 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 minimise coordination costs. This paradigm was replaced by international networks of individual and autonomous suppliers that specialise 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 highly 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 two organisational 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. A general definition, adapted from the Global Value Chain Initiative at Duke University, states that *"A global value chain describes the full range of activities undertaken to bring a product or service from its conception to its end use and how these activities are distributed over geographic space and across international borders."* (DFAIT, 2011, p.86).

International trade literature has labelled this phenomenon using a wide set of terms: "vertical specialisation", "outsourcing", "offshoring", "internationalisation of production", "international production sharing", "disintegration of production", "multi-stage production", "intra-product specialisation", "production relocation", "slicing up the value chain", "international segmentation of production", etc. Nevertheless, international trade theorists tend to call it "fragmentation", a term originally 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.

As discussed in Molnar et al. (2007), offshoring, outsourcing and internationalisation of production are slightly different concepts that overlap only partially. Outsourcing refers to the purchase of goods and services that were previously produced inside the firm. The firm providing the intermediate inputs can be located inside the home country (domestic outsourcing) or outside (international outsourcing). Offshoring refers to the purchase abroad of goods and services previously produced inside the firm. Thus, it includes not only international outsourcing, but also international insourcing, with the foreign affiliates exporting to their domestic parent firms. The internationalisation of production refers to the establishment of affiliates abroad. These affiliates may export back to the parent company (international insourcing) or provide goods and services to home and foreign markets. The goods and services produced by affiliates need not have been previously produced inside the parent firm. Sturgeon (2001) discusses in detail a set of terms and concepts associated with global economic integration in three dimensions (organisational 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 paper.

In theoretical terms, the organisation of production along GVCs tends to follow the classical determinants of comparative advantage, but a comprehensive theoretical framework encompassing the specificities of GVCs is still missing. Arndt and Kierzkowski (2001) and Antràs 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 organisational choices of individual firms, their boundaries and incomplete-contracting.

When the analysis turns to the economic consequences of GVCs, the complexity is even larger and theoretically challenging. The pervasiveness of GVCs on the world economy impacts strongly on trade and labour markets but also on topics like inequality, poverty and the environment. At present, even the measures that usually inform the policy-debate, such as bilateral trade balances, export market shares or real exchange rates, need to be redefined in order to disentangle the domestic and foreign value-added embodied in trade flows.

The review of the vast empirical literature on the impacts of GVCs is beyond the scope of this paper. In addition, the elaboration a unifying model or the computation of different measures with similar data are hardly feasible given the very different scales of analysis, which range from specific industry case studies to global analysis. Instead, this survey offers a guide to the mapping and measurement of GVCs, while also discussing its main drivers. As far as we know, this approach has not been adopted in the literature yet. The remainder of the paper is organised 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 Global Value Chains

This section provides a broad discussion of the major driving forces 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. The lack of data has limited the empirical assessment of these drivers, while important inter-linkages make it difficult to disentangle their individual effects. Figure

1 illustrates the main channels of influence of the several factors behind the development of GVCs. Although reciprocal impacts exist (e.g., technological progress affects trade costs, but trade costs also shape technological progress), the figure highlights only primal effects. In addition, classical structure effects can also explain the overall expansion of GVCs, notably if demand grows strongly on sectors where this type of organisation is pervasive. However, these effects are also not signalled in Figure 1.

Figure 1: Schematic illustration of the main drivers of GVCs
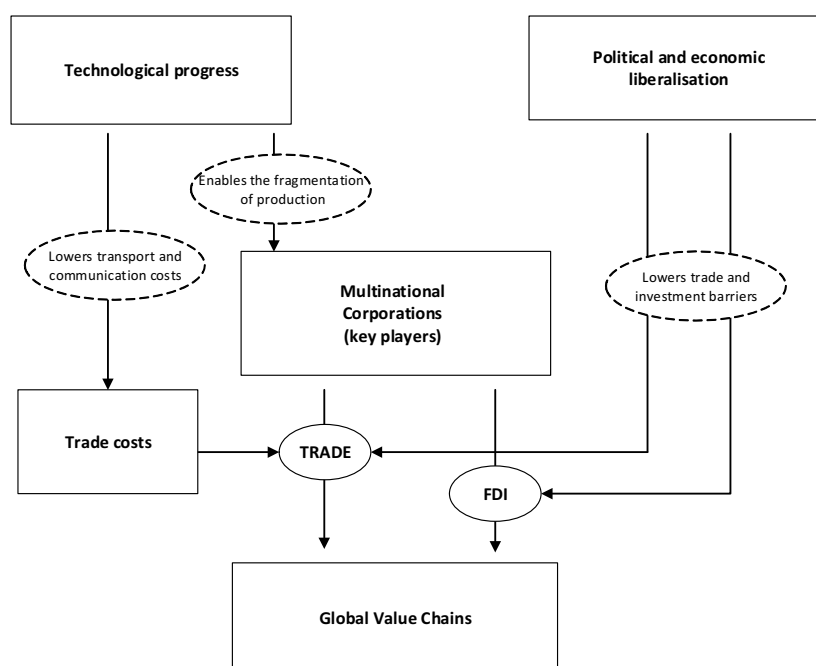
Hillberry (2011) points the more readily available air transport and the integration in the world economy of new countries in Eastern Europe and East Asia as important sources of growth in the international production fragmentation. WTO (2008) highlights the importance of two main factors as driving this process: the decline of international trade costs (including the reduction in tariff rates, lower transportation and communication costs and the reduction in the 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. Finally, Baldwin (2013) provides an interesting framework for the understanding of global supply chains, putting them in historical perspective and discussing factors likely to affect their future evolution, namely the trade-off between specialisation gains and coordination costs.

