Consistency of Micro- and Macro-level Data on Global Value Chains: Evidence from Selected European Countries

A. Giunta*, P. Montalbano♣, S. Nenci♠

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Abstract

This study investigates the degree of consistency and fungibility of micro and macro sources of global value chain (GVC) data. We combine two datasets for selected European countries over the period 2001–2014: the European Union-European Firms in a Global Economy (EU-EFIGE) firm-level dataset (integrated with panel balance sheet data from Amadeus) and the World Input–Output Database (WIOD) at the country and sectoral level. Although the two datasets come from different sources and are based on different assumptions, we find that (i) the WIOD-based country and sectoral GVC indicators are positively correlated with firm-level proxies based on EFIGE data; and (ii) the GVC indicators from both sources are positively correlated with firm-level labor productivity. These outcomes are robust to various empirical tests and specifications, as well as to controlling for firm, sector, and country heterogeneity. Our results hold relevance for scholars by demonstrating that the available inter-country input–output (ICIO) data can be used to compensate for the scarcity of firm-level data for evidence-based GVC analyses.

Keywords: global value chains; firms' internationalization; trade in value added; inter-country input–output tables; European countries.

JEL codes: F14; F60; D22; L22; O52.

Highlights

- We contribute to the applied literature by making methodological advances in GVC data use.
- We combine the available micro and macro GVC data for four European countries.
- We demonstrate that GVC measures computed from the two data sources are highly consistent.
- We advocate utilizing the available ICIO data sources for evidence-based GVC analyses.

* *Corresponding author*. Roma Tre University and Rossi-Doria Centre (IT), Via Silvio D'Amico 77, 00145 Rome, Italy. Phone +39 06 57335688. E-mail: anna.giunta@uniroma3.it

♣ Sapienza University of Rome (IT) and Sussex University (UK). E-mails: pierluigi.montalbano@uniroma1.it, P.Montalbano@sussex.ac.uk

♠ Roma Tre University. E-mail: silvia.nenci@uniroma3.it

1. Introduction

In the last 10 years, empirical studies on global value chains (GVCs) (Grossman and Rossi-Hansberg, 2008; Antràs et al. 2012; Baldwin, 2012; Costinot et al., 2013; Baldwin and Yan, 2014) have taken advantage of the availability of new data and methods for measuring GVC linkages (see, inter alia, Hummels et al., 2001; Yi, 2003; Koopman et al. 2011; Johnson and Noguera, 2012; Stehrer, 2013; Wang et al., 2013; Koopman et al., 2014; Timmer et al., 2015; Wang et al., 2016; Borin and Mancini, 2019).

Remarkable advancements have been made in collecting sector-level statistics; thus, inter-country input–output (ICIO) tables are now widely used to describe the level of GVC integration of countries and industries (De Backer and Miroudot, 2014; Nagengast and Stehrer, 2016).[1] Unfortunately, statistical advancements have been less remarkable at the micro level. Making the most of scarce firm-level data, researchers have investigated the impact of firms' participation and positioning along GVCs on firm performance. Some studies have relied on qualitative survey data, whereas others have used international trade data to quantify the relevance of offshoring in the firm (Agostino et al., 2015; Giovannetti et al., 2015; Cainelli et al., 2018; Rungi and Del Prete, 2018). [2]

Micro and macro approaches to measuring GVCs have advanced on parallel tracks, heading in the same direction but with limited overlap. Research on this topic is valuable because each data source has strengths and caveats—in terms of availability, complexity, accuracy, and coverage—that are sometimes overlooked (for a wider discussion, see Amador and Cabral, 2016). Firm-level data provide a granular picture of multiple interaction flows among firms and allow us to consider firm heterogeneity. However, they mostly rely on *ad hoc* surveys lacking a unified framework and methodological approach regarding the unit of analysis and variables of interest (Giovannetti and Marvasi, 2018). Furthermore, firm-level data require a high demand for data (see Antràs and Chor, 2021). First, they require information on intra-country inter-industry flows and a method to preserve the confidentiality of firm identities when

[1] These analyses mainly focus on the manufacturing sector, because of larger availability of data compared to other sectors. However, new insights on agriculture and food are also emerging (Greenville et al., 2017; Balié et al., 2018; Montalbano and Nenci, 2020).

