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Mapping global value chain participation and positioning in agriculture and food: stylised facts, empirical evidence and critical issues

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Abstract. This paper aims to overview the recent body of empirical work on the importance of Global Value Chains (GVCs) in international production and trade. We begin by reviewing different approaches and levels of GVC analysis. We then consider developments in methods and data. Focusing on the agriculture and food sector, we present a map of GVC measures - at the country and sectoral level - computed using trade in value added data to allow researchers to better assess the countries' engagement in GVCs. We also apply this data to show some stylized facts on GVC participation and positioning in agriculture and food and provide empirical evidence of the economic impact of the GVCs on these sectors. We conclude with some critical issues and speculative thoughts regarding the future of GVCs.

Keywords: global value chains, participation and positioning, trade in value added, agricultural and food sectors, survey.
JEL codes: F14, O50, Q17.

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1. THE IMPORTANCE OF GLOBAL VALUE CHAINS: PAST AND PRESENT

Over the past twenty years, the term "global value chains" (GVCs) has become increasingly popular among economists, particularly those in the area of international trade. GVCs can be defined as the full range of activities – dispersed across different countries – that firms and workers engage in to bring a product from its conception to its end use (see Gereffi and Fernandez-Stark, 2011). Starting from the early 1990s, the world-wide economy experienced a radical transformation through a significant fragmentation in the production of goods and services and a deeper international division of labour, resulting in larger returns from specialization. This new era has been driven by at least two main factors. First, the information and communication technology (ICT) revolution facilitated the global outsourcing and offshoring of manufacturing activities. Second, the sharp drop in effective

trade costs, which has been driven both by a significant increase in the rate of reduction of man-made trade barriers and faster methods of shipping goods (Antràs and Chor, 2021).

The dramatic fragmentation in the organization of world production raised by the GVCs has also been witnessed by a sharp increase in the trade of intermediate goods, accounting for more than 50 percent of world trade in the last years and increased tenfold in value over the last thirty years (Figure 1), thus justifying the growing interest of trade economists in understanding global production arrangements.

The evolution of GVC is having a deep impact in many sectors such as resource-based commodities, apparel, electronics, tourism and business service outsourcing, with significant implications in terms of global trade, production and employment, for both developed and developing countries. For industrialized economies, GVCs ensure access to lower priced inputs, wider variety and economies of scale. For developing economies, GVCs represent a valid shortcut to industrialization since they allow them to join existing supply chains instead of building them. Moreover, entering in a proven supply chain eliminates the need to acquire a comparative advantage in a broad range of production stages domestically.

The specialized literature analyses the impact of GVCs by distinguishing between *economic upgrading*, usually defined in terms of efficiency of the production process or characteristics of the product or activities performed (Humphrey and Schmitz, 2002), and *social upgrading* often referred to outcomes related to employment and pay, gender and the environment (Milberg and Winkler, 2010). As for the former, the literature has pointed out a positive relationship between GVC participation and productivity both in developed and developing countries (Kummritz, 2016; Montalbano and Nenci, 2018; Constantinescu et al., 2019). Offshoring and GVCs can lead to significant gains in productivity through numerous channels: the availability of broader input varieties (Halpern et al., 2015); finer division of labour across countries, even by inducing firms to specialize in core tasks (Grossman et al., 2008; Criscuolo et al., 2017; Antràs, 2020); greater competition; learning-by-doing externalities and technology spillovers (Baldwin et al., 2014; Piermartini et al., 2014; Benz et al., 2014). Even though some of these channels are related to traditional trade as well, welfare benefits can be larger when considering a multiple-sector framework and the input-output linkages (Caliendo et al., 2015). This evidence shows that GVCs are a key factor in increasing wages and boosting development and long-term growth. However, the relationship between GVC participation and inclusive development does not fall automatically from the premises. As for *social upgrading*, the specialized literature also highlights the positive effects of GVCs on employment. This

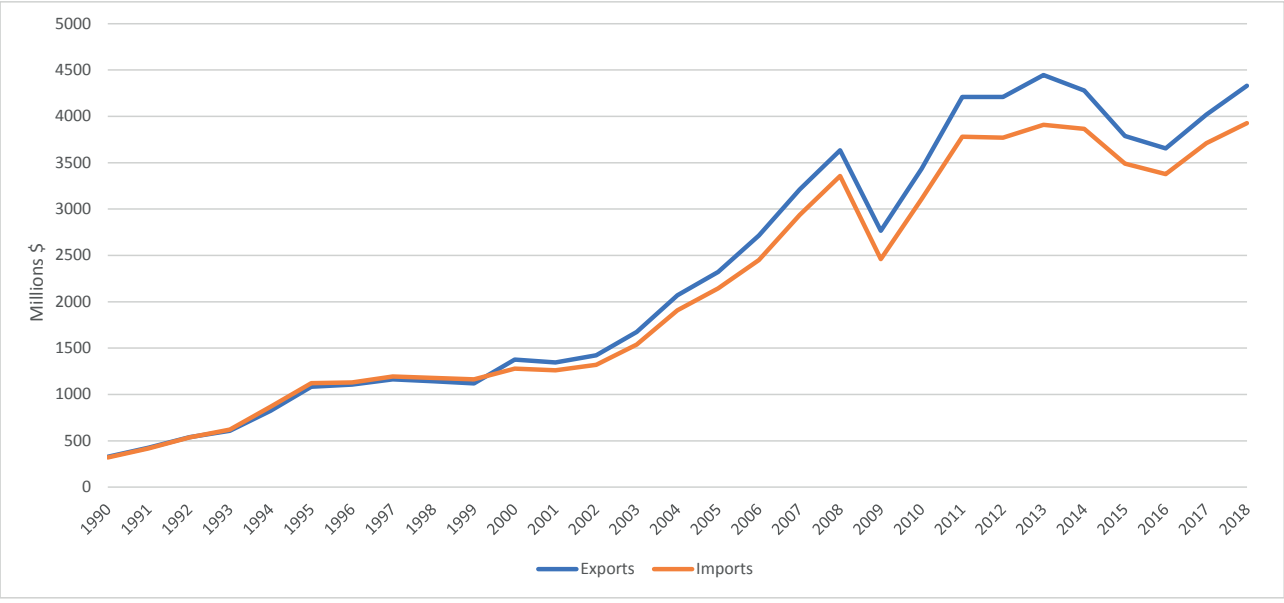

Figure 1. Trend in international trade in intermediate goods (millions of USD). Notes: values of intermediate goods for all the industries included in the BEC - Broad Economic Categories Rev.5 classification. Source: Authors' elaboration on UN-Comtrade data using BEC Classification.

may vary depending on the industry characteristics and the relative engagement in the value chain of the activities that are not outsourced. Relevant employment effects have been observed also in the agro-food sector in Southeast Asia, with countries having the highest shares of workforce associated with agro-food GVCs (Lopez-Gonzalez, 2016). A strand of the literature has also explored the beneficial effects of trade in intermediate inputs on a country's innovation performance, through the transmission of technology and research and development spillovers (Tajoli and Felice, 2018; Fracasso and Marzetti, 2015; Piermartini and Rubinova, 2014).

Turning to sectoral value chains, studies on agri-food chain are not new (Davis and Goldberg, 1957), and the literature embraces some complementary traditions: commodity chain analysis focuses on worldwide temporal and spatial relations (Hopkins and Wallerstein, 1986); *filière* analysis focuses on national political regulation and institutions (Lauret, 1983), whereas value chain analysis focuses on international business organisation and profitability (Porter, 1990). There have also been several applications of industrial organisation to economic and policy issues in the food and agricultural sector as well as analysis of the interaction between industrial organisation and policy in a trade setting: see (among many) Karp and Jeffrey (1993), Scoppola (2007), McCorriston and Sheldon (2011), and Sexton (2012). Much empirical evidence on agri-food GVCs is largely focused on capturing the impact on national economies through an analysis of case studies on the globally integrated value chain at the product level. The increasing importance of global agricultural trade registered during the past three decades comes with changes in the way GVCs are organised, with increasing levels of vertical coordination, upgrading of the supply base and the increased importance of large multinational food companies (Swinnen and Maertens, 2007; McCullough et al., 2008; Scoppola, 2021). A relatively small number of companies now organise the global supply of food and link small producers in developed or developing countries to consumers all over the world (Gereffi and Lee, 2009). This is generally referred to as agro-food GVCs (Humphrey and Memedovic, 2006; Liapis and Tsigas, 2014; Greenville et al., 2016; Balié et al., 2019).

The review of the huge empirical literature on the different dimensions of GVCs is beyond the scope of this article. This survey aims to deepen our understanding of GVCs by measuring and mapping them mainly from a macro perspective, using international trade data, with special attention to the agriculture and food sectors, a subject that, as far as we know, has not yet been summarized.

2. DIFFERENT APPROACHES AND LEVELS OF ANALYSIS OF GVCs

The high complexity and the different scales of analysis make it impossible to define, measure and map GVCs in a single way. This phenomenon of organizationally fragmented international production has been subject to investigation in a wide range of academic disciplines, including economic sociology, international economics, economic geography, international political economy, supply chain management and international business (see Kano et al., 2020). Therefore, the economic literature has evolved along different strands of research, using different approaches and levels of analysis.

2.1 GVCs as a multidisciplinary topic : development, geography, innovation

The development literature, beyond the early discussion on the role of the state in modern capitalism, has been widely influenced by the emergence of GVCs. Specifically, the debate mainly centred on the perspectives that GVCs would open to firms from developing countries to gain access to markets, to access knowledge and technology from abroad, and to "capture value" and part of the rents generated in the process (Davis et al., 2018; Kaplinsky, 2019). The challenge for local firms would be to "upgrade" by innovating to improve their products and processes, but also notably to "functionally upgrade" by entering value chain segments offering larger shares of value added. More generally, local firms' struggle would be to enter value chains niches with a stronger potential for learning and innovation, and for strengthening their technological and innovation capabilities (Morrison et al., 2008).

Sometimes contrary to the interests of local firms, though sometimes fostering them, lead firms often have an interest to protect, appropriate, and create rents in the process of international production (Davis et al., 2018). Pathbreaking research put the concept of value chain *governance* at the core of the analysis and developed a theory that generates five different forms of GVC governance: hierarchy, captive, relational, modular, and market, which range from high to low levels of explicit coordination and power asymmetry (Gereffi et al., 2005). Three variables would determine how GVCs are governed, and these are: the complexity of transactions, the ability to codify transactions, and the capabilities in the supply-base. This theory, which itself draws on other streams of literature, like transaction costs economics, production networks, and technological capability and firm-level learning, has generated an infinite number of studies

aiming at measuring and testing it with quantitative and qualitative approaches (e.g. Brancati et al., 2021).

