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Participation and positioning of agri-food firms in global value chains: Measures and data

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Abstract

Value chains have become increasingly global over the past decades. Production processes are incrementally fragmented across countries, and more and more firms search for suppliers and customers beyond the domestic market. Still, there is strong heterogeneity in the degree at which individual firms are involved in global value chains (GVCs). Measuring firms' participation and position in GVCs requires both firm-level data on international trade flows and detailed input-output tables. While the former are usually well reflected in countries' customs data, the latter usually aggregate economic activities into a small number of large sectors. This broad definition of sectors/industries narrows down the possibility to differentiate between upstream and downstream activities and products, which is essential for measuring the implication in GVCs of firms from a specific sector or industry. In this paper, we develop a method based on the proportionality hypothesis that permits to properly match the rich U.S. input-output table, where industries/sectors are defined at a very narrow level, with detailed French firm-level trade data. Based on correspondences between industries in U.S. and French data, we rewrite the U.S. input-output table at the level of detail at which industries are defined in the French customs data. We apply the result to the case of the agri-food sector, and characterize the participation and positioning of French agri-food firms in GVCs.

Keywords: global value chains, international trade, input-output tables, agri-food industry

JEL Classification: F10, F14, F23, L23

Participation et positionnement des entreprises agroalimentaires dans les chaînes de valeur mondiales : mesures et données

Résumé

Au cours des dernières décennies les chaînes de valeur sont devenues de plus en plus mondialisées. La production est de plus en plus fragmentée à travers les pays et un nombre croissant de firmes s'approvisionnent et vendent en dehors du marché domestique. Cependant, le degré d'insertion des firmes dans les chaînes de valeur mondiales (CVM) est très hétérogène. Mesurer la participation et la position des entreprises dans les CVM nécessite des données sur les échanges internationaux au niveau firme et des tableaux entrées-sorties détaillés. Alors que les premières sont généralement bien collectés par les douanes, les seconds sont plus problématiques. Généralement les tableaux entrées-sorties regroupent l'activité économique en un petit nombre de grands secteurs, réduisant la possibilité de différencier les secteurs et produits situés plus en amont des ceux situés plus en aval, un point essentiel pour mesurer l'implication dans les CVM des entreprises appartenant à une industrie spécifique. Dans ce papier, nous développons une méthodologie basée sur l'hypothèse de proportionnalité qui permet d'apparier le tableau entrées-sorties américain, où les secteurs sont définis à un niveau très fin, avec les données détaillées sur les échanges des firmes françaises. Nous réécrivons le tableau entrées-sorties américain au niveau des industries dans les données des douanes françaises à l'aide des correspondances entre les industries dans les deux sources. Nous utilisions le tableau résultant pour étudier la participation et le positionnement des entreprises agroalimentaires françaises dans les CVM.

Mots-clés: chaines de valeur mondiales, commerce international, tableau entrées-sorties, industrie agro-alimentaire

Classification JEL: F10, F14, F23, L23

1. Introduction

The emergence of global value chains (GVCs) has transformed international trade over the past decades. Production processes have become highly fragmented across international borders, and an increasing number of firms organize production on a global scale. The development of GVCs is reflected in the higher content of imported inputs in exports and of services in manufacturing, and has encompassed all sectors, including agri-food. The trade literature has analyzed this phenomenon, and developed country- and sector-level measures of GVCs based on countries' input–output tables (Hummels *et al.*, 2001; Antràs *et al.*, 2012; Fally, 2012; Johnson and Noguera, 2012; Antràs and Chor, 2013; Koopman *et al.*, 2014; Miller and Temurshoev, 2017; Alfaro *et al.*, 2019; Borin and Mancini, 2019). However, it should be emphasized that GVCs allow resources to move across sectors, through the stages of production processes carried out by firms. Therefore, the participation and position in GVCs is ultimately a firm-level phenomenon (Antràs, 2020).

It is difficult to construct firm-level measures of GVCs using only usual data sources on international trade flows, such as customs data, and without detailed data on firm output at the product and/or plant level. Most of these measures identify only firms' participation in GVCs relying on customs data or survey-based information provided directly by firms (Baldwin and Yan, 2014; Giovannetti and Marvasi, 2016; Brancati *et al.*, 2017; Giovannetti and Marvasi, 2018; Caslan *et al.*, 2021). More recently, Chor *et al.* (2021) infer the intensity of Chinese firms' participation in GVCs based on the level of upstreamness of the inputs they use and of the outputs they produce. These upstreamness levels are calculated by matching the position of different sectors in value chains, obtained based on data from input-output tables, with the product composition of firms' purchases and sales abroad. Highly disaggregated input-output tables are needed to correctly match the products purchased and sold by firms with individual sectors. This requirement is even more stringent when the analysis focuses on firms from a specific industry rather than the entire economy. Obtaining such input-output tables is challenging as most countries derive inter-sector relationships by breaking down the economy into a relatively small number of broadly defined sectors.

The aim of this paper is to develop an original methodology for constructing a highly disaggregated input-output table. We apply this methodology to the case of France and focus on the involvement in GVCs of French firms from the agri-food industry. To achieve this goal, we develop a three-step strategy. First, we identify the international activities of firms, *i.e.* their imports and/or exports (Antràs, 2020). Second, we determine the position at which a given product enters the production process of a final good (Fally, 2012; Antràs *et al.*, 2012; Antràs and Chor, 2013).[1] Third, we determine the position

[1]For this step, each product is associated to a specific sector. A more narrow definition of sectors

of firms in value chains through the degree of transformation of the goods they use and produce (Chor *et al.*, 2021). In the absence of information on firms' overall output and purchases at the product and/or plant level, we rely on the product composition of firms' imports and exports. The implementation of the latter two steps requires the use of detailed data on international trade flows at the firm × product level. Furthermore, our focus on a specific industry – the agri-food industry – requires the use of a very detailed input-output table.

To measure the degree of transformation of goods, the literature usually relies on the classification of products into intermediate and final, such as the Broad Economic Classification (BEC). However, this approach tends to produce rough results that poorly reflect the degree of transformation of traded goods because the same product can be an input for one industry but an output for another.[2] An alternative solution adopted by more recent works in the literature is to rely on input-output tables that examine the links between all sectors of an economy. This method is particularly attractive when industries are defined at a very narrow level. For France, the data on firms' foreign purchases and sales is highly disaggregated at the product level (thousands of product lines in the 8-digit CN and 6-digit CPF classifications), but not in the input-output table (only 34 and 65 industries in the OECD and GTAP databases, respectively).