2.1 Technological progress and trade costs

Technological progress 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, opening the door to the international fragmentation of production. This differs from the broader concepts of international technology diffusion and transfer, where multinational corporations bring technologies that are new to specific countries, leading to subsequent increases in exports. 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. Therefore, as these costs are relatively more important in internationally fragmented activities, potential savings arising from technological progress act a driver of GVCs. In fact, major past transformations in the 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 and the liberalisation 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 from 2000 to 2004. 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 technology (ICT) and a dramatic fall in telecommunication costs (Figure 2). 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, sectors like financial services, computer and information services and other commercial and business services are increasingly traded internationally. Garner (2004) discusses the main economic, technological, and regulatory factors driving offshoring in the services sector and suggests four characteristics that make a service job more susceptible to offshoring: labour-intensive; information-based; codifiable; and high-transparency in the information. van Welsum and

Figure 2: World indicators of information and communication technology (ICT)
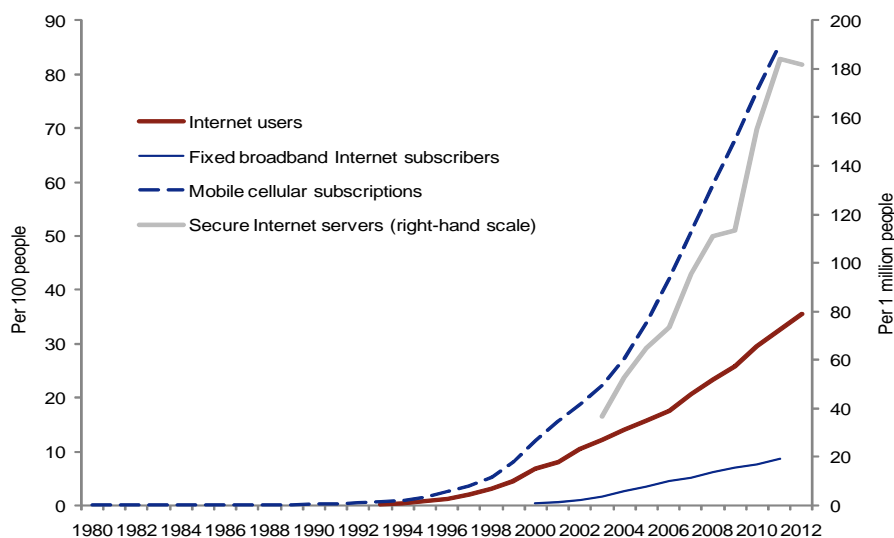
Vickery (2005) highlight the importance of ICT to service offshoring and they also consider four criteria that make a service occupation potentially offshorable: intensive use of ICT; producing an output that can be traded or transmitted via the Internet; highly codifiable knowledge content; and no face-to-face contact requirements.

In this context, the concept of "offshorability" has emerged recently to designate the potential scope for offshoring of a given task. Several studies use data at a detailed occupational level to obtain information about the task content of work and related it to its offshorability, in the line of previous work on the impact of technological change (see, for instance, Autor et al., 2003). Blinder (2009) uses occupational codes to construct an ordinal ranking of the potential offshorability of tasks and Jensen and Kletzer (2010) construct two different measures to identify service activities that are potentially exposed to international trade. Blinder and Krueger (2013) discuss the concept and use survey techniques to develop different measures of offshorability, defined as the ability to perform the work from abroad. They find that offshorability is stronger in production work and in office and administrative tasks. Finally, Autor (2013) provides a comprehensive and interesting discussion of the main concepts and empirical methods associated with this task approach. The exact definition of an offshorable task is problematic but, as discussed therein, it ultimately depends on whether distance leads to a reduction in the quality of the task performed, not on its strict routine content.

As electronic communications progressively replace face-to-face interactions, the importance of geographical distance as a barrier for international service transactions declines. 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 for the theoretical contributions of Marjit (2007) and Kikuchi and Iwasa (2010), which propose models of international trade that capture the role of time zone differences. She finds 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 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 discussed in Hummels (2007), there has been a rapid technological change in air shipping over the last decades, including improvements 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. Nordas (2006) examines the relevance of time as a competitive factor and concludes that effective transport and logistics services, and trade facilitation leading to simpler customs procedures have a positive effect on trade and on the probability of entering an international supply chain.

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. As examined in Hummels (2007), the growth of open registry shipping, the scale effects from increased trade volumes and the introduction of containerisation contributed to shorter transportation time. Open registry shipping is the practice of registering ships under flags of convenience to reduce regulatory and manning costs. 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 containerised 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 sys-

tems, 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 et al. (2002) and Feenstra and Hanson (2004) study the role of Hong Kong in the distribution of China's exports, adding value to the goods through sorting, packaging, testing, marketing and matching suppliers and customers. 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.

Finally, the strong increase of trade associated with the development of GVCs in the nineties coincides with a period of historically low oil prices (Figure 3). Although there is little empirical evidence linking these two factors, a low oil price scenario should impact positively on the costs of doing trade. In fact, transport costs are important for trade and energy is an input to transportation that is difficult to substitute. Bridgman (2008) presents a vertical specialisation trade model with an energy-using transportation sector. In the simulated model, trade growth slows from 1974 to 1985 as the increase in oil prices led to higher transport costs that offset the decline in tariffs. However, higher oil prices during the 2000s did not lead to a decline in international trade because there was a simultaneous increase of productivity in the transportation sector.