Importantly, from all these approaches it has gradually emerged the idea that GVCs are not only a trade phenomenon. Given the variety of organizational arrangements prevailing in GVCs, and the inherent remarkable power asymmetries between lead firms and their different tiers of suppliers, the "relational dimension" of GVCs has gained utmost importance (World Bank, 2020). Therefore, the focus necessarily shifts away from the mere allocation of value added across countries through anonymous exchanges of goods and services. In contrast, the characteristics of the agents participating in a GVC become crucial, and they necessarily influence the distribution of benefits and rents along the value chain. The introduction of such a relational concept of GVCs, echoed by the World Bank but originally developed by economic sociologists, and international political economists like Gereffi, Sturgeon, Ponte and others, puts on a central stage a variety of themes, like for example the nature of the lead firms, i.e. multinational firms and foreign buyers and traders, and that of their suppliers, the institutional factors shaping the inter-firm relations and the location of global production, as well as the institutions affecting the decisions to invest in learning and innovation and their effectiveness.

Moreover, sometimes this literature has also crossed over a tradition of studies in economic geography that look at how the territorial context may influence enterprise behavior and performance. In many instances, local clusters of firms interact with lead firms and their first-tier suppliers, generating the need to understand how the local and the global dimensions of value chains influence and condition each other. Thus, some authors studied the interface between enterprise clusters and GVCs, discovering their deep and mutually-influencing relationships (Bathelt et al., 2004; De Marchi et al., 2018; Giuliani et al., 2005; Humphrey and Schmitz, 2002; Pietrobelli and Rabellotti, 2007).

More recently, in the effort to understand the evolution and the dynamics of GVCs and foresee the potential they offer to local firms and countries, the issue of innovation in GVCs has also been studied extensively. It has been shown how GVCs may act as conduits of knowledge, channels for technology transfer, and in the end, opportunities to learn and innovate (Lema, Pietrobelli and Rabellotti, 2019). A structured effort to understand the relationship between GVCs and national innovation systems has been attempted with various methods (Fagerberg et al., 2018, Pietrobelli and Rabellotti, 2011). Some authors concluded that a coevolution between GVCs and innovation systems would be constantly at play, though with remarkable sector-specific varieties (Lema et al., 2018, 2019 and 2021).

Finally, the GVC approach is beginning to be employed also for the analysis of natural resource-based sectors, due to the remarkable restructuring and changes that these sectors are undergoing as a result of technological changes and the growing relevance of local communities and environmental considerations (Kaplinsky and Morris, 2016; Pietrobelli et al., 2018; Katz and Pietrobelli, 2018).

2.2 Firms level analysis

Although it is undeniable that, in the real world, it is not countries or industries that participate in GVCs, but rather firms, the analysis of GVC at the firm-level is still at an "infant stage" (Antràs, 2021) and fall well behind the measurements' advances put forward by the literature based on country-sector level data (see Section 3). This is mainly because of the partial lack of good quality firm-level data, not to mention its scarce accessibility and the lack of standardisation of the different (proprietary) firm-level sources. Indeed, to accomplish a fully integrated picture of the back-and-forth features of firms' global linkages, a vast array of countries' harmonized information is needed, which comes from different sources, such as custom-level data together with census-level information. For instance, in order to build up a firm-level counterpart of the country–industry GVC index of backward participation, one has to collect, for the exporting firm, information on: the percentage value of imported intermediate goods on the total value of intermediate goods used in the production; country of imports; the exports' destination. And such a calculation, already difficult to achieve with the available data, will only provide information on a single portion of the trade in value added at the firm level[1]. Going beyond the mere calculation of a backward participation index, census-level information would then be needed to link a firm's trade behaviour to several dimensions of firms' heterogeneity.

Notwithstanding the relative lack of good quality data, in recent years, a few papers, mostly relying on general firm-level surveys, have tried to carry out empirical analyses to investigate the firms' involvement in GVCs and their impact on performance. A list of recent papers and firm-level datasets applied for GVCs empirical analysis is reported in the Appendix.

In order to provide a brief overview of the most recent findings, we will focus here on contributions

[1] On the virtual impossibility of coming up with analogous firm-level measures of forward participation, see Antràs, 2021.

related to the analysis of GVC participation and positioning at the firm level[2] (the analysis at the country-sector level is presented in Section 3). These firms' level analyses still lack a unified framework and unit of analysis. This is due to the fact that, in general, studies rely on different datasets (mainly firms' balance sheets, surveys, etc.), each containing different information. As a result, there are currently several measures of the GVC participation index of firms, without a unified framework. Among the few studies, it is useful to distinguish between the ones ending up with a firm's participation index similar to the one envisaged by the input-output based literature (see Section 3) from those whose indexes rely on firms' internationalization modes. In the first category, Veuglers et al. (2013) use as a proxy of a firm's participation the percentage of imported intermediates over total inputs. The second typology of studies focuses on the firms' internationalization operation modes as a proxy of GVC involvement. Although ending up with different proxies of the GVC participation index, those studies share a certain degree of common ground based on the assumption that a two-way trader firm can be univocally defined as a firm participating in GVCs. Giunta et al. (2021), following on from Veugelers et al. (2013), divide firms' participation in GVCs into two categories: i) single forward mode, when firms are only exporters of intermediates; ii) dual-mode when firms are both importers of materials and services and exporters of intermediates or final goods. Similarly, Agostino et al. (2016) take into account the variety of modes of internationalization associated with the operation of GVCs, such as: exports only, intermediate goods imports only, both exports and imports (two-way trade) and international production. Baldwin and Yan (2014), investigating Canadian manufacturing firms, consider as involved in GVCs those firms which engage simultaneously in importing and exporting activities. Del Prete et al. (2017) analyse a panel of manufacturing firms in Egypt and Morocco. In their empirical investigation, firms involved in GVC activities are international traders that received an internationally recognized quality certification. Brancati et al. (2017) and Agostino et al. (2020), by using a representative sample of Italian industrial firms, investigate the GVC participation index by looking at exporters of semi-finished goods/components and two-way traders. Moreover, they also infer firm GVC participation by using a question in the survey that asks about the existence of "long-lasting and significant relationships with foreign companies" (Brancati et al., 2017). Giovannetti et al. (2015) rely on this same question (i.e., a direct answer from a firm's representative) to proxy the manufacturing firm's participation in GVCs. Likewise, Giovannetti and Marvasi (2016), in their investigation of firms operating in the Italian food industry.

Despite the variety of GVC participation measures adopted in the firm-level applied literature, a striking regularity of results emerges: firms' participation in GVC leads to productivity gains activated by several channels. Exporting allows a firm to exploit scale economies, acquire new technologies abroad and learn by exporting. Furthermore, other benefits may accrue to firms active in GVCs through imports of foreign inputs: cost saving, technology transfer, higher input quality and possible complementarities with domestic inputs. Two-way trading may have the additional advantage of exploiting sunk cost complementarity and other positive interactions between export and import activities. Finally, as is highlighted by the literature on firms' internationalization, productivity gains are ordered: the more advanced the firm's mode of GVC participation, the greater the productivity premium.

The literature on firms' positioning in GVCs distinguishes between final firms - those selling their output on the end market – and supplier firms – those selling their intermediate products to other firms[3] (Accetturo et al., 2011; Agostino et al., 2015, 2016; Veugelers et al., 2013; Giovannetti et al., 2015). Why do these different organizational firms' modes (final and supplier) need to be taken into account? There are at least three important reasons: i) suppliers, mostly small and medium enterprises, constitute the bulk of the productive system in the large majority of countries; ii) the impact of shocks differs according to the firms' positioning in the GVCs (Altomonte di Mauro et al., 2012; Békés et al., 2011; Accetturo and Giunta, 2016); iii) final and supplier firms substantially differ in terms of economic performance as well as the benefits that can be obtained by operating in the GVCs.

Despite its relevance, the latter issue has been brought to the fore by very few papers, mainly because of the relative lack of microdata, making it difficult to carry out a proper investigation. Kimura (2002), Razzolini and Vannoni (2011), Veugelers et al., (2013) document a large profitability and productivity gap between supplier and final firms. Yet, some researchers have highlighted the heterogeneous behaviour and performance of supplier firms (Accetturo et al., 2011). Among

[2] We do not overview here the vast literature based on case studies since their findings are not immediately comparable with the ones based on representative samples (for an overview of the literature based on case studies, see Ponte, 2019).

[3] The exact definition used is: suppliers are firms producing to order for other firms. These firms are positioned in GVCs when they produce to order for other firms located abroad.

these, Agostino et al. (2015), who, based on a representative sample of Italian manufacturing firms, confirm that, on average, GVC supplier firms are less productive than final firms. However, since the "ability" of supplier firms increases, their productivity shortfall diminishes. In fact, for those who succeed in both exporting and innovating, Agostino et al. (2015) prove there is no statistically significant difference in productivity between suppliers and final firms. Finally, a "GVC effect" in terms of superior technical efficiency or productivity can also be traced by comparing suppliers operating on local markets vis a vis with suppliers operating in the GVCs (Agostino et al., 2020; Veugelers et al., 2013).

3. COUNTRY AND SECTORAL GVCs ANALYSIS

Parallel to the firm analysis of GVCs, international economists developed various approaches to map and measure these chains at the country and sectoral level by relying on different methods and data sources. The empirical literature in this field mainly follows three approaches that provide different points of view on the quantification of GVCs and present both strengths and caveats in terms of complexity, accuracy and coverage (Amador and Cabral, 2016).[4] The first one compares international trade statistics of parts and components with trade in final products (see the seminal works of Yeats, 1998; Ng and Yeats, 1999; Athukorala, 2005; and Gaulier et al., 2007, among others). The second approach looks at the customs statistics on processing trade (see the works on the US processing trade by Feenstra et al., 2000; Clark, 2006; and Swenson, 2005; those on EU processing trade by Görg, 2000; Baldone et al., 2001, 2007; Helg and Tajoli, 2005; Egger and Egger, 2005; those on China by Lemoine and Ünal Kesenci, 2004; and Xing, 2012; and recently Kee et al., 2016; Koopman et al., 2012; Jiang, 2021; Luck, 2019). The third method considers classical input-output (I-O) tables, sometimes complemented with import penetration statistics computed from trade data. Using these I-O matrices, Feenstra and Hanson (1996) developed the first measure of foreign content of domestic production (computed as the share of imported inputs in production or total inputs, often used as a measure of outsourcing). This measure has been adopted in many subsequent works, such as Campa and Goldberg (1997), Hijzen (2005), Egger *et al.* (2001), Egger and Egger (2003), and Feenstra and Jensen (2012). Exploiting the same data, Hummels *et al.,* 2001 formulated the second measure of fragmentation, which focuses on the direct and indirect import content of exports, labelled "vertical specialization" that has been applied or updated in other studies (see among others Chen *et al.,* 2005; Zhang and Sun, 2007; Chen and Chang, 2006; Amador and Cabral, 2009). However, traditional I-O tables by themselves are no longer able to capture the complexity of the fragmentation and the mechanism ruling trade in intermediate inputs. With the target of tracing value-added trade flows across countries, a strand of work - which has recently become very popular - has therefore combined information from custom offices with national input-output tables to construct global I-O tables (see the works of Hummels et al., 2001; Johnson and Noguera, 2012; Miroudot and Ragousssis, 2009; Koopman et al., 2010, 2014; Foster Mc Gregor and Stehrer, 2013). Since the tables contain information on supply–use relations between industries and across countries, we can identify the vertical structure of international production sharing and measure cross-border value flows for a country or region.