Our contribution is twofold. First, we develop an original methodology to exploit the U.S. input-output table, which is characterized by a high level of industry disaggregation (405 industries, of which 42 are agri-food). The challenge is to match the information between the U.S. and French industry codes. We solve this problem by giving equal weight to all matches within each pair of industry codes. This allows us to construct a very detailed input-output table for France (604 industries, of which 83 are agri-food). We use this table to calculate the upstreamness of each industry. Second, we check the consistency of industries' upstreamness computed based on this transformed input-output table and with more aggregate input-output tables (provided by the OECD, INSEE, and GTAP for France, and by GTAP for the U.S.). The strong correlation of measures derived with different input-output tables provides a solid and highly consistent picture of upstreamness across sectors and countries (France and the U.S.). This finding reveals that France and the U.S. have a similar technological frontier. In other words, we can safely affirm that France and the U.S. share very similar production functions and a similar pattern of input use to produce a given good. As a specific example, the production of cheese requires the same use of dairy products, salt, and other inputs both in France and in the U.S.. We combine the obtained industry-level upstreamness indicators with detailed customs

ensures a better match of product- and sector- level data.

[2]Consider the example of tomato sauce, which can be used as a final good by households or as an intermediate good in the production of frozen pizza.

data at the firm × product level, and compute the upstreamness of each firm's imports and exports. The difference between these two measures indicates the intensity of firm's participation in GVCs. This indicator reveals the range of production stages that the firm carries out on the domestic market (in France), either in-house or through subcontracting or other arm's-length contracts with other domestic suppliers or processors.

The use of the U.S. input-output table for data on French firms is also justified by the results of Antràs *et al.* (2012), who find a high degree of stability of their measure of industry upstreamness computed with U.S. and European data. Similarly, in their analysis of vertical integration, Acemoglu *et al.* (2009) and Alfaro *et al.* (2016) assume that the U.S. input-output structure carries over to other countries, *i.e.* it accurately describes the technological possibilities all over the world. Authors combine the U.S. input-output table with firm-level data from a wide panel of countries to build their firm-level vertical integration indices. The robustness of their results on the determinants of vertical integration (across countries and industries) confirms the validity of their assumption, at least for countries with a similar level of development. The present paper adds to this literature by focusing on the relevance of using a detailed input-output table from one country together with detailed firm-level data from another country, and how adapt the former to different definitions/classifications of industries that do not match directly (one-to-one). It also checks the consistency of GVC measures derived using micro and macro data (Giunta *et al.*, 2022), and whether these measures can be used interchangeably. More broadly, our work also relates to the empirical literature on GVCs that seeks to identify the different sources of value added embedded in trade flows (Hummels *et al.*, 2001; Johnson and Noguera, 2012; Koopman *et al.*, 2014; Borin and Mancini, 2019).

The paper is structured as follows. Section 2 describes our data on French agri-food firms and the measure of firms' GVC participation. Section 3 presents the design of a detailed input-output table at the level at which industries/sectors are defined in these data. It permits to construct a more accurate measure of the intensity of firms' participation to GVCs. In section 4, we provide some descriptive statistics and facts on the evolution of GVCs in the French agri-food industry. Our conclusions and perspectives for further analysis are summarized in section 5.

2. Data sources

French firms in the agri-food industry. We use the AMADEUS database to identify French agri-food firms over the period 2004-2017. This dataset records firms' main economic activity (NACE Rev.2 4-digit), and annual financial data (*e.g.*, the number of employees and total sales). We select the agri-food sector which includes 32 NACE activity codes and construct additional time-varying characteristics of firms, such as productivity, computed as total sales per employee. Focusing the analysis on a single industry permits to limit the effects of unobserved factors.

International trade statistics. Our second data source is the French customs. This database contains annual information on the value (in euro) and the quantity (in tones) of bilateral imports and exports of firms by product and source/origin country for the period 2004-2017. This database covers only firms' direct imports and exports, *i.e.* foreign trade transactions performed by firms themselves and ignore those done through intermediaries. Products are defined at a very detailed level: 8-digit of the Combined Nomenclature (CN) and 6-digit of the *Classification des Produits Fran caise* (CPF). This data provides a detailed picture of the product composition of firms' international purchases and sales. The information in the customs database is collected at the border by the French customs services and provides information on the international activities of companies whatever their activity code. Firms in all sectors (manufacturing, intermediation, wholesale, retail, catering, *etc.*) may import and/or export agri-food products.

Each firm is identified in both datasets with a unique identification number (SIREN). Matching the two datasets according to firms' SIREN numbers yields a data panel that permits to characterize international activity of French agri-food firms. We focus on food processing firms, *i.e.* those whose main activity falls within chapters 10 and 11 of the 2-digit NACE Rev.2 nomenclature (manufacture of food products and manufacture of beverages).

A binary measure of firms' GVC participation. We can split the French agri-food firms into four categories according to their involvement in international trade transactions: domestic firms, firms that exclusively export, firms that exclusively import, and firms that both export and import. As noted by Antràs (2020), it can be assumed that only firms that both import and export are truly involved in GVCs. Since firms' imports may be embodied in their exports, a product flows needs to cross at least two borders to qualify as being part of a GVC. It is straightforward that this captures backward GVC participation. The identification of forward GVC participation requires information on whether firms' exports of intermediate inputs are imported by foreign firms before the product reaches final consumers in third markets. Firm-to-firm trade data (firm-level customs data linked between countries) are necessary to identify these flows (Antràs, 2020). We do not possess such data for France.

Therefore, in line with previous works (Baldwin and Yan, 2014; Antràs, 2020), we assume that participation in a GVC is reflected in the data by firms' joint involvement in import and export activities. The construction of this measure requires the aggregation of import and export data at the firm × year level (by summing trade across products and countries of origin or destination). This is the simplest and most basic way of capturing the involvement of firms in GVCs.

Selection of firms into GVCs. Let us compare the import and export decisions of French agri-food firms in our data panel. Our final database includes 5,796 individual firms that imported, exported, or both imported and exported some products in at least one year between 2004 and 2017, with a total of 43,376 observations. Of these observations, 9,125 (21%) relate to exclusively importing firms, 14,874 (34%) to exclusively exporting firms, and 19,377 (45%) to firms jointly importing and exporting.

Table 1 shows the distribution of firms in 2004 and 2017 according to their exporter and importer status. The sample is dominated by firms that are both importers and exporters, that we label henceforth as GVC firms (44% in 2004 and 46% in 2017). In addition, the number of employees per firm in 2004 and 2017 is significantly higher for these firms (136.83 and 835.29 respectively); it was four to fourteen times higher than for exclusively importing or exporting firms. Meanwhile, the difference in productivity between the three groups of firms is less spectacular. These differences are not specific to the case of France or the agri-food industry. A similar picture is generally observed in the international trade literature (see for example Castellani *et al.*, 2010).