Figure 3: World vertical specialisation activities and oil prices
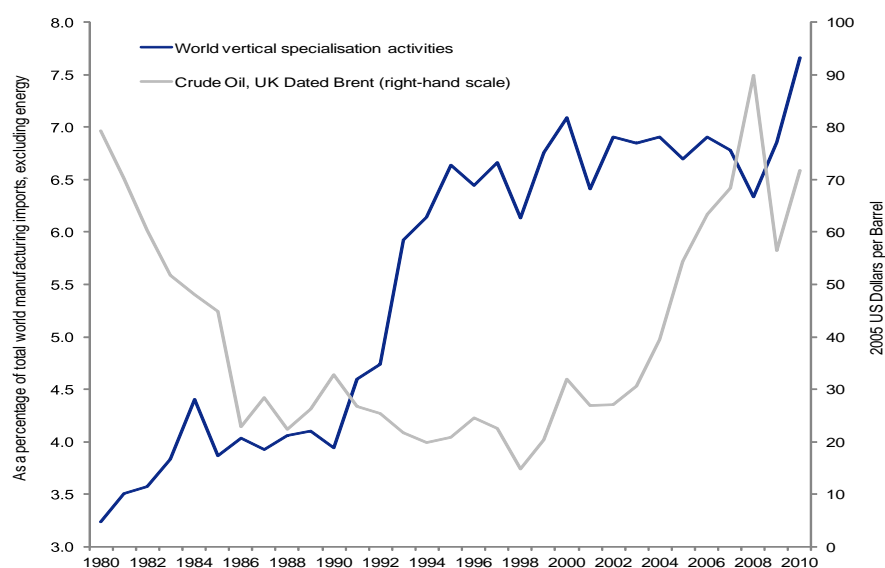
Sources: IMF - International Financial Statistics (IFS) and authors' calculations.
Note: The measure of vertical specialisation activities is computed as the "excess" imports of an intermediate good for a country with very high exports of a related output good (see Amador and Cabral, 2009).

2.2 Economic and trade liberalisation

The fall in political and economic barriers has been an important driver of trade, in general, and of GVCs, in particular (Figure 4). As discussed in Baldwin (2012), supply-chain trade is very regionalised, 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 localised 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.

Figure 4: Global economic and trade liberalisation
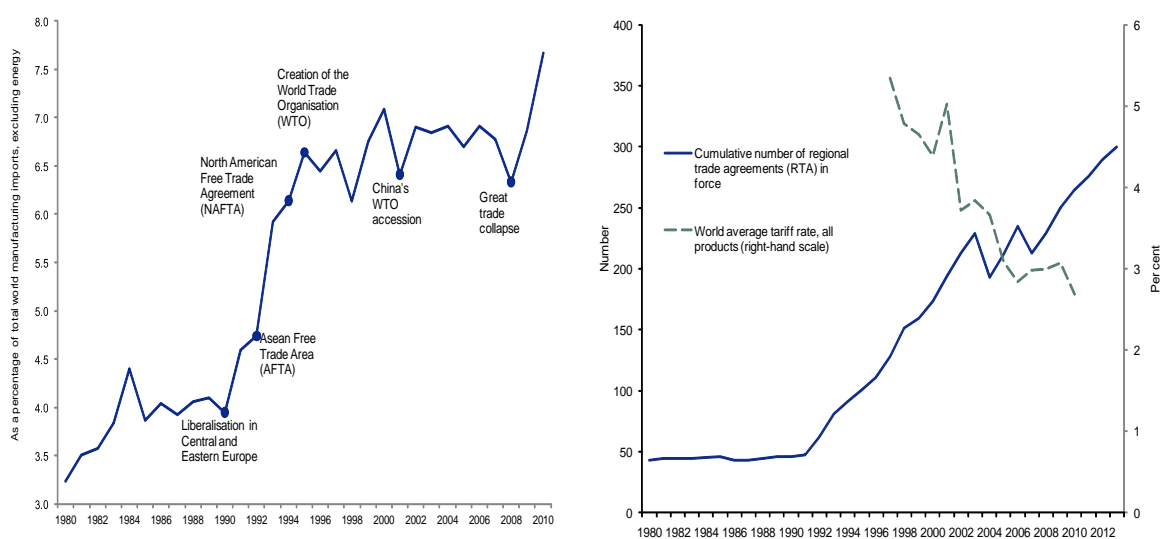
(a) A timeline of main trade events

(b) Trade agreements and tariffs

Sources: World Trade Organisation (WTO) for the RTA data, World Bank - World Development Indicators (WDI) for the tariff rate data and authors' calculations.

Notes: Measure of vertical specialisation 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.

At present, the global production network is organised around three major regional blocks in Europe, in Asia and in North America. The political and economical liberalisation in Europe is vividly illustrated by the successive enlargements of the European Union (EU) towards Central and Eastern European countries. This fact brought such economies into the European Common Market and created an intense net of international trade linkages, includ-

ing important GVCs. Kaminski and Ng (2005) investigate network trade in ten Central and Eastern European countries until 2002. They show that network trade in these countries 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 German and Austrian firms investment projects in Eastern Europe from 1990 to 2001 to document the pattern of intra-firm trade among these countries and the emergence of some Eastern European countries as new players in the international division of production. Behar and Freund (2011) use international trade data in parts and components to examine how fragmentation in Europe has evolved and discuss how the process of EU integration may have facilitated the volume and increasing complexity of intra-EU trade in intermediate products.