Since the flows of goods and services within the global production chains are not always reflected in conventional international trade measures, many initiatives and efforts have recently been addressed to measure international fragmentation using trade in value added. The Appendix shows the main available databases.

3.1 Decomposition methodologies and trade in value added components

In parallel, new methodologies have also been developed to exploit data from multi-region input-output (MRIO) tables. These methodologies decompose gross trade flows in different value-added components and allow new GVC indicators to be computed.

One of the most widely used decomposition methodologies is that proposed by Koopman, Wang and Wei (KWW) (2014), who fully decompose gross exports into various sources of value added and connect official gross statistics to value-added measures of trade. Specifically, KWW (2014) break gross exports down into nine different components of domestic value added (domestic value embedded in a country's exports) and foreign value added (foreign value embedded in a country's exports) plus double-counted items (that arise when intermediate goods cross borders multiple times). The result is a complete picture of the value-added generation process in which various preceding formulas for measuring value-added trade are systematically integrated into a single accounting framework.[5] This method encompasses most

[4] For details of the three types of data, see the survey by Amador and Cabral (2016).

[5] For technical details, see Koopman, Wang and Wei (2010 and 2014).

of the methodologies previously proposed in the literature (e.g. Hummels et al., 2001; Daudin et al., 2011; and Johnson and Noguera, 2012).

A second methodology is that developed by Borin and Mancini (BM) (2015, 2019). They extend the KWW (2014) methodology providing exhaustive and rigorous value-added decompositions of exports at the aggregate, bilateral and sectoral levels which are consistent with the KWW framework and overcome shortcomings that affect the KWW decomposition and other previous attempts to obtain a bilateral counterpart (such as Wang et al, 2013).[6]

Using the Koopman et al. (2014) methodology extended by BM (2015, 2019), two key value added components of gross exports are traditionally selected to provide measures of country and sectoral GVC participation:

- The *indirect domestic value added* (DVX), that is, the share of domestic value added in intermediate goods further re-exported by the partner country. It measures the joint participation of the trade partners in a GVC since it contains the exporter's value added of a specific sector that passes through the direct importer for a (or some) stage(s) of production before it reaches third countries. More specifically, it captures the contribution of the domestic country to the exports of other countries;
- The *foreign value added* (FVA) used in the production of a country's exports, that is, the share of value added provided by intermediate inputs imported from abroad and then exported in the form of final or intermediate goods. It measures the contribution of the foreign country to the country's exports.

3.2 GVC participation and positioning indicators[7]

An important question raised in the GVC empirical literature is to what extent single countries and sectors are involved in international production networks.

The Hummels et al. (2001) measure of "vertical specialization" (the VS measure), mentioned above, is probably one of the first and most popular measures of participation of a country in the phases of international production chains. However, this is a partial measure of participation in global value chains since it only considers the backward linkages (i.e. it measures the import content of a country's exports). Therefore, they also suggest considering the exports of intermediate products later processed and re-exported as the VS1 measure.

Following the seminal article of Hummels et al. (2001), various measures of a country's integration in international production networks have been proposed. Using some of the trade in value added components of their decomposition, KWW (2010) propose one of the most widely used indicators of GVC participation in the field literature. They calculate GVC participation by using the trade in value added components mentioned above: the foreign value added (FVA) component and the indirect domestic value added (DVX) component. More specifically, FVA is referred to as a measure of "backward participation", given that it measures imported intermediate inputs that are used to generate output for export. DVX captures the contribution of the domestic sector to the exports of other countries and indicates the extent of involvement in GVC for relatively upstream industries. Therefore, it can be considered as a measure of "forward GVC participation".

By expressing both measures as a percentage of exports, the formula for GVC participation is as follows:

$$GVC\ Participation = \frac{FVA + DVX}{Gross\ Exports}$$

The larger the ratio, the greater the intensity of involvement of a particular country (or sector) in GVCs.

Other studies have measured a country's forward GVC participation by identifying the export components that are later re-exported by the direct importer (see, among others, Rahman and Zhao, 2013; and Ahmed et al., 2017). However, these contributions rely on the KWW decomposition of gross exports. As discussed, this methodology does not properly allocate countries' exports between the share that is directly absorbed by importers and the one that is re-exported abroad. The resulting measures of GVC participation are thus imprecise.

Borin and Mancini (2019) calculated their measure of overall GVC participation. This is given by the sum of a 'backward' component, corresponding to the VS Index, and a 'forward' component, the VS1 indicator suggested by Hummels et al. (2001):

$$GVC\ overall\ Participation = GVCbackward + GVCforward = VS + VS1$$

[6] In particular, Borin and Mancini (2015, 2019) provide proper definitions for some components that are incorrectly specified by KWW: i) the domestic value added that is directly (and indirectly) absorbed by the final demand of the importing country; ii) the foreign value added in exports; iii) the double counted items produced abroad. They also overcome the main problems that make imprecise and at least partially incorrect the value added decompositions of bilateral exports previously proposed in the literature.

[7] This paragraph is largely based on Nenci (2020).

In this work, we refer to this indicator to measure and map GVCs in the agriculture and food sectors.

Recently, a strand of the international trade literature has developed measures of the positioning of countries and industries in GVCs (see Fally, 2012; Antràs et al., 2012; Antràs and Chor, 2013; Fally and Hillberry, 2015; Alfaro et al., 2019; Miller and Temurshoev, 2017; Wang et al., 2017). Using the global Input-Output tables, with information on the various entries, it is now possible to compute the upstreamness or downstreamness of specific industries and countries. To do this, a common approach is to consider the extent to which a country-industry pair sells its output for final use to consumers worldwide or sells intermediate inputs to other producing sectors in the world. A sector that sells disproportionately to final consumers would appear to be downstream in value chains, whereas a sector that sells little to final consumers is more likely to be upstream in value chains.

Following this approach, Antràs and Chor (2018) present the two GVC positioning measures most popular in the literature. The first indicator is a measure of distance or upstreamness of a production sector from final demand which was developed by Fally (2012), Antràs et al. (2012) and Antràs and Chor (2013).[8] Fally's model, as well as the variation proposed by Antràs et al. (2012), capture the average number of production stages by pegging the endpoint of the sequence at final consumption, which enables us to measure the *distance to final demand* of a product along the production chains. More specifically, this measure aggregates information on the extent to which "an industry in a given country produces goods that are sold directly to final consumers or that are sold to other sectors that themselves sell disproportionately to final consumers. A relatively upstream sector is thus one that sells a small share of its output to final consumers and sells disproportionately to other sectors that themselves sell relatively little to final consumers" (Antràs and Chor, 2018). The second measure, originally proposed by Fally (2012), is based on a country-industry pair's use of intermediate inputs and primary factors of production. It captures the distance or downstreamness of a given sector from the economy's primary factors of production (or sources of value-added). According to this measure, an industry in each country is downstream if its production process embodies a larger amount of intermediate inputs relative to its use of primary factors of production. Conversely, if an industry relies disproportionately on value-added from primary factors of production, then this industry is relatively upstream.

In this work, we adopt the first measure – the upstreamness indicator (Fally, 2012; Antràs et al., 2012; and Antràs and Chor, 2013) – computed by Nenci (2020) at the country-industry level for the "Agriculture" and "Food & Beverages" sectors to present some stylized facts for the countries in the Eora dataset for the period 1995-2015.

4. MAPPING GVC PARTICIPATION AND POSITIONING IN AGRICULTURE AND FOOD: SOME STYLIZED FACTS

Focusing on the global I-O tables and trade in value added data, this section aims to show some recent facts and trends on GVCs using the GVC participation indicator and the upstreamness positioning indicator for the "Agriculture" and "Food and Beverages" sectors. To do this, we refer to the indicators computed by Nenci (2020) from Eora data at the country-industry level relying on Borin and Mancini (2019)'s extension of the Koopman *et al.* (2014) methodology. These indicators are available for 190 countries in the period 1990-2015.[9]

4.1 Mapping GVC participation

Using Nenci (2020)'s data, Dellink et al. (2020) show how GVC participation between 1995 and 2008 is globally around 30-35 percent for both agriculture and food and beverages (Figure 2), although with significant variations across countries (highlighted by the shaded areas in the figure). However, further integration essentially stalled in the subsequent period. This trend is similar for both sectors. This may be because common factors driving GVC participation dominate sectoral and structural change effects. Hence, although agricultural commodities are perhaps less complex than manufacturing products, fragmentation of the associated value chains has also occurred in the agricultural sectors. This has important implications for developing and less developed countries: although they cannot compete internationally in the manufacturing sectors of final goods, they can still participate in GVCs and increase exports.

The effects of the 2008 crisis are evident in both sectors. These effects were also widespread across regions:

[8] Although the arguments used to develop the index differ in Fally (2012) and Antràs and Chor (2013), Antràs et al. (2012) emphasize that the resulting indexes are equivalent.

[9] Due to some inconsistencies in the EORA data, the Republic of the Sudan and the Republic of Zimbabwe are not included in the empirical analysis. These inconsistences are attributable to missing, incomplete, and conflicting raw data that can lead to distorted (i.e., not consistent and unbalanced) IO tables for a country in a given year.