Table 1: Descriptive statistics of firms by status in international trade

	# Firms (share of total)		Employees per firm		ln productivity	
	2004	2017	2004	2017	2004	2017
Importing firms [a]	768 (26%)	579 (17%)	34.81	58.25	5.31	6.18
Exporting firms [b]	876 (30%)	1,230 (37%)	15.44	69.18	5.28	5.97
Firms in GVCs [c]	1,268 (44%)	1,528 (46%)	136.83	835.29	5.58	6.00
Total	2,912 (100%)	3,337 (100%)				

Notes: Authors' computations on matched data from AMADEUS and French customs. [a] Exclusively importing firms. [b] Exclusively exporting firms. [c] Firms that both export and import.

3. Measuring the intensity of firms' involvement in GVCs

Measuring how intensively firms participate in GVC is not an easy task (Antràs, 2020). Our focus on a particular industry – the agri-food sector – further complicates this challenge, as it requires detailed data on the position of the narrowly defined industries that compose this sector, *i.e.* a very detailed input-output table. An approach adopted by recent works (Ju and Yu, 2015; Chor *et al.*, 2021) is to calculate a measure of firm's *upstreamness* based on the degree of transformation (processing) of the goods it uses as inputs and those it produces as outputs. We concur with this point of view. The main difficulty we face is the lack of a sufficiently detailed input-output table that would allow us to distinguish between the upstreamness of the input and output products of firms in our panel.

3.1. Input-output table

The most detailed French input-output table is provided by the Global Trade Analysis Project (GTAP) database and covers 65 products and services, of which 26 are related to the agri-food sector. Another table is available from the OECD Structural Analysis database (OECD STAN). It includes 34 industries, with only two reflecting agri-food products. We have therefore chosen to use as a starting point the U.S. input-output table developed by the Bureau of Economic Analysis (BEA), which is available online in open access.[3] More specifically, we use the most recent version of this table, redefined at producer prices for 2012.

The U.S. input-output table has the advantage of providing information on production linkages between industries at a high level of disaggregation. It covers 405 industries (identified by individual 6-digit I-O codes) of which 42 fall in the agri-food sector. It is important to include all industries in the economy because the production of agri-food products involves the use of inputs, raw materials, and intermediate products from other sectors (*e.g.* packaging). However, using the U.S. input-output table for an application to French data poses significant classification and matching challenges. We have developed a methodology to convert the U.S. input-output table to the level of 4-digit NACE Rev.2 industry codes used in French firm-level data, that we resume in Figure 1. Entries a_{gh} in Figure 1a report the value of intermediate goods of industry g used in the production of goods of industry h. Column (F_g) reports the value of products from this industry allocated to aggregate final uses: final consumption, investment, changes in inventories, and net exports.

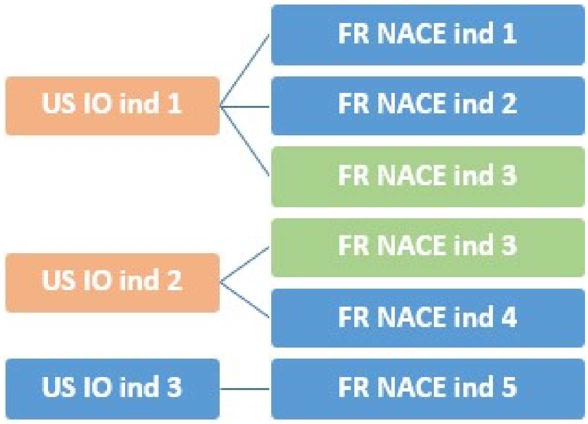
The main challenge in using the U.S. input-output (I-O) table for French data is the presence of multiple correspondences between the industries in the two data (there is not a one-to-one correspondence between the U.S. I-O and the NACE Rev.2 industry codes). Note that the U.S. I-O codes are specific to the 2012 structure of the North American Industry Classification System (NAICS). A U.S. I-O code may correspond to one or more NAICS codes. NAICS codes, in turn, have different levels of aggregation, ranging from 2 digits (the most aggregated level) to 6 digits (the least aggregated level). We have mapped the U.S. I-O codes to the 4-digit NACE Rev.2 codes using the links between the U.S. I-O codes and the NAICS 2012 codes and the correspondence table between NAICS

[3] https://www.bea.gov/industry/input-output-accounts-data

Figure 1: U.S. input-output table and correspondences with NACE Rev.2

		Used inputs and value added			Final use	Total use
		US IO ind 1	US IO ind 2	US IO ind 3		
Supply of inter-medi-ate inputs	US IO ind 1	a_{11}	a_{12}	a_{13}	F_1	Y_1
	US IO ind 2	a_{21}	a_{22}	a_{13}	F_2	Y_2
	US IO ind 3	a_{31}	a_{21}	a_{33}	F_3	Y_3
Value added		VA_1	VA_2	VA_3		
Total output		Y_1	Y_2	Y_3		

(a) U.S. input-output table



(b) Multiple industry correspondences

2012 and NACE Rev.2 provided by Eurostat.[4] However, there are several concerns with this mapping. As shown in Figure 1b, a 6-digit I-O code may correspond to several 4-digit NACE Rev.2 codes. Similarly, a 4-digit NACE Rev.2 code may correspond to several 6-digit U.S. I-O codes. Of the 1,547 combinations of U.S. I-O and NACE Rev.2 codes, only 31 industries (and 2 in the agri-food sector) have a one-to-one correspondence. In these circumstances, we decide to divide each a_{gh} entry in the U.S. input-output table equally between all (r, s) combinations of NACE Rev.2 codes to which the (g, h) entry corresponds (Figure 2a). We then simply take the sum of the (r, s) entries that are identical to obtain the entries b_{rs} of the new input-output table at NACE Rev.2 level. We end up with the table pictured by Figure 2b.

For example, in Figure 1b the U.S. IO1 and IO2 codes correspond to 3 and 2 NACE codes respectively, and the NACE3 code corresponds to 2 I-O codes. Therefore, in order to convert the structure of the U.S. input-output table from the U.S. I-O code level (Figure 1a) to NACE Rev.2 code level (Figure 2b), we apply the following transformation:

$$b_{rs} = \sum_{g,h} \frac{a_{gh}}{n_g \times n_h}, \text{with } (g \supseteq r \text{ or } g \subseteq r) \text{ and } (g \supseteq s \text{ or } g \subseteq s)\,, \tag{1}$$

where n_g and n_h respectively represent the number of different NACE Rev.2 codes associated with input g (U.S. I-O codes in the rows in Figure 2a), and output h (U.S. I-O codes in the columns in Figure 2a). This transformation allows us to stay as close as possible to the structure of the original U.S. input-output table, *i.e.* at the level of the U.S. I-O codes. We also produce a very detailed input-output table, the economic activity being split into 604 4-digit NACE Rev.2 industries, of which 83 are agri-food industries. Once

[4] http://ec.europa.eu/eurostat/ramon/documents/NACE_REV2-US_NAICS_2012.zip.