An essential element of the movement towards trade liberalisation was the accession of China to the WTO in 2001. Zhao (2005) provides a detailed description of the process of China's external liberalisation over the last decades, examining the reforms leading to the accession to the WTO. Athukorala (2009) investigates how China's emergence as a major trading nation is affecting the export performance of other East Asian countries, in a context of increased global production sharing. He 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). The AFTA agreement was signed in 1992 and now comprises the ten countries of the ASEAN (Indonesia, Malaysia, the Philippines, Singapore, Thailand, Brunei, Myanmar, Cambodia, Laos, and Vietnam). 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 (see Chia (2013) for a detailed discussion on the evolution of ASEAN economic integration). As examined in Athukorala (2011), network trade strengthened economic interdependence in Asia, with China playing a key role as a centre of final assembly. The rise of China as a major player in the organisation of production in Asia, replacing to some extent Japan and the US, is also highlighted by Kalra (2010). 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 organisation, namely the US, Japan and China.

One of the most debated regional trade agreements 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.

2.3   FDI flows and intra-firm trade

Although it is difficult to set clear borderlines, the flows of FDI and intra-firm trade are mostly a consequence of the expansion of GVCs and not exactly drivers for its expansion. The evolution of these variables is the final outcome of a complex interaction of factors, where multinational corporations play a key role. However, given the importance of FDI flows and multinational firms in the current organisation of global production and in the recent literature on GVCs, we briefly discuss some relevant issues below.

Economic liberalisation and deregulation contributed to the strong growth of FDI flows since the nineties (Figure 5). Productivity differences play a major role in firms' decisions to offshore parts of the production process and whether to do so through FDI or via arm's-length trade. As multinational firms adopt the new paradigm of production and become

prominent players in international trade, GVCs are increasingly associated with FDI flows, with subsidiaries providing inputs to their parent firms. In this case, trade in intermediate goods takes the form of intra-firm transactions with production stages located in different countries, i.e., vertical production networks within multinationals.

Figure 5: World vertical specialisation activities and FDI flows
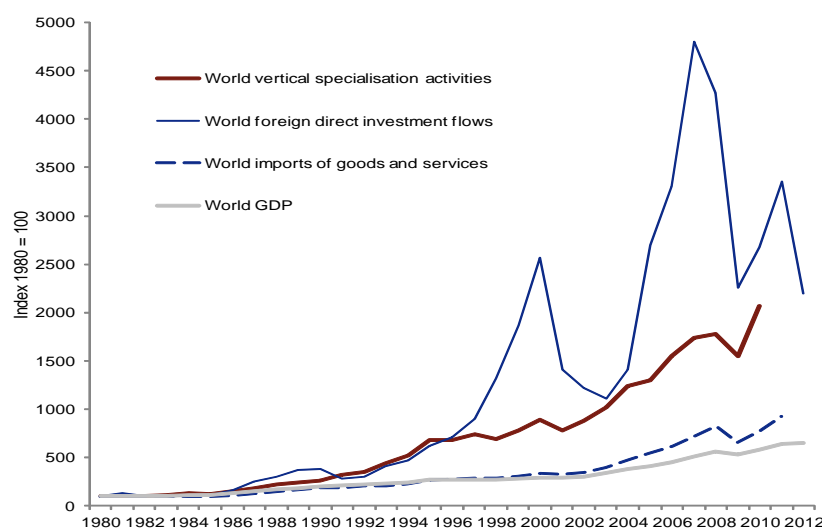
Sources: World Bank - World Development Indicators (WDI) and authors' calculations.
Note: The measure of vertical specialisation activities is computed as the "excess" imports of an intermediate good for a country with very high exports of a related output good (see Amador and Cabral, 2009).

Traditionally, vertical FDI is motivated by cross-country differences in relative factor abundance. In this framework, firms locate production facilities in foreign countries to take advantage of factor-cost differentials in specific stages of production, which are different in factor proportions and geographically separable. This reasoning explains why a firm from a skill-abundant country establish an affiliate in a low-wage country. However, empirical evidence for the US shows that intra-firm trade is concentrated in capital-intensive industries and is mostly between capital-abundant countries (Antràs, 2003). These patterns of intra-firm trade led to new theoretical work on the boundaries of the firm and a new strand of the empirical literature focused on the integration strategies of multinational corporations, and the consequent intra-firm trade, and on the choices of firms between different international outsourcing modes.

Some articles use intra-firm trade data aggregated by product and country of origin of the imported inputs. For the US, Yeaple (2006) find that the share of intra-firm imports tends to be higher in more capital and R&D-intensive industries. Nunn and Trefler (2008, 2013) use product-level data on US intra-firm and arm's-length imports and find that vertical integration is increasing in the share of non-contractible inputs provided by US parent firm. They also conclude that intra-firm trade is larger where these headquarter inputs are impor-

tant and productivity is high. Bernard et al. (2010) provide evidence on the impact of several interactions of country and product characteristics in the shares of US intra-firm trade. They find that intra-firm trade is high for products with low levels of contractibility sourced from countries with weak governance, for skill-intensive products from skill-scarce countries, and for capital-intensive products from capital-abundant countries.