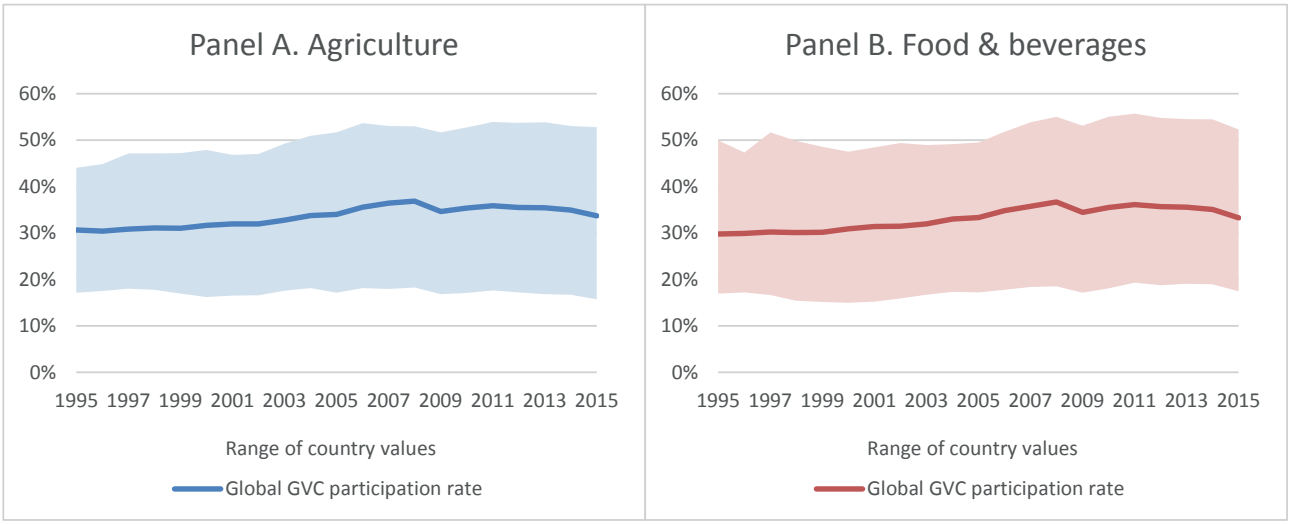

Figure 2. Evolution of global GVC participation rates in Agriculture and Food sectors. Notes: the shaded areas show the range of country values. Source: Dellink, Dervisholli and Nenci (2020) based on Nenci (2020)'s data.

until 2008, about 7 percent of the countries in the database observed a decline in GVC participation. These are primarily economies affected by war, droughts and other major disturbances. After 2008, only 8 percent of the economies – a widely varying group of mostly relatively small countries – further continued their integration in the global economy.

The long-term increase in GVC participation comes with the overall rise of gross exports of agricultural and food commodities. Figure 3 shows the composition of gross exports divided into: backward-linked GVC exports, that is the sum of FVA across countries; forward-linked GVC exports, which are exports that will later be re-exported, aggregated across countries; non-GVC exports, which are exports that do not flow through GVCs but are absorbed in the destination country. The sum of the three components (plus some pure double-counting) equals gross exports. While roughly two-thirds of the export value is not part of a GVC, both backward and forward linkages contribute significantly to the export value. Global exports of food and beverages are roughly twice as large as those of agricultural commodities and, in absolute terms, the rapid increase in food exports after 2002 is remarkable (see Figure 3, Panel B). As expected, GVC linkages in agriculture are mostly forward linked, since agricultural products serve as basic ingredients in other production processes. Food and beverages are much more in the middle and at the end of a value chain and include the processing of agricultural inputs. The backward linkages in food and beverages are mainly imports from agricultural commodities. In contrast, the backward linkages of agriculture refer to imports of inputs for agricultural production and are linked to international trade in fertilizers and seeds as well as to the increased servitization of the economy. The forward linkages in food and beverages are mainly exports by the sector itself – agricultural commodities are lightly processed in one country, then re-exported and further processed and distributed. However, other downstream sectors embed value added created in the food and beverage industry, such as, for example, sugar in pharmaceuticals and cosmetics (Dellink et al., 2020).

Finally, it is important to underline that the exports of agriculture and food sectors can also stimulate value added creation in other sectors, just as agriculture and food value added can be part of the exports of another downstream sector. In both the agriculture and food sectors, the biggest share of sectoral FVA is provided by services (42 percent and 38 percent in 2015, respectively, see Figure 4). This means that any boost to GVC participation in the two sectors leads to increased value-added creation in some foreign services sectors. In agriculture, a significant share of foreign inputs is delivered by chemicals and raw materials – this mainly reflects the globalization of the seeds market. In the food and beverages industry, the second largest FVA input share is agricultural commodities (20 percent). The share of manufacturing in FVA is also sizable in both sectors (this includes machinery). Finally, while foreign inputs from the food sector into agriculture are small, intra-sectoral trade in the food and beverages industry is more substantial (Dellink et al., 2020).

Moving on to GVC analysis at the country level, Figure 5 reports the GVC participation indicators for the

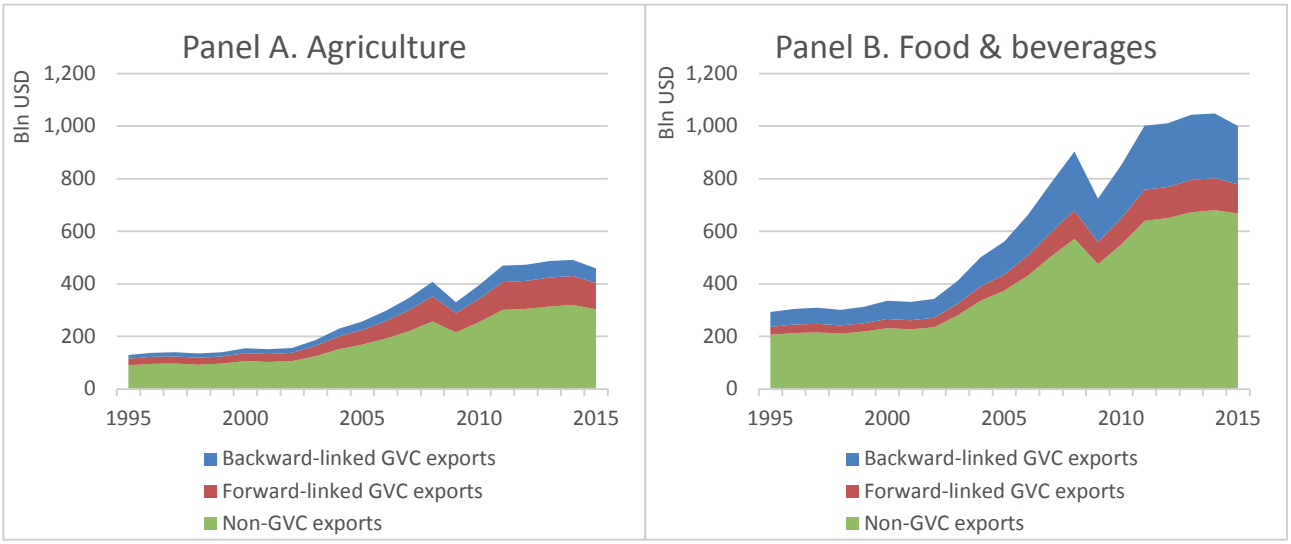

Figure 3. Composition of gross exports in Agriculture and Food sectors. Note: values calculated at the country level and then aggregated. Source: Dellink, Dervisholli and Nenci (2020) based on Nenci (2020)'s data.

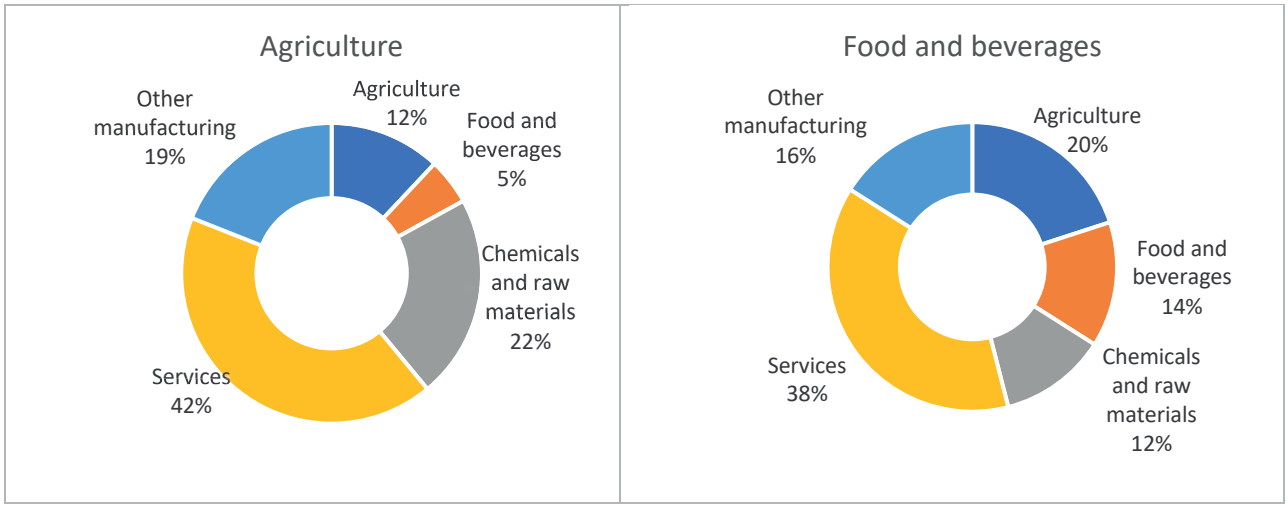

Figure 4. Origin of foreign value added in Agriculture and Food sectors (2015). Source: Authors' elaboration based on Nenci (2020)'s data

agricultural sector for each country in the world in 2015. The European countries present, on average, the highest rate of GVC participation (about 40–45 percent of its total exports, on average, considering both the foreign value added and its domestic value added content embedded in third country exports). Despite low trade shares at the global level, the African region turns out to be deeply involved in agriculture GVC participation too (about 37 percent, on average). This is higher than the average values for America and Asia and is consistent with the relative importance of the African continent in the global agri-food value chains highlighted by the literature in the field. However, we can also detect country heterogeneity in both areas, with Estonia and Latvia showing the highest share of GVC related trade in agriculture in Europe and the Democratic Republic of Congo in Africa. Conversely, the Commonwealth of Independent States (CSI) shows the lowest shares (except for Belarus).

Figure 6 shows a similar picture for the GVC participation indicators for the food and beverages sector. In this case, apart from the usual heterogeneity by country, the African and the European continent share a similar degree of involvement in GVC trade (about 40 percent of their respective total exports).