Figure 2: Convert the U.S. input-output table to the NACE Rev.2 4-digit level

		US IO ind 1			US IO ind 2		US IO ind 3
		FR NACE ind 1	FR NACE ind 2	FR NACE ind 3	FR NACE ind 3	FR NACE ind 4	FR NACE ind 5
US IO ind 1	FR NACE ind 1	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{6}a_{12}$	$\frac{1}{6}a_{12}$	$\frac{1}{3}a_{13}$
	FR NACE ind 2	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{6}a_{12}$	$\frac{1}{6}a_{12}$	$\frac{1}{3}a_{13}$
	FR NACE ind 3	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{9}a_{11}$	$\frac{1}{6}a_{12}$	$\frac{1}{6}a_{12}$	$\frac{1}{3}a_{13}$
US IO ind 2	FR NACE ind 3	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{4}a_{22}$	$\frac{1}{4}a_{22}$	$\frac{1}{2}a_{13}$
	FR NACE ind 4	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{6}a_{21}$	$\frac{1}{4}a_{22}$	$\frac{1}{4}a_{22}$	$\frac{1}{2}a_{13}$
US IO ind 3	FR NACE ind 5	$\frac{1}{3}a_{31}$	$\frac{1}{3}a_{31}$	$\frac{1}{3}a_{31}$	$\frac{1}{2}a_{21}$	$\frac{1}{2}a_{21}$	a_{33}

(a) Equal weights for all correspondences within each pair of industry codes

	FR NACE ind 1	FR NACE ind 2	FR NACE ind 3	FR NACE ind 4	FR NACE ind 5
FR NACE ind 1	$b_{11}=\frac{1}{9}a_{11}$	$b_{12}=\frac{1}{9}a_{11}$	$b_{13}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}$	$b_{14}=\frac{1}{6}a_{12}$	$b_{15}=\frac{1}{3}a_{13}$
FR NACE ind 2	$b_{21}=\frac{1}{9}a_{11}$	$b_{22}=\frac{1}{9}a_{11}$	$b_{23}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}$	$b_{24}=\frac{1}{6}a_{12}$	$b_{25}=\frac{1}{3}a_{13}$
FR NACE ind 3	$b_{31}=\frac{1}{9}a_{11}+\frac{1}{6}a_{21}$	$b_{32}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}$	$b_{33}=\frac{1}{9}a_{11}+\frac{1}{6}a_{12}+\frac{1}{6}a_{21}+\frac{1}{4}a_{22}$	$b_{34}=\frac{1}{6}a_{12}+\frac{1}{4}a_{22}$	$b_{35}=\frac{1}{3}a_{13}+\frac{1}{2}a_{13}$
FR NACE ind 4	$b_{41}=\frac{1}{6}a_{21}$	$b_{42}=\frac{1}{6}a_{21}$	$b_{43}=\frac{1}{6}a_{21}+\frac{1}{4}a_{22}$	$b_{44}=\frac{1}{4}a_{22}$	$b_{45}=\frac{1}{2}a_{13}$
FR NACE ind 5	$b_{51}=\frac{1}{3}a_{31}$	$b_{52}=\frac{1}{3}a_{31}$	$b_{53}=\frac{1}{3}a_{31}+\frac{1}{2}a_{21}$	$b_{54}=\frac{1}{2}a_{21}$	$b_{55}=a_{33}$

(b) Group weights across NACE industries

this transformation has been carried out, we can compute the upstreamness indicator for each 4-digit NACE Rev.2 industry.

3.2. Industry-level upstreamness

We apply the methodology developed by Fally (2012), Antràs *et al.* (2012), and Antràs and Chor (2013) to the input-output table at the 4-digit level of NACE Rev.2 constructed in the previous section, and calculate the position of an industry with respect to final demand (upstreamness indicator). This methodology starts from a basic identity of gross output accounting. Assuming an economy with S ($S \geqslant 1$) industries, the total gross output of industry r is given by:

$$\begin{aligned} Y_r &= F_r + B_r = F_r + \sum_{s=1}^{S} d_{rs} Y_s \\ &= F_r + \sum_{s=1}^{S} d_{rs} F_s + \sum_{s=1}^{S}\sum_{k=1}^{S} d_{rk} d_{ks} F_s + \sum_{s=1}^{S}\sum_{k=1}^{S}\sum_{l=1}^{S} d_{rl} d_{lk} d_{ks} F_s + \ldots, \end{aligned} \tag{2}$$

where F_r (B_r) is the value of industry r used for final consumption (as intermediate input), d_{rs} is the value of the input of industry r required to produce one unit of the output of industry s, *i.e.* the coefficient of *direct requirements*. According to the second row of equation (2), the gross output vector Y is obtained in matrix form as:

$$\begin{aligned} \mathrm{Y} &= \mathbf{F} + \mathbf{B}\cdot\mathbf{F} + \mathbf{B}^2\cdot\mathbf{F} + \ldots \\ &= [\mathbf{I} - \mathbf{B}]^{-1}\cdot\mathbf{F}, \end{aligned} \tag{3}$$

where $\mathbf{B}$ is the matrix of direct requirements of dimension $S \times S$, $\mathbf{I}$ is the identity matrix, and $\mathbf{B}^m \cdot \mathbf{F}$ is the vector of the value of gross output used for final consumption, after $m+1$ production stages. Equation (3) expresses the classical Leontief inverse matrix formula that generates the gross output Y required to produce the vector of final uses $\mathbf{F}$. Y is equal to the sum of an infinite number of terms, which can be approximated by the matrix $[\mathbf{I} - \mathbf{B}]^{-1}\,\mathbf{F}$, and Y_r is the $r-th$ term of Y. Each term on the right-hand side of the second row of equation (2) indicates the number of stages of production through which the output of industry r passes before it is absorbed as final consumption. Expression (2) can therefore be interpreted as the sum of the value of the output of industry r used directly (F_r) and indirectly $\left(\sum_{s=1}^{S} d_{rs}F_s + \sum_{s=1}^{S}\sum_{k=1}^{S} d_{rk}d_{ks}F_s + \sum_{s=1}^{S}\sum_{k=1}^{S}\sum_{l=1}^{S} d_{rl}d_{lk}d_{ks}F_s + \ldots\right)$ to produce the final consumption. From this point of view, a stage of production is counted each time a good is absorbed as final consumption or used as an intermediate input. In an economy where $S \geqslant 1$, the upstreamness of industry r is calculated as:

$$\begin{aligned} U_r &= 1\cdot\frac{F_r}{Y_r} + 2\cdot\frac{\sum_{s=1}^{S} d_{rs}F_s}{Y_r} + 3\cdot\frac{\sum_{s=1}^{S}\sum_{k=1}^{S} d_{rk}d_{ks}F_s}{Yr} \\ &\quad +4\cdot\frac{\sum_{s=1}^{S}\sum_{k=1}^{S}\sum_{l=1}^{S} d_{rl}d_{lk}d_{ks}F_s}{Y_r} + \ldots \end{aligned} \tag{4}$$