Other studies use firm-level data to analyse the firms' choices between intra-firm and arm's-length trade, but the evidence is still scarce and has produced mixed results. Kohler and Smolka (2012) find a productivity ranking across different sourcing strategies of Spanish firms, in line with the predictions of the model of Antràs and Helpman (2004). Firms who choose vertical integration tend to be more productive than those who rely on arm's-length transactions, and firms who offshore are generally more productive than those who source their inputs domestically. Using a sample of Japanese firms, Tomiura (2007) also concludes that FDI firms are more productive than foreign outsourcers and exporters, which in turn are more productive than domestic firms. Using data on French firms, 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) examines the offshoring strategies of French manufacturing firms and finds that those more productive tend outsource through arm's-length transactions, while less productive firms integrate vertically. Defever and Toubal (2013) use detailed data on imports of French multinationals and also find that the most productive multinationals import through a foreign unrelated supplier while the least productive import their intermediate inputs from a foreign related party.

A complementary strand of research studies the organisation of international sourcing strategies within multinational networks. Alfaro and Charlton (2009) use a global firm-level dataset that establishes the location, ownership, and activity of more than 650,000 multinational subsidiaries at a high level of sectoral disaggregation. They find that the number of vertical multinational subsidiaries is larger than commonly thought, even within developed countries. Many of the foreign subsidiaries in the same 2-digit industry as their parents are located in 4-digit sectors that produce highly specialised inputs close to their parents' final good. The authors named these subsidiaries unveiled at higher levels of disaggregation "intra-industry vertical FDI" and found that a large proportion of these firms are located in high-skill countries.

This pattern of intra-industry North-North vertical FDI is interpreted as reflecting multinationals' decision to own the stages of production closest to their own. Engemann and Lindemann (2013) find that German multinationals tend to locate affiliates that produce goods positioned at later stages of the production process in more productive countries. Hanson et al. (2005) use firm-level data on US multinationals to examine trade in intermediate goods

between parent firms and foreign affiliates. They conclude that imports of inputs from 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 the propensity of foreign affiliates to import intermediate goods from their US parent companies, relating it to several firm, industry and country characteristics. Their results also point to a vertical specialisation between more technologically advanced activities performed by the parent and lower-skilled activities performed by the affiliate. Tanaka (2011) uses panel data on Japanese and US multinationals and finds that unskilled-labour abundance in foreign countries has a significantly positive impact on offshore production by Japanese firms but it has no significant effect on foreign affiliate sales to US multinationals.

3   Mapping and measuring Global Value Chains

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 6 presents a timeline of the main articles in each methodological approach, which are detailed in the next subsections. The research on GVCs using firm-level data 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 subsection 3.4.

Figure 7 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 truly captures the characteristics of GVCs; 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.

Figure 6: Measuring GVCs using sector-level data - Timeline of main research
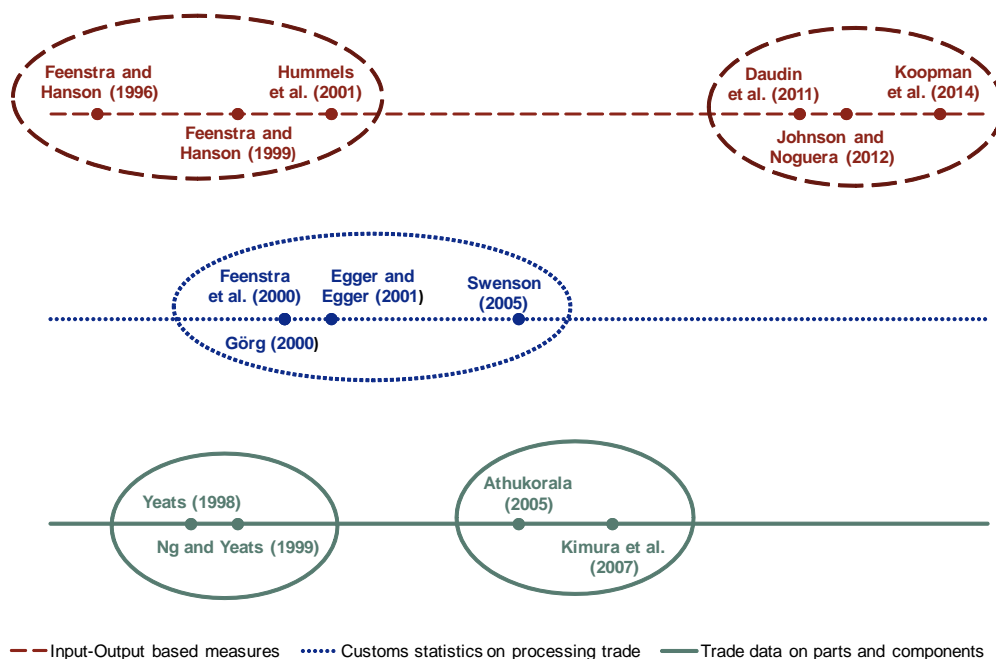
Figure 7: Summary of main strands of the empirical research on GVCs
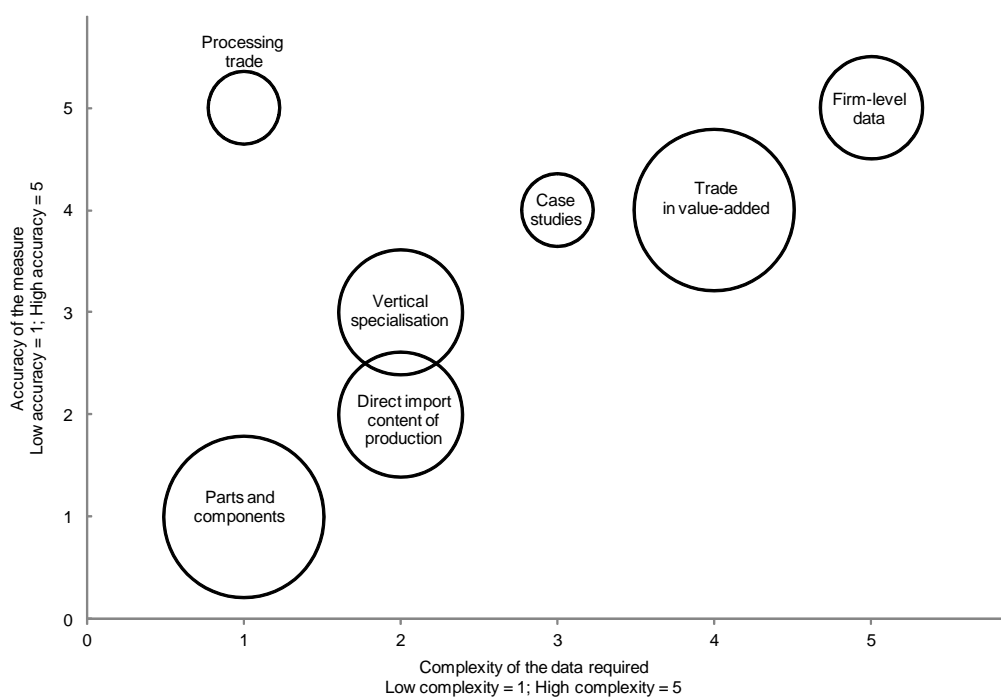
Notes: The size of the circles represents the coverage of each measure relatively to the real size of the GVCs phenomenon in the world economy, with larger circles standing for higher coverage. The x-axis corresponds to the complexity of data required to compute the measure and the y-axis stands for 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.