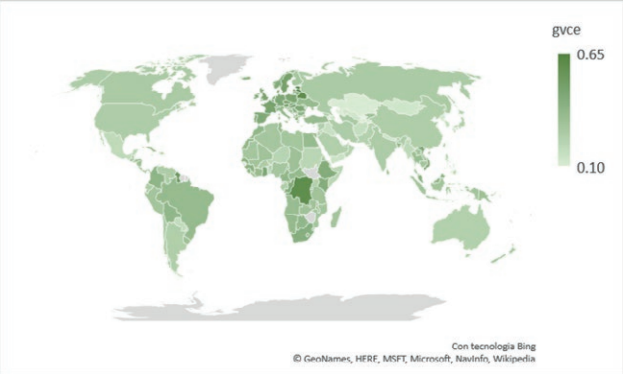

Figure 5. GVC participation for the Agricultural sector by country (2015). Source: Montalbano and Nenci (2022).

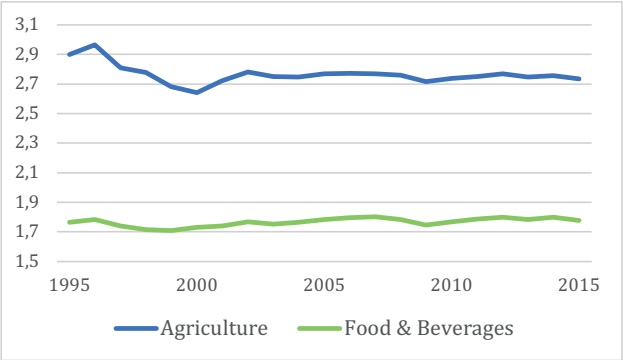

Figure 7. GVC upstreamness at global level. Source: Authors' elaboration based on Nenci (2020)'s data.

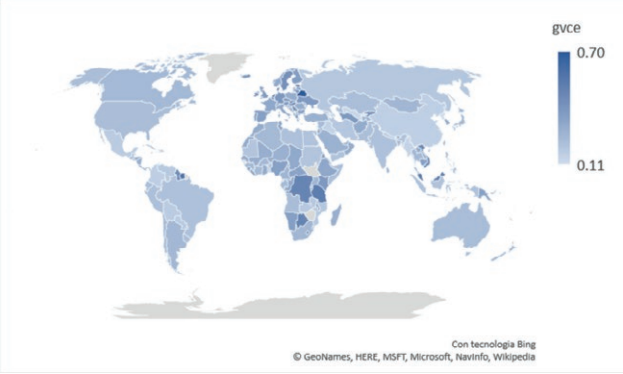

Figure 6. GVC participation for the Food and beverages sector by country (2015). Source: Montalbano and Nenci (2022).

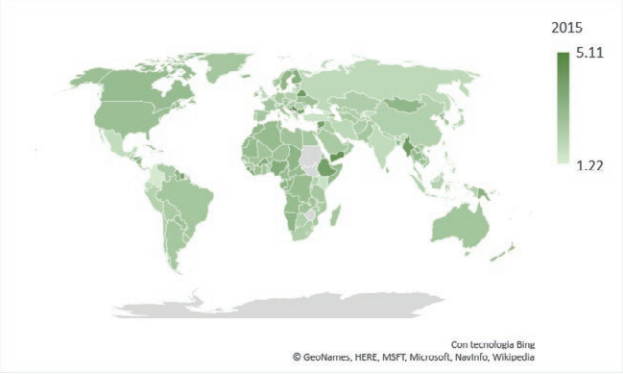

Figure 8. Upstreamness of the agricultural sector by country (2015). Source: Montalbano and Nenci (2022) based on Nenci (2020)'s data.

4.2 Mapping GVC positioning

Another valuable way to analyse and map GVCs is understanding the positioning of countries and/or industries within GVCs. At a descriptive level, these indicators provide information on the specialization of a country in relatively upstream activities or ones that are more proximate to final demand.

Figure 7 shows the evolution of the upstreamness indicator at the sectoral level. Unsurprisingly, agriculture has a higher score on upstreamness (measuring the distance of the sector from final demand in terms of the number of production stages) than the food and beverages sector. While the median for agriculture is positioned more than 2.7 stages upstream of final demand, the one for food and beverages is constantly two stages lower. This positioning indicator closely depends on the length of the chains: between 2000 and 2008, the upstreamness of the two sectors rose modestly but steadily, suggesting an increase in fragmentation in production.

Moving to an analysis by region-country, Figure 8 shows the degree of countries' upstreamness for the agriculture sector in 2015. In this case, Africa, America and Europe share the same average degree of upstreamness (about 3 stages of production from the final consumers), which is above the average world level of 2.25. At the country level, the most upstream countries in Europe are Serbia and Bosnia-Herzegovina (their agriculture production is, on average, concentrated on activities that are up to 5 stages away from the final consumers), whereas in Africa a pick of about 4 stages of production is registered for the agricultural sector in Ethiopia.

Figure 9 shows the degree of countries' upstreamness for the food and beverage sector. As expected, the average degree of upstreamness for Africa and Europe is lower than in the agricultural sector (less than 2 stages of production from final consumers). At the country level, the food and beverage sector also shows a lower degree of heterogeneity. The most upstream country

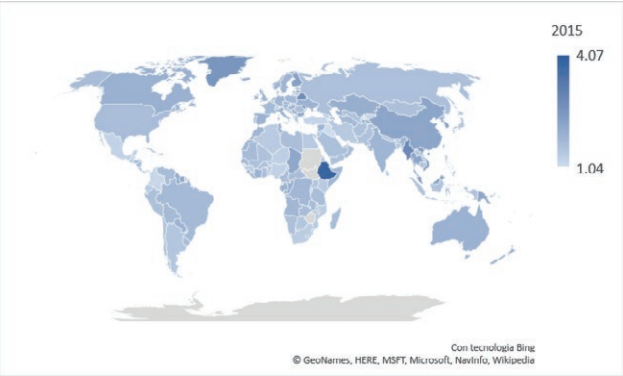

Figure 9. Upstreamness of the Food and Beverages sector by country (2015). Source: Montalbano and Nenci (2022) based on Nenci (2020)'s data.

in Europe is Moldova together with the small European States (about 4 stages away from final consumers), whereas in Africa again, about 4 stages of production away from final consumers are registered in Ethiopia.

5. IMPACTS OF GVCs ON AGRICULTURE AND FOOD PERFORMANCE: EMPIRICAL EVIDENCE

The empirical analyses on the impacts of agricultural and food GVCs have traditionally relied on case studies (Salvatici and Nenci, 2017). Thanks to the availability of MRIO tables and the possibility to compute a new set of GVC indicators based on trade in value added data, scholars have recently acquired the possibility to benefit from true global analyses. These global analyses look at different kinds of effects. A preliminary distinction is between *economic upgrading*, usually defined in terms of efficiency of the production process or characteristics of the product or activities performed (Humphrey and Schmitz, 2002), and *social upgrading* often referred to improvements in the rights and entitlements of workers as social actors, as anchored in the ILO decent work framework, and/or enhancement of outcomes related to employment and pay, gender and the environment (Milberg and Winkler, 2010; Barrientos et al., 2011; Gereffi and Lee, 2016).

As for *economic upgrading*, some studies have analysed the role of intermediate goods in generating a positive impact on the total factor productivity of industries (see, *inter alia*, Bas and Strauss-Kahn, 2014; Halpern *et al*., 2015; Olper *et al*., 2017). Empirical results from Southeast Asia suggest that foreign sourcing in the production of exports is a complement to, rather than a substitute for, the creation of domestic value added in exports (Lopez-Gonzalez, 2016). Other studies confirming the positive relationship between the use of foreign imported inputs and an increase in firm productivity growth in developing countries are: Amiti and Konings (2007) for Indonesia; Kasahara and Rodrigue (2008) for Chilean manufacturing plants; Halpern *et al*. (2011) for Hungary; Topalova and Khandelwal (2011) for India; Montalbano *et al*. (2018a) for Latin America and the Caribbean. Constantinescu et al. (2019) and World Bank (2020) also underline the significance of backward linkages for growth and labour productivity. By focusing on the GVCs' participation in agricultural and food and beverages sectors at the global level for a relatively long time span (1995–2015), Montalbano and Nenci (2022) confirm that, on average and ceteris paribus, there is a positive relationship between changes in agriculture value added per worker and changes in both agriculture and food GVC participation, both backward and forward. These outcomes complement similar established empirical evidence on manufacturing and confirm the positive effect of GVC participation on domestic value added with reference to both backward and forward linkages.

Some scholars have interpreted the notion of economic upgrading as a need for targeting specific production stages and "moving up along the value chain" (Kowalski et al., 2015). This debate has been largely influenced by the "Smiley curve" thesis[10] and has been interpreted as implying that in order to increase the domestic value added share, it may be beneficial to move away from the assembly or manufacturing parts of the chain to be involved in "more sophisticated" downstream stages. This interpretation looks in principle inconsistent with the principle of comparative advantage. This latter argues that the most profitable segments of the value chain should be jointly determined by the characteristics of the production process as well as the relative skills and resource endowments of firms and countries in question. Unfortunately, the empirical analyses on the economic effects of GVC positioning are still rare. Montalbano and Nenci (2022), using global indicators of *upstreamness* for agriculture and food sectors for the usual long time span (1995–2015), highlight a robust negative association cross-country between agriculture value added and the relative distance from final consumers. Although this could be seen as possible confirmation of the fact that moving up the agriculture and food value chains could be seen as a good strategy for participating countries, the authors warn that GVCs are get-

[10] This argument has been made in business management and refers to a graphical depiction similar to a smile where the two ends of the value chain show higher value added than the middle part of the value chain. For a deeper analysis of the "smiley curve", see Elms and Low (2013).

ting longer over time and additional investigations are needed in this field.

As for *social upgrading*, the existing literature on GVCs often implicitly assumes that economic upgrading will automatically translate into social upgrading through better wages and working conditions (Gereffi and Lee, 2016; Knorringa and Pegler 2006; de Oliveira 2008). However, pressures to reduce costs might indeed lead employers to combine economic upgrading with social downgrading (for example, by outsourcing employment to an exploitative labour contractor or delocalizing in countries with lower labour standards, (Barrientos et al., 2011). Preliminary empirical evidence confirms that firm performance is associated with improvements in working conditions (World Bank, 2015). Unfortunately, this strand of the literature, although addressing a key issue in the GVC debate, is still largely based on case studies and anecdotal evidence.

6. CRITICAL ISSUES ON GVCs

There are some critical aspects that are currently affecting the GVCs – global but also agri-food ones - which may affect and shape the future of GVCs. They include: the rise of protectionism, technological development, environmental issues, trends in emerging economies, and recently the Covid-19 pandemic (Antras, 2020; OECD, 2017; Fortunato, 2020). Among the issues identified by scholars, we want to focus on the following: the bidirectional nexus between GVCs and trade policy, the advent of new technologies that have become widespread in recent years and the impact of COVID-19.