[2] For recent firm-level initiatives in business statistics, see Nielsen (2018).

merging data across countries.[3] A second data challenge is the presence of multiproduct firms (Bernard et al., 2010, 2011). There are no detailed data on the intermediates imported by these firms. Even if such data are available, one would still require information on how these inputs are distributed across the manufacturing processes of different products to accurately account for value-added flows. A third measurement issue is that the observed input-sourcing patterns can differ systematically across firms, even within the same industry (de Gortari, 2019). A method to overcome the differences in firm-level surveys across countries is necessary. Given these demands on data, existing studies that incorporate firm-level data to improve value-added accounting either focus on individual countries or have limited geographic coverage. The lack of standardization among the different firm-level sources used in the literature not only hampers the consistency between micro-and macro-level data sources, but also hinders comparability between otherwise similar firm-level studies.

In contrast, ICIO tables provide a sound and consistent picture of global trade flows, but also exhibit shortcomings. They are constructed by collecting and combining data from various sources (such as supply and use data from country-level I–O accounts, time-series data on production and expenditure from national accounts, disaggregated bilateral trade data, and firm surveys). In some cases, data are unavailable for significant intervals of time, often asynchronous across countries, and technical features, such as sector classifications and price concepts used in recording data, also differ across countries (Johnson, 2018). Furthermore, some important assumptions concern most ICIO tables. These are the proportionality assumptions that state (Feenstra and Jensen, 2012; de Gortari, 2019) that (i) industry-level bilateral final and intermediate trade shares are identical (proportionality at the border); and (ii) the allocation of imported inputs across sectors is the same as the allocation of domestic inputs (proportionality behind the border).[4]

Consequently, scholars have been struggling to develop a consistent, comprehensive empirical portrait of these macro and micro linkages. As stated by Johnson (2018), there is scope for convergence: micro data can improve the I–O approach, and I–O analysis can strengthen the

[3] The existence of cross-country firm-level survey data covering several years is also scarce due to domestic regulations on statistical confidentiality as well as different national criteria for collecting and recording the information.

[4] The World Input–Output Database (WIOD) dataset is an exception, as the data on imports by product and importing country from bilateral trade statistics are divided into final and intermediate use based on detailed information from the Broad Economic Categories (BEC) classification and import use tables.

micro-quantification exercise. In this respect, the optimal method would be to measure firm-to-firm international transactions and then build a global I–O table at the firm level. These hypothetical firm-level data would then aggregate up to the industry-level I–O tables. Unfortunately, such data are not available yet (among the few exceptions are Feenstra and Jensen, 2012; de Gortari, 2019). They are also subject to possible aggregation bias induced by within-sector heterogeneities (Bems and Kikkawa, 2019).[5] The second-best method enables the disaggregation of I–O tables, thus tracking GVC linkages at a higher resolution. However, such data are also not available yet. This is further complicated by the presence of a set of assumptions generally adopted for computing trade in value added by using sectoral I–O. Some recent studies have proposed a combination of macro and micro approaches (see, inter alia, Del Prete et al., 2017; Blaum et al., 2018; Michel et al., 2018; Montalbano et al., 2018; Bernhard et al., 2019).

Our study fits precisely in this context. Because of the shortcomings of using firm-level data suitable for GVC analysis, we utilize GVC sectoral measures to approximate GVC firm measures. To this end, we investigate the degree of consistency and fungibility of the GVC measures derived from micro and macro GVC data sources. Specifically, we match the EU- European Firms in a Global Economy (EFIGE) dataset (integrated with Amadeus), which includes data from a survey of European manufacturing firms, with the World Input–Output Database (WIOD), which provides global I–O tables at the country/sectoral level for the same selected European countries over the period 2001–2014. Although both datasets are popular among scholars and primarily trace export flows across the European Union, to the best of our knowledge, this is the first attempt to use them in an integrated manner. The popularity of these datasets enhances the relevance of our empirical exercise.[6] Our empirical findings show that sectoral level indicators of GVCs, derived from the WIOD, and firm-level GVC indicators, derived from EU-EFIGE data, look highly consistent across sectors and countries. This consistency extends to testing the relationship between both indicators on firms' performance. This result is robust to various empirical tests and specifications, as well as to controlling for heterogeneity registered