3.1 International trade data on parts and components

The first and simplest methodological approach makes use of international trade statistics to measure fragmentation by comparing trade in goods classified as 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 than trade in final goods until mid-2000s (see Athukorala and Yamashita (2006) and Jones et al. (2005) for a review). 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 specific trading partner relationships. A drawback is the low accuracy of the measure and the fact 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 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 specialisation 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 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) examine patterns of final and intermediate goods trade at the country level and find a growing involvement of developing countries in GVCs. The authors also 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 the three industries.

3.2 Customs statistics on processing trade

The second methodological approach relies on the analysis of customs statistics. 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 datasets 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).

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 dataset to examine how competition and production persistence influence outsourcing decisions and finds that sunk costs have a large effect on assembly location choices. Swenson (2013) also use product-country level data from the US offshore assembly program to examine the incomplete pass-through of production and trade costs to outsourcing import prices. Clark (2006) examines data on the use of offshore assembly provisions in the US tariff code and concludes that firms tend to shift the simple assembly operations to unskilled-labour abundant countries. 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 characterised by relatively intense use of skilled-labour.

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. 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.

Processing trade 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.

3.3 Input-output based measures

3.3.1 Classical input-output 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. 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 fragmentation activities and the assessment of its 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 type of I-O based measure 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 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 of that input (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 from 1990 to 1998, 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 initially formulated by Hummels et al. (1998) and Hummels et al. (2001), which labelled it "vertical specialisation". 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 specialisation 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) update the analysis of Hummels et al. (2001) using more recent I-O tables and conclude also that trade in vertical specialised 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 specialisation activities. Some examples are Amador and Cabral (2008) for Portugal, Breda et al. (2007) for Italy and six other 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. Dean et al. (2011) also estimate the vertical specialisation of Chinese merchandise exports, adjusting for the importance of Chinese processing imports. 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. In the same vein, 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 specialisation-based trade that combines information from product detailed and country generic I-O matrices with international trade data. If a country has a simultaneous high export share of a product and a high import share of a related intermediate good used in its production, then this "excess" of intermediate imports is used as a proxy of trade related to vertical specialisation activities. 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 levels of vertical specialisation-based trade must be interpreted in relative terms and as proxies. The article finds a substantial increase of vertical specialisation activities in high-tech products in East Asia over the last two decades. This is the measure used to illustrated the evolution of GVCs in Figures 3 to 5.

In a different framework, recent studies use classical I-O data to measure the average position of an industry in the production line. 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. An equivalent measure of industry upstreamness was proposed by Fally (2012) based on the notion that industries selling a disproportionate share of their output to relatively upstream industries should be relatively upstream themselves. Fally (2012) also develops a measure of the number of production stages embodied in an industry's output. Antràs and Chor (2013) propose two related measures of the average position of an industry in the value chain to capture the downstreamness of an industry in production processes. The first is the ratio of aggregate direct use to aggregate total use of an industry as an input and the second one is the reciprocal of the measure of industry upstreamness defined in Antràs et al. (2012). 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 input-output 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). Hence, the analysis 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. As a result, 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 basic concept of trade in value-added is that domestic value-added combines with foreign value-added in order to produce exports, which may be latter embodied in other products or consumed as final goods and services. Therefore, imports of intermediate products to be embodied in exports are an important part of the production process, making the gross value of exports much larger than their domestic value-added component. In addition, the domestic value-added embodied in exports can circulate in the global economy included in intermediate products used along the production chain and part of it can return to the domestic economy in this process. Figure 8 presents these linkages in a stylised way.