6.1 Trade policies and GVCs

A critical and important issue in the analysis of GVCs is that of the relationship with trade policies. Recent developments in international trade literature have attempted to shed light on the interrelation between trade policies and trade patterns within regional and GVCs. GVC-trade policy nexus is bidirectional: the reduction in trade barriers has been identified as one of the determinants of the spread and diffusion of GVCs (Antràs, 2020a) and, conversely, the global fragmentation of production influences trade policy (Goldberg and Pavcnik, 2016; Blanchard et al., 2016).

6.1.1 Impact of trade policy on GVCs

The literature highlighted two main potential effects of trade policy on GVCs: a) a "magnification effects", whereby goods that cross national borders multiple times incur multiple tariff costs. As such, tariffs are applied to gross imports, even though the value added content may be only a fraction of this amount. Different ways of international involvement, notably upstream or downstream participation, shape the extent to which countries are affected by this cost magnification (Yi 2003, 2009; Muradov 2017); b) a "chain effect", which influences all the stages of a GVC and, consequently, a country's backward and forward participation. In terms of forward participation, a depressing impact is expected on the domestic value added content of a country embodied in partner countries' exports. This is because, by reducing the gains for foreign producers of final goods, tariffs also hurt their upstream suppliers. In terms of backward participation, when import-competing sectors use foreign inputs, tariffs allow to pass some protectionist rents from the domestic producers on to upstream foreign input suppliers. This could represent an incentive for foreign suppliers to move to those countries/sectors to get the benefits of the protection (Blanchard et al., 2016; Balié et al., 2019). This may have important policy implications since trade policies no longer exclusively depend on the location of the imported goods but on the nationality of the value added content embodied in traded goods. Consequently, there may be a need to reformulate trade policy priorities, especially in the more downstream food sector (Montalbano and Nenci, 2020a).

Differently from the standard narrative, which focuses mainly on gross exports' performance, trade policy should thus consider that access to imports is an essential component of value-added exports. This implies broadening the scope of tariff and non-tariff trade policies, including softening barriers to imports to facilitate access to world-class inputs (Montalbano et al., 2018b). Moreover, integration into GVCs should be promoted, especially upstream integration that implies producing quality inputs for other countries' productions and exports. OECD (2016) finds that the greatest effects were found to be on trade in intermediates for low and middle-income countries and suggests that protectionist policies, particularly in the form of tariff escalation, are likely to hamper the development of GVCs. Greenville et al. (2017) outline that the levels of tariffs charged and faced, along with sanitary and phytosanitary (SPS) and other technical barriers to trade (TBT) were correlated with lower GVC participation and suggest that higher levels of barriers to the flow of agricultural and food products across borders are associated with lower levels of agricultural and food GVC participation as the cost of being part of GVCs for individual countries increases and thereby decrease their competitiveness.

To quantify the effects of trade policies on countries' economic activity, prices and welfare, computable general equilibrium (CGE) models have been adopted. Some of these models allow for supply chain cross-border linkages, including the GTAP-SC ("Supply-Chains") model (Walmsley et al., 2014) and the IESC model (Minor and Walmsley, 2017) which use a nested Armington demand structure to distinguish between imports for different usages from different source regions. Antimiani et al. (2018b) develop the GTAP-VA ("Value Added") model to account for trade in value added flows when assessing trade policy shocks. In the same vein, the OECD-METRO model includes GVC indicators similar to the approach used in the OECD-WTO TiVA database (OECD, 2018).

A key empirical issue in this literature is that applied tariffs alone are not useful metrics to assess trade protection when intermediate trade is pervasive. Diakantoni et al. (2017) argue that after falling into relative obscurity, at least from a normative perspective, effective protection rates (EPRs) may be back to the central stage as international trade moves from "trade in (final) goods" to "trade in tasks". From a national account perspective, what is internationally traded is the value added (the primary inputs) and the adequate measure of trade distortion is no more the nominal tariff structure on the output, but the effective rate of "protection" on value added. Feenstra (2017) extends the concept of effective protection to reflect the impact of import tariffs on the foreign value added in an industry's exports. More recently, Antimiani et al. (2018a) define in a general equilibrium framework different benchmarks with which to measure restrictiveness, according to where the value added originates: the resulting Value Added Trade Restrictiveness Indexes (VATRIs) are equivalent to the actual protection policies in terms of the impact on domestic or foreign value added embedded in imports. Similarly, Fusacchia et al. (2021) define an index capturing the effects that the tariff structure has on exporting firms that rely on imported intermediate inputs. Rouzet and Miroudot (2013) compute the 'cumulative tariff' (i.e. the accumulated burden of upstream tariffs for a given importer), which quantifies the total cost-push effect of direct and indirect tariffs, taking into account the upstream GVC structure. Muradov (2017) extends the concept to account for indirect bilateral trade flows and proposes two alternative measures to account for related costs, the cumulative tariff at origin and destination.

6.1.2 Effects of GVCs on trade policy

As far as the political economy is concerned, there is growing evidence that GVCs affect trade policy. Antràs and Staiger (2012) make a theoretical contribution by examining trade agreements in the presence of offshoring. Their findings support the view that terms-of-trade motives for cooperation are no longer sufficient when off-shoring is relevant and suggest the need for deep integration, with more individualized agreements that can better reflect member-specific needs (Ruta, 2017). A key issue in this respect is the provision of "rules of origin". These imply that trade agreements can have systemic consequences for the allocation of production across countries. Despite the rules of origin, when the share of intermediate goods increases between a non-member country and a member country, the trade diversion of exports from the non-member country to the member country is largely mitigated. Conversely, the disruption created by trade wars and dismantled agreements may be transmitted to other trading partners and may not be easily avoided by reorganizing buyer–seller relationships (Salvatici, 2020).

Blanchard et al. (2016) develop a value-added approach to modelling tariff setting with GVCs, in which optimal policy depends on the nationality of value-added content embedded in home and foreign final goods. There are two mechanisms in play: the importing country's incentive to manipulate the terms of trade is reduced if foreign producers use inputs from the home country in production, and when domestic producers use foreign inputs in production, some of the protectionist rents from higher tariffs accrue to foreign input suppliers. They find strong empirical support for the predictions of the theory stating that discretionary tariffs decrease in the domestic content of foreign-produced final goods and the foreign content of domestically-produced final goods. Following the predictions of this model and emphasizing political economy considerations, Ludema et al. (2019) and Bown et al. (2020) find similar empirical results using firm-level GVC interlinks and anti-dumping duty and confirm that GVCs matter for trade policy determination.

Lastly, Raimondi et al. (2021) extend the focus on the agricultural and food sectors by assessing how GVC participation affects trade policy. Besides tariffs, they include the bilateral index of non-tariff measures (NTMs) for both SPS requirements and TBT measures which have the greatest impact on trade for most agri-food sectors. They find that a rise in domestic value added (but not the foreign value added) reduces both tariffs and NTM regulatory distance. In their sample of 150

countries for the period 1995-2015, a movement from low to high domestic value added induces a reduction in tariffs/NTMs of about 30%.

International trade of agro-food products is influenced not only by tariff and non-tariff measures, but also by the role played by domestic agricultural policies in determining the competitiveness of the sector. Distortive agricultural policies that promote subsidies for the use of inputs or subsidies outputs addressing directly the producers or the sector as a whole have been found to have a negative effect on GVC participation and on domestic value added creation (Greenville et al., 2017). Along with protectionist policies, agro-food trade faces other economic barriers such as standards and intellectual property rights. Where governments lack the capacity to enforce regulations, MNCs may privately enforce standards necessary both to avoid the risk from media exposure of poor working conditions and to ensure the health and safety of the products all along the GVC. To date, little empirical evidence exists on the relationship between private standards and a country's participation in GVCs. Though some studies have found that compliance with private standards can have positive effects on firms' trade growth and employment (Colen et al., 2012; Otsuki, 2011; Volpe-Martinicus et al., 2010), more recent evidence is mixed (Beghin et al., 2015). In particular, the critique on private standards has concentrated on its developmental implications, arguing that standards are not poor inclusive. Some empirical studies have suggested that the inclusion of smallholders in high-standard trade is only possible with external support from development programmes, public-private partnerships or collective action.

6.2 New technologies and GVCs

The increasing adoption of industrial automation, data exchange, advanced robotics and smart factories (the so called "new technologies") can change the production processes considerably and reshape world production, thus also affecting international trade (Hallward, 2017). These new technologies are also promising in boosting productivity, reducing costs and supporting the speed of catch-up (Dollar, 2019). However, since typically demand for automation arises for labour cost saving reasons and it covers all those tasks that are repetitive and codified, emerging innovations can prove to be quite disruptive and lead to a reduction in the demand for workers (Rodrick, 2018; Acemoglu and Restrepo, 2020, Acemoglu et al., 2020). Consequently, the impact of these technologies on GVCs is twofold. On the one hand, automation represents an alternative to offshoring for those firms in developed countries looking to reduce their labour costs, thus raising the so-called process of "de-globalization" (Antràs, 2020b). However, the degree of substitution between automation and workers is low, especially in the more advanced firms deeply integrated into GVCs. This is because of the demanding precision and quality standards associated with these technologies, which generate a disadvantage, especially for unskilled workers (Rodrik, 2018). On the other hand, new technologies can foster productivity and increase the demand for intermediate inputs. Artuc et al. (2018) show that automation in industrial countries boosted imports from developing countries and a growing literature seems to confirm this trend (see Stapleton and Webb, 2020; and Wang, 2020).

Digital technologies are also useful in enhancing GVC participation by reducing barriers at the entrance. Digital platforms allow the matching of buyers and sellers, fostering verification and monitoring in firm-to-firm relationships and thus lowering the initial fixed costs associated with GVC participation and information frictions (Antràs, 2020a). Furthermore, in these contexts in which language barriers are still prohibitive, the usage of artificial intelligence, big data and machine learning techniques could provide efficient translation services (Brynjolfsson et al., 2019).

Those technological advancements and the associated business and product innovations are also affecting structural and agricultural transformations across the globe (Christiaensen et al., 2021). They hugely reduce transaction costs, change economies of scale and modify the optimal inputs mix in agricultural production, processing and marketing. Since some agricultural tasks are highly automatable, automation could accelerate the exit of workers out of agriculture in developing countries and transform farms and food processing firms in the industrialized world. Robots are beginning to be used in fields and packaging plants, together with tech-savvy agricultural workers, to integrate new technological solutions into specific goods and tasks. Solar-driven water pumps, cold storage and agro-processing equipment are also beginning to spread in developing countries, accelerating the transition away from subsistence production (Banerjee et al., 2017; World Bank, 2020).