[5] Feenstra and Jensen (2012) attempt to construct an industry-to-industry import I–O table using the US Linked/Longitudinal Firm Trade Transaction Database. de Gortari (2019) develops a new framework that combines I–O data with additional information on supply chain linkages based on richer micro-level datasets to construct more precise value-added trade measures.

[6] Furthermore, the process of compensating for the lack of firm-level GVC measures by enlarging the number of the different (and proprietary) firm-level data available cannot be taken for granted without the due processes of harmonization and standardization, which are hard to perform.

at both sectoral and country levels. Our results are relevant for scholars because we demonstrate that we can use ICIO data to compensate for the scarcity of firm-level data suitable for GVC analysis.

The remainder of this paper is organized as follows. Section 2 describes the data and the adopted GVC indicators. Section 3 presents the descriptive statistics. Section 4 presents the results of the empirical analysis. Section 5 provides the conclusions.

2. Data and GVC indicators

We combine data from two different databases over the period 2001–2014: the WIOD and EU-EFIGE datasets, as integrated with panel balance sheet data drawn from the Amadeus database. To combine the WIOD and EFIGE GVC measures at the sectoral level, we convert the NACE-CLIO classification used by the EFIGE dataset into the ISIC rev. 4 classification (two digits) used by the WIOD.

2.1 The World Input–Output Database (WIOD)

The WIOD provides global I–O tables for 43 countries[7] and 56 sectors of activity (two-digit, according to the ISIC nomenclature, Rev. 4), including 19 manufacturing sectors, for the period 2000–2014 (released 2016) (see Table 1A in the Appendix for the list of manufacturing sectors used in our empirical analysis). We use this dataset to calculate trade in value-added components and GVC indicators at country and sectoral levels. Within GVCs, value is added in different countries throughout the production process, and countries' exports therefore include both domestic and foreign value added.[8] Looking at trade from a value-added perspective better reveals how domestic industries contribute to exports as well as how (and how much) they participate in GVCs. Economies participate in GVCs both as users of foreign inputs and suppliers of intermediate goods and services used in other economies' exports.

Following Hummels et al. (2001), we refer to the notion of "GVC trade." Specifically, GVC trade measures the value of goods and services exported by a sector or country that crosses more than one border, whereas "traditional trade" measures the value of goods and services that cross only one border (see Borin and Mancini, 2019). GVC trade can be seen as the sum of two

[7] The EU-28 countries plus Australia, Brazil, Canada, China, Norway, India, Indonesia, Japan, Korea, Mexico, Russia, Switzerland, Taiwan, Turkey, and the USA.

[8] "Value added" reflects the value that is added by foreign and domestic industries in producing goods and services by all factors that are involved in any stage of the production.

measures of cross-border linkages: backward and forward GVC participation. The first measure looks *back* along the value chain by measuring the value added of foreign inputs included in a country's exports, whereas the second measure looks *forward* by measuring the value added of the domestic inputs of the country contained in the exports of other countries along the value chain. Broadly speaking, these two linkages trace how much imports of intermediates are embedded in a country's exports and how much of a country's own production of intermediates is absorbed by demand from global markets, respectively (see Borin et al., 2021).

To disentangle these two modalities, we apply the methodology developed by Wang et al. (2013).[9] Thus, we compute the following GVC trade indices at the industry level:

- *backward GVC trade* proxied by the *foreign value-added* (FVA) component of sectoral exports, that is, the value added contained in the intermediate inputs imported from abroad embedded in the exports of intermediate goods (including pure double counting).[10] This captures the extent of involvement in the GVC of relatively downstream industries;
- *forward GVC trade* proxied by the *indirect domestic value-added* (DVX) component of sectoral exports, that is, the domestic value added in the exported intermediate goods, further re-exported by the partner country.[11] It measures GVC participation, as it contains the exporter's value-added for a specific sector that passes through the direct importer for a (or some) stage(s) of production before it reaches a third country (or eventually returns home).[12] More specifically, it captures the contribution of the domestic sector to the exports of other countries and indicates the extent of involvement of relatively upstream industries in the GVC.