U_r is the weighted average of the number of stages of final demand (consumption or investment) at which the goods of industry r enter the production process as an input. The weight corresponds to 1 for the share of industry r goods that go into final consumption (are consumed without further transformation), to 2 for the share used as inputs in another industry before being absorbed as final consumption, to 3 for the share used as inputs in another industry that provides inputs for a third industry the products of which are use in final consumption, and so on. The ratio terms on the left-hand side of equation (4) reflect the fraction of industry r's output used at each stage of production. In matrix form, this equation writes as follows:

$$\mathbf{F} + 2 \cdot \mathbf{B} \cdot \mathbf{F} + 3 \cdot \mathbf{B}^2 \cdot \mathbf{F} + 4 \cdot \mathbf{B}^3 \cdot \mathbf{F} + \cdots = [\mathbf{I} - \mathbf{B}]^{-2} \cdot \mathbf{F}. \tag{5}$$

The right-hand side term of equation (5) is the vector of final consumption $\mathbf{F}$ pre-multiplied by the square of the Leontief inverse matrix ($[\mathbf{I} - \mathbf{B}]^{-2}$). The numerator of each right-hand side term of (4) is the $r - th$ element of the right-hand side expression in equation (5).

An alternative measure of upstreamness is proposed by Fally (2012). It assumes that an industry r that sells a disproportionately large share of its output to another industry s located further upstream is itself located relatively further upstream. This formalized by the following recurrence equation:

$$U_r = 1 + \sum_{s=1}^{S} \frac{d_{rs} \cdot Y_s}{Y_r} \cdot U_s, \tag{6}$$

where $(d_{rs} Y_s) / Y_r$ is the total share of the output of industry r that is purchased by industry s. Industry r is thus considered to be at a higher "upstream stage" than the weighted sum of industries s that use the products of industry r as intermediate inputs. Fally (2012) and Antràs *et al.* (2012) show that the measure of upstreamness expressed by equation (4) is the unique solution of expression (6). Using matrix algebra, they establish the following equivalence between these different measures of upstreamness:

$$U_r = [\mathbf{I} - \Delta]^{-1} \mathbf{1}, \tag{7}$$

where Δ is a matrix whose generic term (r, s) is equal to $(d_{rs} Y_s) / Y_r$, and $\mathbf{1}$ is a unit column vector. In general, the upstreamness indicator is greater than or equal to unity. The higher the value of this indicator, the further upstream an industry is in the value chain. If upstreamness is equal to one, it means that all the output of industry r is used directly for final consumption.

3.3. Consistency of industry-level upstreamness

Table 2 reports the level of upstreamness computed according to equation (7) for some of the 604 NACE Rev.2 industries in our transformed input-output table. Unsurprisingly, retail sales and services – industries located close to final consumption – feature a very low level of upstreamness (close to one). On the opposite, agriculture and farming are among the most upstream industries, as they provide raw materials for a large array of sectors. Food processing industries re situated between these two extremes, and exhibit

Table 2: Industry upstreamness (selection)

NACE industry	Upstreamness
Retail sale of fruit and vegetables in specialised stores	1.01
Retail sale of meat and meat products in specialised stores	1.01
Retail sale of fish, crustaceans and molluscs in specialised stores	1.01
Retail sale of bread, cakes, flour confectionery and sugar confectionery	1.01
Retail sale of beverages in specialised stores	1.01
Manufacture of rusks and biscuits; of preserved pastry goods and cakes	1.08
Manufacture of soft drinks; of mineral waters and other bottled waters	1.09
Manufacture of bread; manufacture of fresh pastry goods and cakes	1.10
Manufacture of macaroni, noodles, couscous and similar farinaceous products	1.15
Manufacture of beer	1.19
Manufacture of prepared meals and dishes	1.20
Manufacture of grain mill products	1.21
Restaurants and mobile food service activities	1.22
Manufacture of wine from grape	1.23
Growing of vegetables and melons, roots and tubers	1.28
Processing and preserving of poultry meat	1.31
Manufacture of condiments and seasonings	1.35
Production of meat and poultry meat products	1.37
Operation of dairies and cheese making	1.38
Manufacture of cocoa, chocolate and sugar confectionery	1.39
Manufacture of sugar	1.42
Processing and preserving of meat	1.44
Growing of perennial crops	1.46
Processing of tea and coffee	1.47
Manufacture of fruit and vegetable juice	1.47
Processing and preserving of fish, crustaceans and molluscs	1.60
Marine fishing	1.66
Freshwater fishing	1.69
Freshwater aquaculture	1.86
Sewerage	1.89
Growing of sugar cane	2.07
Marine aquaculture	2.10
Raising of swine/pigs	2.10
Raising of other animals	2.15
Raising of poultry	2.16
Manufacture of starches and starch products	2.16
Manufacture of oils and fats	2.72
Raising of dairy cattle	2.98
Manufacture of prepared feeds for farm animals	3.24
Raising of other cattle and buffaloes	3.30
Growing of rice	3.38
Growing of cereals (except rice), leguminous crops and oil seeds	3.45
Post-harvest crop activities	3.61
Seed processing for propagation	3.61

Source: Computations by authors based on the U.S. input-output table converted to the level of NACE Rev.2 4-digit industries.

Table 3: Summary statistics for industry upstreamness

	Frequency	Min	Max	Mean	Std. dev.
Upstreamness of all industries	604	1.00	4.51	1.89	0.75
Upstreamness of agri-food industries	83	1.08	4.51	2.16	0.96

intermediate levels of upstreamness. Table 3 shows that the industries that constitute the agri-food sector (from farming to the manufacture of most processed foodstuff) are on average more upstream than the overall industries of the economy: an average upstreamness of 2.16 for the former compared to 1.89 for the latter.

To test the relevance of our method, we check the stability, constancy of industries' upstreamness obtained with our transformed input-output table constructed above. For that, we compare them with industry-level upstreamness computed using alternative input-output tables. More specifically, we use the French input-output tables obtained from OECD STAN, INSEE, and GTAP databases, and the U.S. input-output table from GTAP. These alternative tables operate with much broader industries, and accordingly provide a much lower level of detail. The OECD STAN table resumes all economic activities into 34 industries, the INSEE input-output table in only 15 industries, while the GTAP tables include 65 industries. To compare industry upstreamness computed with different input-output tables, we need to have the same classification of industries. Therefore, we aggregate the input-output table constructed above to match the industry classification in each alternative data source on input-output linkages (OECD STAN, INSEE, GTAP), and recompute the industry upstreamness according to equation (7).