Understanding the direction of innovations is particularly important for developing countries and GVCs will play a key role in this process. Extending access to high-speed internet and expanding e-commerce has the potential to greatly facilitate increased GVC participation by relatively small firms and also firms in countries with bad logistical infrastructure (Antràs, 2020a). Since GVCs are a channel through which new technolo-

gies are transmitted between developed and developing countries, participation in GVCs could generate spillover effects in terms of learning (Dollar, 2019). Conversely, the reshoring of routine activities induced by technological progress could threaten unskilled workers in developing countries. Since technological progress seems to be skill-biased, the impact of this could be non-trivial. Chang (2016) estimated that almost 80% of Cambodian, Vietnamese, and, to a lower extent, Indonesian workers could face possible replacement by automation. De Vries et al. (2016) highlighted that the biggest impact is on the higher value added and more skill-intensive activities. They found a lower demand for production workers by about 55 million workers in China, but no significant effects on demand for R&D jobs. Bertulfo et al. (2019), using regional input-output tables and a labour force survey for developing Asian economies, found that technology within GVCs is associated with a decrease in employment levels across all sectors.

Technological changes may have a deep impact even on income differentials. A vast strand of literature points out that participation in GVCs increases the skill premium, thus exacerbating wage inequality, especially in developing countries (Chaudhuri et al., 2010; Li et al., 2016; Shen and Zheng, 2020). Chongvilaivan and Thangavelu (2012) show that a 1% rise in GVC participation leads to a rise in skill premium of approximately 2.5% in Thailand. Similarly, Mehta and Hasan (2012) found that GVC participation in services accounted for 30–66% of the increase in return to skills from 1993 to 2004 in India. Based on empirical evidence at manufacturing firm-level data, Wang et al. (2021) argue that the rise of wage inequality in China mainly arises from moving to more upstream sectors rather than changing GVC participation.

6.3 COVID-19 and GVCs

The COVID-19 pandemic has disrupted global economies, with restrictions in the movement leading to large unemployment and GDP downturns across the world. It has also had a significant impact on international trade with a reduction in trade flows induced by government-mandated lockdowns (Baldwin and Freeman, 2020; WTO, 2020; Hayakawa and Mukunoki, 2021): the volume of world merchandise trade contracted by 5.3% in 2020 (a contraction smaller than initially feared). Trade in nominal US dollar terms fell more sharply, 8%, while commercial services exports declined by 20% (source: WTO).

Although the disruptions from COVID-19 are ongoing, there is a growing body of research on the economic impacts of the pandemic. It is worth noting that these works are still in progress and those available are based on anecdotal evidence, estimates, or simulations based on incomplete and imperfect data. Consequently, their results cannot be considered conclusive and much will be learned from more detailed future studies on the topic. That said, a negative impact is what has emerged from initial evidence.

The hot issue is to assess whether or not this negative economic impact of the pandemic turns to be strictly related to the degree of participation of countries in global production networks (Eppinger, 2020). It is undeniable that the Covid-19 pandemic has affected GVCs through several channels (Baldwin and Tomiura, 2020; Baldwin and Freeman, 2020; Miroudot, 2020; Antràs et al., 2020), and the production has been directly cut because of lockdown measures. On the supply side, the lack or scarcity of foreign suppliers due to disruptions in foreign production and transport networks determined a great bottleneck that has affected - and continues to affect - the entire value chain. On the demand side, demand for most products has fallen sharply because of the economic crisis, whereas shocks in consumer markets have affected all foreign upstream suppliers. On the other hand, global demand for certain medical products has increased substantially, even resulting in temporary shortages and export restrictions (for instance, the pandemic led to shortages of medical equipment and pharmaceutical products in many countries as demand spikes exceeded existing supply and production capacity), whereas other sectors and markets significantly expanded because of the pandemic.

Sforza and Steininger (2020) show that the economic effects of the pandemic are heterogeneous across sectors, regions and countries. Di Nino and Veltri (2020) employ international input-output tables to evaluate the transmission via foreign trade of adverse shocks generated by lockdown and containment measures across the euro area. They highlight not only the presence of a large propagation effect in the euro area but also estimate that foreign demand weakness depressed the aggregate activity of the euro area by about one fifth the size of the foreign shock (a quarter of this effect is due to transmission of lower intermediate and final goods demand within the area). Exploring the vulnerability of developing countries to both demand and the supply shock of the pandemic occurring in major economic hubs, Pahl et al. (2021) find that the most integrated economies tend to suffer more through the GVCs.

With specific regard to GVCs in the agriculture and food sectors, since the COVID-19 outbreak, agri-food supply chain disruptions have been widely observed

across the world (Christiaensen et al., 2021). The pandemic has imposed shocks on all segments of this supply chain, simultaneously affecting farm production, food processing, transport and logistics, and final demand. In this respect, the non-pharmaceutical interventions imposed by local and/or national authorities to flatten the spread curve of the virus weakened the local food system, thus acting as a real threat to food security, especially for the most vulnerable households (Barrett, 2020; Béné, 2020). However, not all sectors and products have been equally affected and different products have experienced disruptions at different stages of the supply chain (OECD, 2020c). Furthermore, if agri-food supply chains in the developed world have demonstrated remarkable robustness and resilience in the face of COVID-19,[11] in the developing world, the impacts on agri-food-supply chains are expected to be felt widely but unevenly. Farm operations may be spared the worst, while small and medium-sized enterprises in urban areas will face significant problems (Reardon et al., 2020). In terms of actions, local governments have actively strengthened food safety nets and social protection mechanisms to maintain access to food. Specific government measures also addressed the impact of income reductions through subsidies, tax breaks and transfers to those affected. These measures have been indispensable but acted basically as coping strategies. The challenge is to stabilise global supply and consumption, heading the global food system towards a sustainable and resilient path. This revamps the important role of risk exposure and international trade in general, and GVCs' participation in particular, as the key tools for fostering resilience among the poor, and reducing their vulnerability to external shocks (Morton, 2020; Montalbano and Nenci, 2022).

To sum up, some key features of GVCs that matter for efficiency also determine the exposure to shocks and the propagation of these shocks along the chain. A high reliance of sales on foreign demand and high dependence on foreign value-added inputs are associated with high-risk exposure, but not necessarily to higher vulnerability since the latter is mainly related to how people actually manage risks (Montalbano, 2011). In this respect, the COVID-19 pandemic has led firms to a partial diversification of sources of supply whose extent will vary by sector depending on the costs of value chain reorganization. Moreover, according to some scholars, the world economy has already entered an era of de-globalization before the pandemic and the observed slowdown is the consequence of the remarkable and unsustainable period of hyperglobalization experienced in the two decades that preceded the 2008-2009 crisis (Antràs, 2020b). The Covid-19 crisis could have only fortified some of the trends noted above. However, its effects are ambiguous.

7. CONCLUSIONS AND THE FUTURE OF GVCs

This work has analysed a wide range of aspects related to the study of GVCs, mainly using a "macro" lens and an empirical focus. We have first reiterated the economic centrality of GVCs, despite the slowdown recorded after the 2009 crisis and the further disruptions induced by the COVID-19 pandemic. We have then reported the different approaches to the GVC analysis and presented indicators for measuring and mapping GVCs at micro and macro levels. Subsequently, we have shown some stylized facts focusing on GVC participation and the position of the agriculture and food sector, underlining a growing involvement on a global level, although with variation across regions and countries. After, we have summarized the main empirical evidence regarding the impact of value chains on the performance of the sectors under interest, highlighting an improvement in productivity and a supported economic growth. Finally, we have introduced and discussed some of the main critical issues affecting current and future GVCs, such as policy space, new technologies and the effect of Covid-19 pandemic.

As illustrated in this work, we should acknowledge that with respect to GVC measurements and mapping, the literature is still scant. A growing empirical literature emerged by taking advantage of the availability of global I-O matrices and aggregate trade data to map and measure GVCs, whereas sectoral, country coverage and firm-level data remain weak. Mainly, the relative lack of good quality microdata is underwhelming. Researchers struggle to envisage satisfactory proxies for both firms' participation and positioning in the GVCs. Moreover, a lot more is currently left out because it is hard to investigate it. Issues in point are, for instance, the channels of technology transmission in the GVCs; the pros and cons of specific, idiosyncratic investments, in the presence of contractual incompleteness and low quality of institutions; the understanding of the different layers of GVCs and the availability of suppliers according to the tier they operate in.[12] All that remains is to provide

[11] See The Economist, "The World's Food System Has So Far Weathered The Challenge of COVID-19 – But things could still go awry", 9 May 2020.

[12] Antràs (2021:16) advocates "a novel, [..] conceptualization of GVCs in which the focus is shifted away from the mere allocation of value added across countries resulting from anonymous, spot exchanges of goods and services. Instead, a new paradigm emerges in which the identity of the specific agents participating in a GVC is crucial".

more and more data to allow both a more robust understanding of the GVC phenomenon and, consequently, the design of effective policy measures.

The recent slowdown and retrenchment in the global fragmentation of production have induced a growing body of authors to suggest that this trend is the prelude to a new era – the so-called "deglobalization"- whose speed of development may even be powered by the COVID-19 pandemic. Following this track, some trends could arise: first, *reshoring,* resulting in a shorter and less dispersed value chain characterized by a higher geographical concentration of value added (Javorcik, 2020); second, diversification, with a broader distribution of tasks along the GVC, especially for intensive manufacturing industries (Antràs, 2020); third, regionalization, as a consequence of the reduced length of the chains, dominated by three large regions: North America, Europe and a China-centric Asia (Baldwin and Freeman, 2020; Enderwick and Buckley, 2020; Wang and Sun, 2021). Several preliminary analyses seem to deny that *reshoring* and nationalization of production can improve resilience: it would result in lower exposure to foreign shocks, but this comes at the cost of higher exposure to domestic shocks, i.e., value chains are still dependent on single suppliers, which does not protect against disruption in production (Antràs, 2020; Bonadio et al., 2020; OECD, 2020b; Arriola et al., 2020; Espitia et al., 2021). Furthermore, such different kinds of risk exposure are not symmetric, being the foreign markets characterized, on average, by many players and a higher degree of competition. The demand for diversification, on the other hand, seems to find greater consensus: a larger network of diversified suppliers in multiple countries is the better response to avoiding the bottleneck (see Antràs, 2020; Bacchetta et al., 2021; Caselli et al., 2020; Miroudot, 2020). Lastly, the process of regionalization of the GVCs was indeed already in place with hubs in China, the US and Germany (Baldwin and Lopez-Gonzalez, 2015).