[9] Wang et al. (2013) generalize the gross exports accounting framework proposed by Koopman et al. (2014) from a country-level perspective to one that decomposes gross trade flows at the sector, bilateral, or bilateral-sector level. The Wang et al. (2013)'s framework is informative because it not only allows us to extract value-added exports from gross exports, but also to recover additional useful information on the structure of international production with a high level of disaggregation. In our work, we calculate the Wang et al. (2013)'s components at country-sector level by aggregating the bilateral-sector trade flows. Other concurring methods propose detailed breakdowns of trade flows: see, among others, Los and Timmer (2018) and Borin and Mancini (2019).

[10] In the WIOD dataset, products are distinguished into intermediates by other industries, intermediate inputs, and final products by firms, stocks, and gross fixed capital formation (other than household and government consumption). Backward GVC participation sums up the terms T12, T13, T15, and T16 of the Wang et al. (2013)'s decomposition. It includes the pure double counting from foreign sources arising when intermediate goods cross borders back and forth multiple times.

[11] It sums up the terms T3–T8 of the Wang et al. (2013)'s decomposition.

[12] The DVX component also includes the returned value added, that is, the portion of domestic value added that is initially exported but ultimately returns home by being embedded in the imports from other countries and is consumed at home.

Summing up the two indicators, we obtain an overall measure of the WIOD sectoral GVC trade.

2.2 The EU-EFIGE dataset

The EU-EFIGE dataset includes data from a survey of manufacturing firms in seven EU countries (Austria, France, Germany, Hungary, Italy, Spain, and the United Kingdom (UK)) with 10 or more employees.[13] Using EFIGE data, we aim to compute the firm-level counterparts of the industry measures of GVC trade computed using the WIOD, as mentioned above. Our goal here is to determine the firm-level categories of GVC trade that are comparable to sectoral GVC measures, although derived from different data sources. To this end, we adopt a two-step procedure. First, following Veugelers et al. (2013), we classify firms into the following modes:[14]

> i) *Single* mode, in which firms are only exporters of intermediates (that is, they act as outsourcers of inputs for other firms abroad);[15]
>
> *ii) Dual* mode, in which firms are both importers of materials and services and exporters of intermediates.

These firm-level categories represent the nearest micro counterpart of country/sectoral GVC trade because they include imports and exports of intermediates that flow across at least two borders. Taking advantage of the availability of panel-level balance sheet data from the Amadeus database for a subset of surveyed firms included in the EFIGE data, we also compute

[13] EFIGE data are fully comparable across countries, as they are derived from responses to the same questionnaire administered over the same time span (January–May 2010). The fact that the EFIGE dataset does not include micro enterprises (i.e., with less than 10 employees) introduces a small source of bias in our comparative exercise with sectoral GVC measures. However, according to Eurostat data for our investigated countries, the average number of the exporting micro enterprises is less than five percent of the total number of firms (see Eurostat ext_tec01 available at https://ec.europa.eu/eurostat/databrowser/view/ext_tec01/default/table?lang=en).

[14] Due to the nature of the EFIGE dataset, we have retained the same firm modes through the panel. Furthermore, we believe that this assumption is better than the alternative of lacking any kind of information about firms' trade characteristics, as usually done in the context of MRIO data.