Results reveal a strong correlation between the industry upstreamness obtained with different input-output tables (see Table 4). We find large values for Spearman rank and Pearson correlation tests that range from 0.65 to 0.73. Both tests are always of similar magnitude, and are significantly different from zero at a p-value of 0.01. These findings confirm the consistency of our results, and that we can confidently use the constructed input-output table to identify the position of French industries in value chains. The cross-industry variation in the upstreamness computed based on the original French input-output tables (from OECD STAN and INSEE) and our constructed NACE-level input-output table from the U.S. table is broadly consistent with the range of values reported by Antràs *et al.* (2012) for a subset of EU countries (Czech Republic, Luxembourg, Germany, Spain, *etc.*). Furthermore, the strong correlation of industry upstreamness computed with the GTAP input-output tables for France and the U.S. (0.89 and 0.90) confirms our hypothesis that the two countries share the same patterns of input use for the production of identical outputs. In sum, this evidence gives us great confidence that industry-level upstreamness measures are stable between the U.S. and France, at least at a high level of

Table 4: Correlation of industry upstreamness computed with different data

	The input-output table at the 4-digit NACE Rev.2 level aggregated into			
	34 industries	15 industries	65 industries	65 industries
OECD (34 industries)	0.65 [0.66]			
INSEE (15 industries)		0.68 [0.67]		
GTAP France (65 industries)			0.70 [0.68]	
GTAP U.S. (65 industries)			0.73 [0.73]	0.89 [0.90]

Notes: Results report the Spearman rank correlation. Pearson correlation in brackets. The U.S. input-output table converted to the level of 4-digit NACE Rev.2 level was aggregated to match the classification of industries in the OECD STAN, INSEE, and GTAP input-output tables.

aggregation, and confirms the relevance of using the U.S. table with French data.

3.4. A measure of the intensity of firms' participation in GVCs

Now we turn to computing the upstreamness at the firm level, using the approach introduced by Chor *et al.* (2021). We assume that all products in a given industry have the same level of upstreamness. In the absence of product-level data on firms' sales and purchases on all markets (domestic and foreign), we rely on international trade data. Thus, we assume that the product composition of firms' imports and exports match the composition of their overall purchases and sales. We compute the upstreamness of imports (U_{ft}^M) of firm f as the weighted average of the upstreamness of the industries into which fall the products it imports. We use a similar approach to calculate the upstreamness of exports (U_{ft}^X). Weights are derived from the product composition of firms' imports and exports. The difference $U_{ft}^M - U_{ft}^X$ reflects the number of production stages in the global production line carried out by the firm. We label it the intensity of GVC participation. More specifically, we have:

$$\begin{aligned} U_{ft}^M &= \sum_r^S \frac{M_{frt}}{M_{ft}} U_r \\ U_{ft}^X &= \sum_r^S \frac{X_{frt}}{X_{ft}} U_r \\ GVC_{ft} &= U_{ft}^M - U_{ft}^X = \sum_r^S \left(\frac{M_{frt}}{M_{ft}} - \frac{X_{frt}}{X_{ft}} \right) U_r \end{aligned} \quad (8)$$

where M_{frt} and X_{frt} are the value of imports, respectively exports, of firm f of products in industry r in period t. $M_{ft} = \sum_r^S M_{frt}$ and $X_{ft} = \sum_r^S X_{frt}$. Intuitively, the degree of processing of sold (exported) products is higher than the degree of processing of purchased (imported) products ($U_{ft}^X < U_{ft}^M$), as sold products are closer to final consumption. The intensity of firms' participation in GVCs mainly reflects the extent of processing activities carried in-house.

Based on these firm-level measures, we can compute the aggregate import and export upstreamness of the French agri-food sector as a weighted average of firm-level upstreamness:

$$U_t^M = \sum_f \frac{M_{ft}}{M_t} \cdot U_{ft}^M, \text{ and } U_t^X = \sum_f \frac{X_{ft}}{X_t} \cdot U_{ft}^X. \tag{9}$$

We use firm size, measured by the value of their imports and exports, as weights. $M_t = \sum_f M_{ft}$ and $X_t = \sum_f X_{ft}$ are total sector-level imports and exports in year t.

4. The French agri-food sector in GVCs

In this section, we question how intensely the French agri-food sector is inserted, integrated in GVCs. For that, we focus on firms from this sector that participate in GVCs, *i.e.* the ones that both import and export in a given year. Re-exports account for a large share of our data (around 53% and 71% of the total value of imports and exports, respectively).[5] In most cases, firms re-export products that fall under their main economic activity (about 46%). To account for this aspect, we consider two data panels in our computations: (a) all import and export transactions of French agri-food firms, and (b) transactions that exclude re-exports. Since our aim is to capture the actual processing activities of firms in GVCs, we focus our discussion on results obtained with the second panel, *i.e.* after dropping out re-exports. However, results obtained using all international transactions draw a similar picture. Note that agri-food firms declare some type of farming or food processing as their main economic activity. Accordingly, they produce and export mainly goods that fall under the agrifood sector. Differently, they can import a much wider variety of products, as the production process may require inputs from other sectors. Therefore, one should keep in mind that the exports of firms analyzed in this section cover only agri-food products, while their imports include products from all sectors.

Firms' involvement in GVCs. Table 5 summarizes import and export upstreamness statistics for French agri-food firms over the 2004-2017 period. Our sample includes 2,973 firms that are both importers and exporters (firms in GVCs) in at least one year between 2004 and 2017. They feature an average import upstreamness of 1.9275 and an average export upstreamness of 1.5332. The difference indicates that, on average, these firms perform in-house 0.3943 production stages of the global production line. Comparatively, Chor *et al.* (2021) find an average value of 0.42 for the Chinese manufacturing sector.

Figure 3 resumes the variation in the GVC position and participation of French agri-food firms. The picture on the left reports the evolution of sector averages across time.

[5] Re-exports refer here to situations when a firm imports and exports the same product, defined at the narrowest level (CN8), during the same year.