Although the undeniable slowdown of recent years and several trends that will limit the expansion of GVCs in the near future, the complexity and high restructuring costs related to GVCs will probably prevent the large-scale dissolution of the existing GVCs (Bonadio et al., 2020; Simola, 2021). The key question then becomes how to consolidate GVCs in the future. In this context, policies can play a critical role. Brancati, Pietrobelli et al. (2021) collect from the field literature four types of policies to build more robust and resilient value chains: i) participation policies aimed at entering in and enhancing the local economy's participation in GVCs. These are market-enabling policies that assist the private sector in restructuring productive activities according to a country's latent comparative advantage and connectedness policies that reduce the costs related to linking domestic firms to foreign value chain partners (e.g. policies that reduce trade costs or information costs); ii) value capture policies intended for strengthening the local economy's value creation and capture within GVCs. Part of the GVC literature suggests supporting product and process upgrading, which implies moving vertically along the value chain to better products or processes as well as the more challenging functional and interchain upgrading, entailing horizontal movement towards new functions or new markets (Gereffi et al., 2005; Humphrey and Schmitz, 2002; Gereffi, 2019). Examples of these policies are: strengthening of local innovation and production ecosystems; building and improving specific types (logistical, digital, and productive) of infrastructures; development of specific skills; establishment of linkages between universities, vocational centers and firms involved in GVCs; provision of advisory services in the areas of standards, metrology, testing, and certifications; iii) GVC inclusiveness policies directed to improve the local social and environmental conditions in GVCs. They concern improvement of labor, social, and environmental regulations and their enforcement, at national and supranational levels; responsible sourcing policies; private standard promotion; involvement of local communities in GVC governance; iv) and finally, resiliency policies designed for strengthening the local economy's resiliency, that is how to ensure that a society's ability to deliver essential goods and services is sufficiently resistant to both local and foreign disruptions. Among these kinds of policies, there are: supply chain and food system stress test; social protection, risk mitigating and risk coping policies; diversification policy; public procurement policy; international cooperation at a bilateral or regional level and to limit export restrictions.

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APPENDIX

1A. Firm-level datasets

Examples of firm level datasets include: the CompNet database that collects indicators computed by national data providers using firm-level data, covering variables referred to competitiveness, finance, labour, productivity and trade. It includes firms from 19 European countries and 56 sectors, ranging from 1999 to 2017 (among papers using this dataset, see Inferrera, 2021; Lopez-Garcia and di Mauro, 2015; Altomonte et al., 2020). Similarly, the EFIGE database combines measures of firms' international activities (such as exports, outsourcing, FDI, imports) with quantitative and qualitative information on about 150 items ranging from R&D and innovation, labour organization, financing and organizational activities, and pricing behaviour. Data consists of a representative sample of almost 15,000 surveyed firms (above ten employees) in seven European economies. Data were collected in 2010, covering the years from 2007 to 2009 (see, among others, Barba Navaretti et al., 2011; Accetturo and Giunta, 2011; Cainelli et al., 2018; Meliciani et al., 2019; Giunta et al., 2021).

Additional works focusing on developing countries have used the World Bank Enterprise Survey (WBES). It provides detailed information on the characteristics of firms across several dimensions, including size, owner-

Table 1A. Main datasets for research on GVCs at the firm level.

Firm-level data (used for GVC analyses)						
EFIGE	Bruegel with the support of the European Commission	Survey	2007-2009	15,000 firms	Manufacturing	Barba Navaretti et al., (2011); Accetturo and Giunta, (2011); Cainelli et al., (2018); Meliciani et al. (2019)
CompNet	European Central Bank	Account statistics, Business registry, Surveys, and Balance sheets	1999-2017	19	56	Inferrera, (2021); Lopez-Garcia and di Mauro, (2015); Altomonte et al.(2020)
Dun & Brandstreet's WorldBase	Dun & Bradstreet			190		Alfaro et al., (2019)
Orbis	Bureau van Dijk	Balance sheets		400 million firms		Bloom et al. (2012a), (2012b); Del Prete et al., (2017)
World Bank Enterprise Survey	World Bank	Survey		174,000 firms		Seker (2011); Amin et al. (2014)
MET	Monitoraggio Economia e Territorio (MET)	Survey	2008, 2009, 2011, 2013, 2015, 2017, 2019	25,000 firms per year observed	38	Giovannetti et al. (2015) Balduzzi et al. (2020); Antonioli et al. (2021)

Source: Authors' elaboration.

ship, trading status, and performances for over 135,000 firms belonging to the manufacturing and services sectors interviewed in 139 countries since 2005 under a common global methodology (see, among others, Montalbano et al., 2018b). Some works also took advantage of the Orbis database provided by the Bureau Van Dijk. It contains data for more than 100 countries covering more than 400 million private and public companies worldwide (with about 120 in Europe, 100 in North and South America, and 80 in Asia), and collecting data primarily from balance sheets (see, among others, Del Prete and Rungi, 2017). Although the huge set of information, the main disadvantage is that the firms included in Orbis represent only a fraction of the entire firm population and, most importantly, they do not form a representative sample (OECD, 2020a). Among commercial databases, we also find the Dun & Brandstreet's WorldBase that provides comprehensive coverage of public and private companies and has been used in the empirical literature (Alfaro et al., 2019). Finally, for the Italian case, it is worth mentioning the MET survey. It is carried out every two years. It collects information on a representative sample of around 25,000 Italian manufacturing firms. It also encompasses micro-sized companies (with less than 10 employees). Waves cover the years: 2008, 2009, 2011, 2013, 2015, 2017 and 2019 (see, among others, Brancati et al., 2017; Agostino et al., 2020; Giovannetti et al., 2015; Giovannetti and Marvasi, 2016).

2A. Country and sectoral level datasets

One of the most widely used country-sectoral datasets is the World Input-Output Database (WIOD) which has been developed thanks to a consortium of 11 institutions led by researchers at the University of Groningen. It covers 43 countries (including OECD and emerging countries) and 56 industries from 2000-2014 (Release 2016). Moreover, it is based on official national account statistics and refers to end-use classification to allocate flows across partners and countries. As a result, it has been extensively used in the literature (see, among others, Baldwin and Lopez-Gonzales, 2015; Costinot and Rodrìguez-Clare, 2014; Timmer et al., 2013; Wang et al., 2013; Koopman et al., 2014; Johnson, 2014; Los et al., 2015; Adao et al., 2017; Fajgelbaum et al., 2016; Timmer et al., 2014).

The ADB multi-region I-O database (ADB MRIO) has been developed by the Asian Development Bank and used in the literature (see De Vries et al., 2016; De Vries et al., 2019). It is basically an extension of the WIOD and includes five additional Asian economies – Bangladesh, Malaysia, Philippines, Thailand and Vietnam – for the years 2000 and 2007-2019. Importantly, the data provided for these countries are derived from estimations produced by researchers and do not refer to official statistics.

Another important source of data is the OECD-WTO Trade in Value Added (TiVA) database. It embodies the national I-O tables from 2005 to 2018 for 45 industries and 64 countries, 27 of which are non-OECD member economies (most East and South-east Asian economies and a selection of South American countries). It provides useful indicators on value-added exports and other measures of the global supply chain used in the empirical studies (De Backer and Miroudot, 2013; Miroudot et al., 2017; Mukherjee, 2018).

The data source presenting the broadest coverage in terms of countries is the Eora Global Supply Chain Database, constructed by a team of researchers at the University of Sydney (Lenzen et al, 2012; and Lenzen et

Table 2A. Public Datasets for research on GVCs at the country and sectoral level.

Country and sectoral level						
Project	Institution	Data Sources	Years	Countries	Industries	Related Papers
Wordl Input-Output Database (WIOD)	EU-based consortium	National Supply-Use tables	2000-2014	43	56	Baldwin and Lopez-Gonzales, (2015); Costinot and Rodrìguez-Clare, (2014); Timmer et al., (2013); Wang et al., (2013); Koopman et al., (2014); Johnson, (2014); Los et al., (2015); Adao et al., (2017); Fajgelbaum et al., (2016); Timmer et al., (2014)
Traded In value Added (TiVA) dataset	OECD	National I-O tables	1995-2018	64	45	De Backer and Miroudot, (2013); Miroudot et al. (2017); Muckherjee, D. (2018)
UNCTAD-Eora GVC Database	UNCTAD/Eora	National Supply-Use and I-O tables from Eurostat, OECD, IDE-JETRO	1990-2018	189	26	Lenzen et al., (2012); Lenzen et al., (2013); Del Prete et al., (2018)
ADB Multi-Region Input-Output Database (ADB MRIO)	Asian Development Bank	WIOD exstension	2000, 2007-2019	63	35	De Vries et al., (2016); De Vries et al., (2019)
Global Trade Analysis Project (GTAP)	Purdue University	Individual researchers/institution	2004, 2007, 2011, 2014	141	65	Trefler and Zhu, (2010); Daudin et al., (2011); Johnson and Noguera, (2012); Koopman, Wang and Wei, (2014); Aguiar et al., (2016)
EXIOBASE3	EU-based consortium	National Supply-Use tables	1995-2015	49	163	Stadler et al. (2018); Owen et al. (2016)
South American Input-Output table	ECLAP/IPEA	National I-O tables	2011, 2014	10	40	CEPAL, (2016); Banacloche et al. (2020)

Source: Authors' elaboration.

al, 2013). This database provides a set of both national and global input-output tables, covering 189 countries and 26 sectors for complete time series from 1990 to 2015. Recently, UNCTAD and Eora developed a time-series from 1990 to 2018 of some key GVC indicators, including foreign value added, domestic value added and domestic value added embedded in other countries' exports. Results from 1990 to 2015 are generated from Eora tables, whereas those for 2016-2018 are nowcasted using different data sources. The adopted methodology interpolates the missing points to provide broad, up-to-date coverage.

Along with this, the GTAP is a comprehensive multi-region database developed by the Purdue University which has been increasingly enriched in terms of data thanks to the contributions of individual researchers and organizations. It covers 121 countries plus 20 regions and 65 industries for 2004, 2007, 2011 and 2014. Thanks to its high coverage and relatively sectoral details, it has been intensely exploited by researchers (see, among others, Trefler and Zhu, 2010; Daudin et al., 2011; Johnson and Noguera, 2012; Koopman, Wang and Wei, 2014; Aguiar et al., 2016).

Major regional initiatives - in addition to ADB MRIO – include: the EXIOBASE promoted by the EU-based consortium. This database extracts information from national supply-use and input-output tables extended to environmental indicators. It covers 44 countries plus 5 rest-of-world regions and 163 industries for the period 1995 – 2015; the South-American Input-Output Table from the Economic Commission for Latin America and the Caribbean (ECLAC) covering 10 Latin America countries and 40 sectors for the years 2011 and 2014.