[15] In the EFIGE dataset, goods purchased by enterprises for their production are distinguished by respondents into raw material and intermediate goods. Unfortunately, EFIGE data do not provide any additional information regarding the final destination of intermediates (whether it is the direct importer or the third countries to which they are further exported). This is different from the sectoral counterpart of the GVC measures, namely DVX. Furthermore, EFIGE data do not observe domestic firm-to-firm transactions of exports. Hence firm-level GVC measures do not incorporate domestic transactions of intermediates between "importer only" and "exporter only" firms. The consistency of the estimated coefficients using both sectoral- and firm-level measures shows that these differences prove to be negligible.

a firm-specific measure of labor productivity for the period 2001–2014.[16] Labor productivity is used as a proxy for firm-level productivity.[17]

3. Descriptive analysis

Our analysis focuses on four major European countries: France, Germany, Italy, and Spain[18]. Figure 1 reports a preliminary descriptive comparative analysis of the shares of GVC trade derived from the WIOD (averages for the period 2001–2014) computed as percentages of gross exports.[19] It shows clear sectoral heterogeneity in all countries under investigation. As expected, food products and beverages showed the lowest degree of GVC trade, whereas input industries (such as basic metals, coke, and petroleum) show the highest degree. Figure 2 compares the shares of GVC trade measures derived from the WIOD and EFIGE. In the latter case, the shares of GVC trade for EFIGE are computed as percentages of exports of the selected GVC firms (single- and dual-mode categories). [20] This confirms the presence of strong sectoral heterogeneity and possible sources of bias in comparing the micro and sectoral measures of GVC trade. This is likely induced by the so-called aggregation bias, that is, the fact that aggregation leads to overstated trade in value added and, correspondingly, understated foreign value added of gross export (Bems and Kikkawa, 2021).[21] Figure 3 provides a preliminary visual inspection of the correlation between these sectoral and micro-measures of GVC trade. [22] It shows a highly significant (99% confidence interval) positive correlation between the two measures (relevant exceptions are "printing and reproduction of recorded media" and

[16] Due to missing variables, firm-level productivity is available for around half of the firms in the original EFIGE sample. Altomonte et al. (2013) provide a detailed discussion of the characteristics of the restricted matched sample and find no major differences with respect to the unrestricted sample, except for country representativeness; Italy, France, and Spain are the countries with the highest level of firm-level productivity data.

[17] Our measure of labor productivity is value added (the values are expressed in thousands of euros) over total labor (total number of permanent and temporary production workers). This proxies the sectoral compensation of employees' domestic value added separately from the other value-added components, and the results less influenced by foreign sources of value added.

[18] We do not include the UK because its productive structure—based on financial and knowledge-intensive business services—is quite different from that of France, Germany, Italy, and Spain. Hungary and Austria are excluded because they are much smaller economies, and hence, comparisons are not unlikely to be particularly significant.

[19] Although the WIOD covers the time span 2000–2014, the empirical analysis is limited to the sub-period 2001–2014, because this is the time span available in the Amadeus panel-level balance sheet data. For consistency, we also report the descriptive data from the WIOD using the sub-period 2001–2014. All WIOD values have been converted to euros by using the World Development Indicators (WDI) annual official exchange rates.

[20] A different version of the same figure, where we computed both FVA and DVX in percentage of intermediate exports is reported in Figure 4A in the Appendix.

[21] The magnitude of this bias is ultimately an empirical issue. Bems and Kikkawa (2021) show that the magnitude of this bias varies across countries (from 2–5 percentage points of gross exports for Belgium to 17 percentage points for China).

[22] A different version of the same figure focusing on GVC trade in intermediates is reported in Figure 3A in the Appendix.