Figure 8: Flows of value-added in a GVC
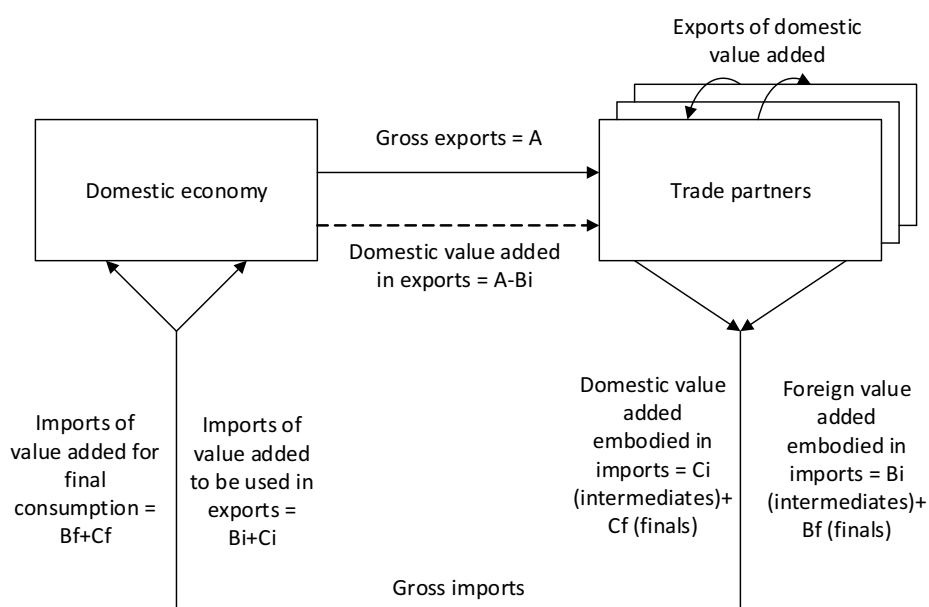
The measurement of trade in value-added requires world I-O tables with information on all bilateral exchanges of intermediate and final goods to allocate the value-added along the GVC to each producer. A recent special issue of the *Economic Systems Research* provides a very useful and detailed description of several global 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 summarises 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 generalise the vertical specialisation concept of Hummels et al. (2001) and capture the different dimensions of international flows of value-added illus-

trated in Figure 8. The initial studies on the measurement of the value-added of trade in a global I-O framework were those of Johnson and Noguera (2012*a*), Daudin et al. (2011) and Koopman et al. (2014), using the Global Trade Analysis Project (GTAP) database.

Johnson and Noguera (2012*a*) define exports of value-added 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. Johnson and Noguera (2012*b*) extend this work linking data on bilateral trade, production and input use at the sector-level for 42 countries from 1970 to 2009. In addition, Johnson and Noguera (2012*c*) use these data to analyse how changes in fragmentation over time are related to proximity. 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, using the GTAP database for 1997, 2001, and 2004. 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, i.e., exports that are embedded in re-imported goods. 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.

In parallel, Foster-McGregor and Stehrer (2013) and Dietzenbacher et al. (2014) discuss the different concepts associated with trade in value-added and the potential of the World Input-Output Database (WIOD) database to study GVCs. Since its release, the WIOD was used to derive new measures of competitiveness that take into account the value-added content of trade (Timmer et al., 2013), to examine the link between international outsourcing and the skill-structure of labour demand (Foster-McGregor et al., 2013), to provide stylised facts on offshoring in Europe, estimating the productivity effects of services and material offshoring (Schworer, 2013), to study the trends in factor income distributions in GVCs (Timmer et al., 2014), among others.

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) summarises the main evidence and policy implications of the OECD's work on GVCs, including trade and investment policies targeted to 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 the OECD-WTO TiVA database include Newby (2013) for Finland, Duprez and Dresse (2013) for Belgium and Beaudreau (2013), which studies the relative specialisation of countries using Balassa-type indicators

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	UNCTAD (2013*a*)
IDE-JETRO (Institute of Developing Economies - Japan External Trade Organisation)	10 countries	76 industries	1975, 1980, 1985, 1990, 1995, 2000	Meng et al. (2013)

of revealed comparative advantage calculated in value-added terms. Baldwin and Lopez-Gonzalez (2014) use both the WIOD database and the OECD-WTO TiVA databases to provide a detailed portrait of the evolution of GVCs between 1995 and 2009.

Finally, a recent collaborative effort between the United Nations Conference on Trade and Development (UNCTAD) and the Eora project[1] has resulted in a multi-regional I-O time series dataset on embodied value-added in trade (the UNCTAD-Eora GVC database). Combining several primary data sources and using interpolation and estimation techniques, a continuous database for the period 1990-2010 with expanded country-coverage was produced. This database is used in the 2013 World Investment Report (UNCTAD, 2013*b*), 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. However, the available empirical articles do not adopt a common methodology. 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

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[1] See http://www.worldmrio.com/ for further information and access to the Eora MRIO Database and Lenzen et al. (2013) for a detailed methodological description.

the relevance of offshoring.