Table 5: The upstreamness of firms in GVCs

	Frequency	Median	Mean	Standard deviation
# Firms	2,973			
Import upstreamness (U^M)	19,377	1.8332	1.9275	0.5077
Export upstreamness (U^X)	19,375	1.3799	1.5332	0.4934
GVC participation ($U^M - U^X$)	19,375	0.3394	0.3943	0.6138

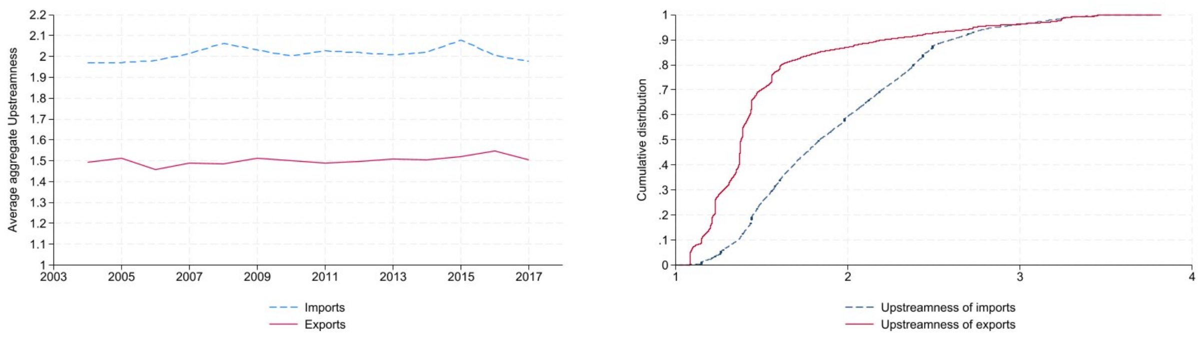
Notes: The sample includes French agri-food firms over the 2004-2017 period that both export and import. Import and export upstreamness computed after excluding re-exports.

The picture on the right shows the cumulative distribution of the import and export upstreamness of firms in our sample. Two observations emerge from the analysis of these patterns.

First, the imports of French agri-food firms are consistently more upstream than their exports. This reflects the fact that firms tend to import less processed intermediate goods, which they use to produce goods with a higher degree of transformation (Figure 3a). A similar pattern was found by Chor *et al.* (2021) in the case of China. Note that this outcome would not apply to countries that mainly export primary goods (*e.g.* natural resources) and import final goods. Chor (2014) mention as examples Brunei, Myanmar, Australia, and New Zealand, whose exports are concentrated in agricultural commodities and raw materials, and therefore feature a higher upstreamness than their imports. The cumulative distribution of firms' upstreamness displays a similar outcome (Figure 3b).

The horizontal gap between the two curves in Figure 3a reflects the average range of production stages carried out by French agri-food firms. It is quite large in the middle of the distribution and narrows down at the tails. The lower gap on the lower end of the distribution (the lower 30%) indicates that firms specialized in the production (and

Figure 3: Variation in the upstreamness of firms in GVCs



(a) **Sector-level average** (b) **Cumulative distribution of firms**

Notes: The sample includes French agri-food firms over the 2004-2017 period that both export and import. Import and export upstreamness computed after excluding re-exports.

export) of highly processed goods use highly processed imported inputs. The nearly overlapping of the two curves on the higher end of the distribution (the top 10%) testifies that some very upstream products qualify as both inputs and outputs. The average gap between import and export upstreamness is close to that of the Chinese manufacturing sector (Chor *et al.*, 2021). This points out that the French agri-food sector contributes significantly to the domestic value added of French exports.

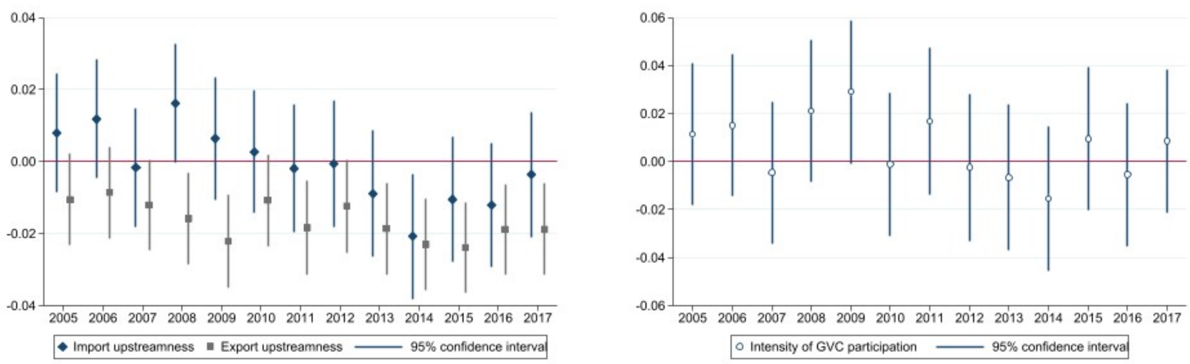
Second, we observe a relative stability across time in the range of production stages carried out by French agri-food firms (Figure 3a). This means that the French agri-food sector has not undergone any major transformation over the 2004-2017 period.

Evolutions across time. For a more accurate understanding of how firms' involvement in GVCs changed over time, we regress the firm-level import and export upstreamness, and the difference between the two on the full set of year dummies (β_t) and firm fixed effects (FE_f):

$$\begin{pmatrix} U_{ft}^M \\ U_{ft}^X \\ U_{ft}^M - U_{ft}^X \end{pmatrix} = \alpha + \beta_{2004} + \beta_{2005} + \cdots + \beta_{2017} + FE_f + e_{ft}. \quad (10)$$

Estimated parameters β_t reflect average annual evolutions with respect to the model constant α. Estimating (10) requires dropping one year dummy because the sum of year dummies is collinear with the constant. We drop the dummy for the first year, and report results in Figure 4. The graph on the left depicts average annual changes in the upstreamness of firms' imports and exports with respect to year 2004; the graph on the right shows changes in the intensity of firms' participation in GVCs. Similarly to Figure 3a, we find non-significant or very small changes in these indicators over the analyzed period.

Figure 4: The evolution of the GVC involvement of French agri-food firms



(a) Import and export upstreamness **(b) Intensity of GVC participation**

Notes: The sample covers firms that both export and import. GVG measures computed w/o re-exports.

Shift-share analysis. We perform a shift-share decomposition to deepen the above analysis. This approach permits to identify the contribution of changes in the composition of firms (at the extensive margin) and within firms (at the intensive margin). We break down the sector-level average annual changes (Δ) in firms' upstreamness into four terms:

$$\Delta U_t^M = \sum_{f \in \Xi_t} \frac{M_{ft}}{M_t} \cdot U_{ft}^M - \sum_{f \in \Psi_t} \frac{M_{f,t\text{-}1}}{M_{t\text{-}1}} \cdot U_{f,t\text{-}1}^M + \sum_{f \in \Gamma_t} \frac{M_{f,t\text{-}1}}{M_{t\text{-}1}} \cdot \Delta U_{ft}^M + \sum_{f \in \Gamma_t} \Delta \frac{M_{ft}}{M_t} \cdot U_{ft}^M,$$

$$\Delta U_t^X = \underbrace{\underbrace{\sum_{f \in \Xi_t} \frac{X_{ft}}{X_t} \cdot U_{ft}^X}_{\text{starting firms}} - \underbrace{\sum_{f \in \Psi_t} \frac{X_{f,t\text{-}1}}{X_{t\text{-}1}} \cdot U_{f,t\text{-}1}^X}_{\text{stopping firms}}}_{\text{extensive margin}} + \underbrace{\underbrace{\sum_{f \in \Gamma_t} \frac{X_{f,t\text{-}1}}{X_{t\text{-}1}} \cdot \Delta U_{ft}^X}_{\Delta\text{upstreamness}} + \underbrace{\sum_{f \in \Gamma_t} \Delta \frac{X_{ft}}{X_t} \cdot U_{ft}^X}_{\Delta\text{mkt share}}}_{\text{intensive margin}}. \quad (11)$$