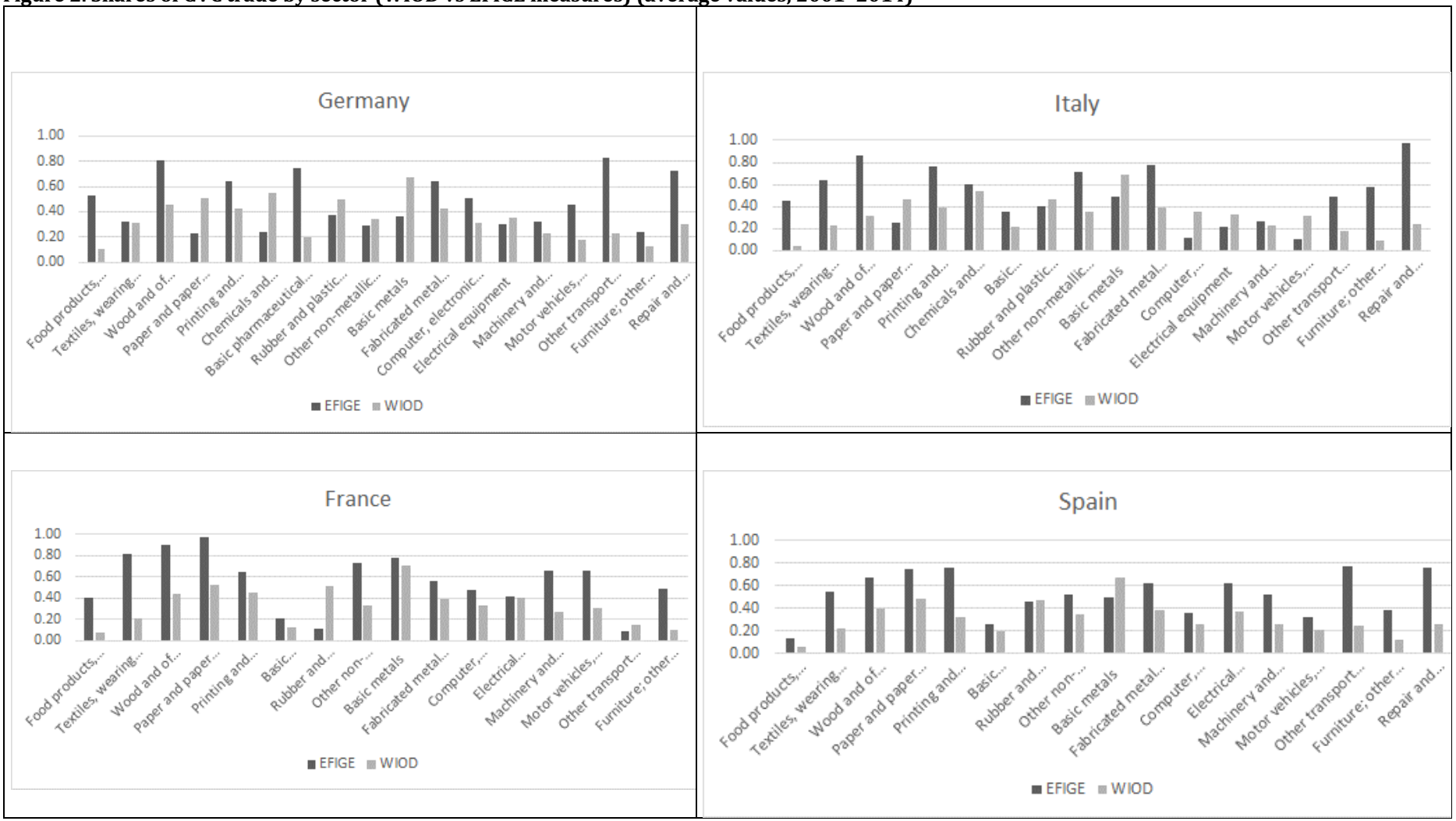
"manufactures of coke and refined petroleum products," which record a very low GVC trade from the WIOD and a very high GVC trade from EFIGE, respectively). Figures 1A and 1B in the Appendix show the same correlation for the backward and forward subcomponents of both measures of GVC trade, confirming the same pattern, whereas a clear heterogeneous pattern is shown in Figure 2A by plotting the same correlation by sector. However, these visual inspections do not consider structural differences among sectors, countries, and times, as shown in Figure 2. Table 1 provides the results of the regression analysis to ease these constraints.

Figure 1. Shares of GVC trade (WIOD data) for the investigated countries (average values, 2001–2014)

Source: Authors' elaboration

Notes: FVA, foreign value added; DVX, indirect domestic value added. The shares of GVC trade (FVA and DVX) are computed as percentages of gross exports.