A related literature examines the international transfer of production activities within multi-national firms, thus focusing only on this specific group of 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 Japanese multinationals, by Hansson (2005) for Swedish multinationals, by Ebenstein et al. (2014) and Ottaviano et al. (2013) for the US, and by Becker et al. (2013) for German multinationals. 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 imported 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 (nominal or real data), the type of transactions (intra-firm and/or arm's-length) and the type of products considered.

In the numerator, most studies use a measure of imports of inputs in real terms but there are different ways of deflating the nominal values. Imports of intermediate goods can be deflated using industry-level price deflators as in Hijzen et al. (2010) for Japan, using official import price deflators as in Amiti and Konings (2007) for Indonesia and Kasahara and Rodrigue (2008) for Chile, or using 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) considers two different measures of offshoring for Japanese firms, one of total offshoring and another of 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. In their case, services inputs include contracted-out services, such as consultancy, maintenance, security, cleaning, and catering, but do not include other indirect costs such as rents and interest payments.

Even considering only studies on materials' offshoring, distinct options still exist: to include only parts and components (defined according to some standard sectoral classification) or imports of all materials (including raw materials). Hijzen et al. (2010) compute two different measures of offshoring. One that includes imports of products, parts, and components and another that includes purchases of any kind (including raw materials) but only from the firm's own foreign affiliates. Lo Turco and Maggioni (2012) use firm imports of non-energy material intermediates from all sectors together with the 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, both by broad geographic origins. Finished goods are defined as products that correspond to the same 3-digit code of the main activity of the firm, while the 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 potentially 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 sum of imports in the same Harmonised System 4-digit category as goods sold by the firm, i.e., imports of raw materials are included in broad offshoring but are omitted from narrow offshoring.

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, to measure the importance of imported intermediates in the production process. 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 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 organisations.[2] 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 internationalisation 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, i.e., they do not allow an analysis of the dynamics of offshoring activities. However, they still offer a potential avenue for empirically validating the predictions of different theories associated with the international fragmentation of production. For example, Antràs (2014) discusses in detail four firm-level datasets that have been used to test the empirical relevance of the property-rights theory in the context of the international organisation 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 dataset (in short the EFIGE dataset), 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). The survey questionnaire contains both qualitative and quantitative data on firms' characteristics and activities, split into different sections. All questions concern the year 2008, but some questions ask information for 2009 and previous years. Navaretti et al. (2011) use the EFIGE dataset to examine the internationalisation of production of European firms. They consider the average share of firm turnover from three different internationalisation modes: importing foreign inputs and components for use in domestic production;

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[2]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.

international outsourcing, which implies setting up specific arm's-length agreements with foreign firms; and carrying out own production through FDI. 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, Ito et al. (2011) and Tomiura et al. (2013) use the Research Institute of Economy, Trade and Industry (RIETI) survey of corporate offshore activities by manufacturing firms. The RIETI survey covers both offshoring of production activities and offshoring of services, including detailed information on what kind of tasks are offshored to which geographical destinations. The survey also distinguishes three types of suppliers in offshoring: offshore subsidiaries owned by the offshoring firm, offshore subsidiaries owned by other Japanese firms and foreign suppliers. Although quantitative data on how much each firm offshored are not available, the survey includes information on the status of offshoring five years ago as a retrospective question, thus allowing to make some comparative statics analysis.

Another survey with qualitative data on offshoring is the Survey on Manufacturing Firms (*Indagine sulle Imprese Manifatturiere*) for Italy. This is a large survey of Italian firms run every three years by the commercial bank Unicredit-Capitalia, with information on internationalisation activities, investment, R&D and characteristics of the workforce. Antonietti and Antonioli (2011) use data from this survey covering the period 1995–2003 to study the effects of cross-border relocation of production on the skill composition of Italian manufacturing firms. Crinò (2010) also uses this survey to examine the effects of service offshoring on the level and skill structure of domestic employment.

Some recent studies on the mode of internationalisation of French international groups use intra-firm imports from the firm-level survey on the foreign activities of French industrial multinationals carried out by the French Ministry of the Economy in 1999 (*Enquête sur les Échanges Internationaux Intra-Groupe*). For each import transaction of each firm covered by the survey, 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 integration or vertical FDI, partnership and international outsourcing from a third independent party. Examples of studies using this dataset are Defever and Toubal (2013), Jabbour (2012) and Corcos et al. (2013), which examine the offshoring choices of French manufacturing firms.

4 Concluding Remarks

Global value chains (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 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 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. In fact, many services, previously seen as non-tradable, are becoming increasingly important in world trade. Moreover, there is potential for further international trade liberalisation, 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 and skill building, thus enhancing their productive capacity.

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 Input-Output (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 controlling for firm heterogeneity and can give important insights on the widespread impacts of GVCs. Several measures can potentially be computed using firm-level databases but, for example, the assessment of the imported value-added of exports at the firm level is still not available. In addition, it is not possible to trace trade flows along GVCs at the micro-level, establishing the links between firms in the different countries and in different stages of the production process. Empirical research of GVCs at the firm-level is determined by the availability of information, thus further micro-data disclosure and sharing would allow for some progress in this front. A set of stylised facts on GVCs based on micro-data for several countries could be obtained using internationally comparable 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 new paradigm of world production requires an accurate knowledge on the characteristics of the firms, sectors and countries involved in GVCs, as well on the channels through which these networks are established.

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