The first two right hand side terms of identities (11) are the weighted average upstreamness of firms that entered GVCs (started exporting and importing) – denoted by the set Ξ_t – and of firms that exited GVCs (stopped exporting, importing, or both) – denoted by the set Ψ_t. The sum of these two terms reflects the change at the extensive margin, *i.e.* in the panel structure of firms involved in GVC. The last two terms of (11) reflect changes in the GVC involvement of incumbent firms that remain in the GVC (continue to both export and import) – denoted by the set Γ_t. One term expresses the average change in the upstreamness of these firms' imports and exports; the other measures the change in their market share. Their sum captures evolutions at the intensive margin. Left and right hand side terms are summed across years to obtain the overall decomposition for the entire period.

The results of this shif-share decomposition are displayed in Table 6. First of all, we see that the overall import upstreamness of the French agri-food sector has decreased over the 2004-2017 period (-0.2229), meaning that firms switched to more processed foreign inputs. This decrease is driven mainly by the intensive margin: the net change in the upstreamness and market share of incumbent firms (-0.2499) largely exceeds the net effect of firms that start or stop participating in GVCs (0.0270), in absolute values. Firms that remained in GVCs imported, on average, less transformed inputs (their import upstreamness increased by 0.0994), but they suffered a market share loss (which reduced the sector average upstreamness by -0.3493). The sum of these two opposite evolutions yields a negative net effect at the intensive margin.

Second, we also observe an overall decrease in the export upstreamness of French agri-food firms (-0.1692), which indicates that the latter shifted to producing and selling more highly processed outputs. Similarly to the case of imports, this outcome is driven by changes at the intensive margin (-0.1024), and the market share loss of firms in GVCs (-0.4311) outweighs their increase in upstreamness (0.2619).

Table 6: Shift-share decomposition of the change in the GVC participation of the French agri-food sector, 2004-2017

	Overall	Extensive margin			Intensive margin (incumbent)		
		Starting firms	Stopping firms	Net effect	Change in firm's up-streamness	Change in firm's mkt share	Net effect
ΔU_t^M	-0.2229	0.0732	-0.0462	0.0270	0.0994	-0.3493	-0.2499
ΔU_t^X	-0.1692	0.0903	-0.1085	-0.0182	0.2619	-0.4311	-0.1024
$\Delta U_t^M - \Delta U_t^X$	-0.0537	-0.0171	0.0623	0.0452	-0.1625	0.0818	-0.1475

Notes: Column “Overall” shows the total average change at sector level. Column “Starting” displays the contribution of firms that start exporting and importing. Column “Stopping” displays the contribution of firms that stop exporting, importing, or both. The sum of these two effects is shown in the “Net” column of the extensive margin. The “Net” column of the intensive margin sums changes in firms’ upstreamness and market shares.

Third, we note that the net contribution of the extensive margin is quite small (close to zero) for changes in both import and export upstreamness. Indeed, differences in the upstreamness of firms that become integrated in GVCs tend to cancel out those of firms that withdraw from GVCs (0.0732 and -0.0462 for imports; 0.0903 and -0.1085 for exports).

The last row of Table 6 reports the decomposition of the change in the intensity of the GVC involvement of French agri-food firms. Each term of the decomposition is obtained as the difference between terms for the change in import and export upstreamness. The small sector average drop in this indicator (-0.0537) points out a tendency for these firms to slightly reduce the number of production stages performed in-house.

5. Conclusion

The present paper investigates the methodological aspects of measuring the GVC participation of firms from a specific sector. Existing works combine firm-level data on produced outputs and purchased inputs, reflected in firms’ exports and imports, with country-level input-output tables. Detailed information on the flow of resources across sectors is necessary to correctly identify the position of each industry (associated with a group of products) in the economy because a product can be an input for one industry and an output for another. This issue is particularly important when the analysis focuses on firms from an individual sector, who specialize in similar or closely related activities. In the absence of a detailed input-output table for the country under investigation, the table of another country with a similar level of economic development can be employed. This strategy assumes that the patterns through which inputs are used to produce specific outputs do not vary significantly across countries.

We focus on the case of the French agri-food sector, and combine product-level data on firms' foreign trade activity with the U.S. input-output table where industries are classified at a very narrow level, in order to measure the involvement in GVCs at firm level. To match the two data sources, we convert the U.S. input-output table to the level of industry classification used in French data. A main challenge for this step is the presence of complex correspondences (one-to-many and many-to-many) between industries in the U.S. and French data. We solve this difficulty by splitting each entry of the U.S. input-output table (direct-requirements coefficients) equally between all its possible matches with industries in the French data.

The resulting input-output table provides a much higher level of detail than the available input-output tables for France. The new table permits to compute industry upstreamness – the position of each industry in the economy – at a very disaggregated level. The obtained value of this indicator and ranking of industries in terms of their upstreamness are very similar to the ones obtained with alternative input-output tables. This validates our assumption that French and American economies rely on similar production functions, *i.e.* combine inputs likewise to obtain the same output good.

Similarly to previous works in the literature, we use the industry-level upstreamness together with information on the product composition of firms' foreign sales and purchases to measure the involvement in GVCs at firm level. Broadly, the upstreamness of firms' imports and exports reflect the processing level of the inputs they employ and, respectively, of the outputs they produce. The difference between the two illustrates the scope of production stages that firms perform in-house. Despite the important heterogeneity in these measures across firms, sector-level averages vary little across time.

From a methodological point of view, our paper provides a consistent approach for converting an input-output table to a different level of industry classification, in the presence of multiple (complex) correspondences. We have shown empirically that a detailed input-output table of one country can be validly used to analyze the GVC integration of firms from another technologically close country. This paves the way for overcoming the scarcity of detailed input-output tables for most countries in the world. Given the importance of this type of data for understanding the organization of production at national and global levels, the propagation of shocks and the mechanisms for mitigating them, our work represents an important step forward in designing better trade and industrial policies. The strategy we propose increases the feasibility of analyzing GVCs at a detailed firm and sector level for a large array of cases.

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