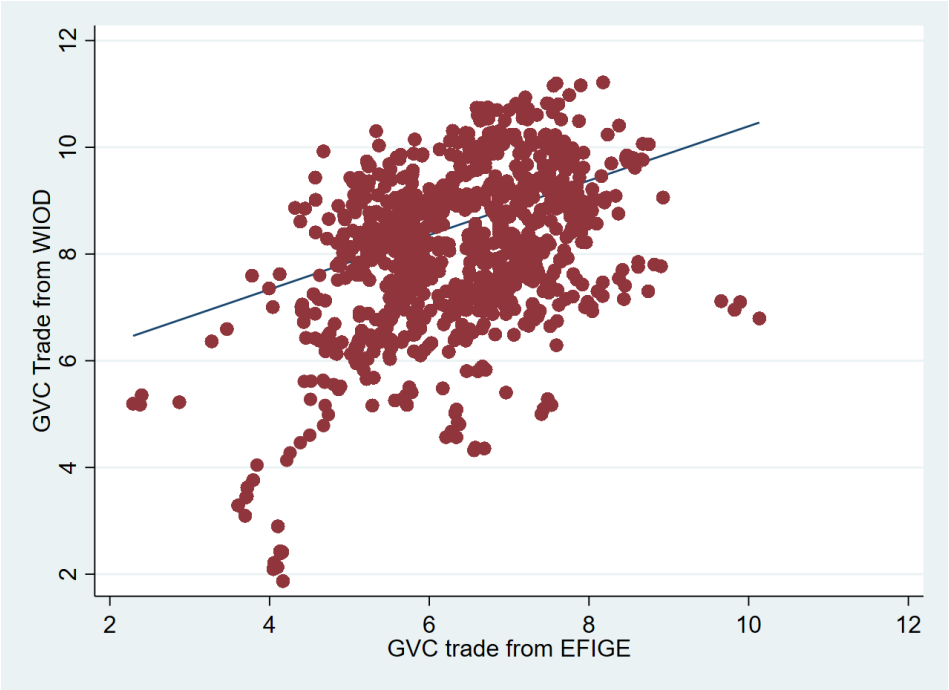
Figure 2. Shares of GVC trade by sector (WIOD vs EFIGE measures) (average values, 2001–2014)



Source: Authors' elaboration

Notes: The shares of GVC trade for the WIOD are computed as shown in Figure 1. The shares of GVC trade for EFIGE are computed as percentages of exports of the selected GVC firms (single- and dual-mode categories).

Figure 3. Linear correlation between macro and micro measures of GVC trade by sector (2001–2014)



Source: Authors' elaboration
The GVC trade is here expressed in natural logs of exports' values. For EFIGE it is computed as the sum of exports of selected GVC firms (single- and dual-mode categories).

To clean our dataset for potential outliers and maintain consistency with the hypothesis of a normal distribution, we also apply the minimum covariance determinant (MCD) estimator, which has become standard in robust statistics to identify outliers and is particularly well suited for multivariate outlier identification.[23] Table 1 confirms the significant positive and strong correlation between the two measures of GVC trade at the sectoral level. In Column 2, we replicate the analysis only for the backward component of GVC trade, and in Column 3, only for the forward measures of GVC trade. In both cases, a significant positive correlation is confirmed (weaker in the case of forward GVC measures). However, this specification does not control for the industry effects. This would help control for possible time-invariant confounders, thus making our correlation more robust. In contrast, industry effects would inevitably absorb part of the sectoral differences in GVC trade (those that are not time variant). Columns 4–6 report the outcomes with the industry fixed effects specification. As expected, although lower, the correlation between our two measures of GVC trade holds. This is because

[23] The basic idea of MCD is to identify the subsample containing 50% of the observations associated with the smallest generalized variance.

industry effects have now absorbed between variations. However, the goodness of fit significantly improves (adjusted R-squared increases to approximately 0.90).[24]

Table 1. OLS correlation between macro and micro measures of GVC indicators by sector (2001–2014)

	ln GVC trade (WIOD)	ln Backward trade (WIOD)	ln Forward trade (WIOD)	ln GVC trade (WIOD)	ln Backward trade (WIOD)	ln Forward trade (WIOD)
	(1)	(2)	(3)	(4)	(5)	(6)
ln gvc trade (EFIGE)	0.471***			0.212***		
	(0.0482)			(0.0210)		
dual-mode trade (EFIGE)		0.487***			0.234***	
		(0.0558)			(0.0225)	
single-mode trade (EFIGE)			0.254***			0.0687***
			(0.0352)			(0.0115)
cons	2.418***	2.012***	4.935***	5.105***	5.874***	6.493***
	(0.643)	(0.753)	(0.468)	(0.292)	(0.313)	(0.185)
country effects	yes	yes	yes	yes	yes	yes
time effects	yes	yes	yes	yes	yes	yes
Industry effects	no	no	no	yes	yes	yes
Obs	996	992	877	996	992	877
adj. R-sq	0.314	0.275	0.233	0.914	0.907	0.885

Notes: Coefficient is statistically significant: * at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk indicates that the coefficient is not significantly different from zero.
Robust standard errors in parentheses.

4. Empirical analysis

After verifying the presence of high correlation between our two measures of sectoral GVCs, to further check the consistency of the micro-and macro-level data, we investigate the relationship between both GVC indicators and firms' productivity. This relationship is one of the most debated issues in literature. The findings of the few studies based on firm-level data highlight the positive impact of GVC firms' participation on firm performance (Pietrobelli and Rabellotti, 2011; Veugelers et al., 2013; Giovannetti et al., 2015; Del Prete et al., 2017; Bahn et al., 2020; Brancati et al., 2020; World Bank, 2020) while outlining that gains from GVC participation significantly depend on firms' positions in the chains (Veugelers et al., 2013; Agostino et al., 2015; Accetturo and Giunta, 2018; Alfano-Urena, 2022). The boost in firm productivity, particularly significant for the two-way traders' firm typology (here approximated by the firms' dual mode), is due to several factors that take place due to the vertical specialization of firms. The interconnectedness among firms favors, in fact, technology transfer, knowledge spillovers, firms' specialization, use of a variety of intermediate goods, and increasing pressure to innovate.

[24] Notably, although different GVC measures computed from the same data sources are highly correlated, consistency between micro and macro data cannot be taken for granted.

Our empirical investigation of this relationship is the ideal playground for testing pilot combinations of micro and macro approaches by integrating firm-level characteristics and sectoral-level GVC participation indices derived from global I–O tables. The cross-sectional nature of the original EFIGE data survey hampers a comprehensive empirical investigation of the determinants of labor productivity augmented with empirical measures of GVC participation. However, by taking advantage of the availability of balance sheet panel data for a subsample of surveyed firms, we can produce sound empirical estimates of the relationship under investigation by controlling for both time effects and time-invariant sectoral and firm characteristics. Specifically, we test the following two empirical specifications:

$$\theta_{jt} = \alpha_0 + \alpha_1 gvc_{jt} + \eta_c + \tau_j + \gamma_t + \epsilon_{jt} \qquad [1]$$

where j denotes the sector, and t denotes time. θ is the natural logarithm of labor productivity by sector; gvc represents the measures of GVC trade (that is, alternatively, the natural logarithms of the values of exports of firms classified under single forward and dual modes of internationalization and the natural logarithms of the WIOD indicators of GVC trade); η_c, τ_j, and γ_t are country, industry, and time effects, respectively; and ϵ is the error term.

$$\vartheta_{ijt} = \beta_i + \beta_1 gvc_{ijt} + \psi_c + \varphi_j + \omega_t + \varepsilon_{ijt} \qquad [2]$$

where i denotes firm; ϑ is the natural logarithm of firms' labor productivity; gvc indicates the natural logarithms of GVC trade by sector/firm; a_i, ψ_c, φ_j, and ω_t are firm, country, industry, and time effects, respectively; and ε is the error term.

Table 2 provides the empirical results of Eq. 1. This shows that both measures of sectoral GVC indicators are significantly and positively associated with average firm productivity, as expected.[25] Note that the magnitudes of the estimated coefficients of the two (macro and micro) measures are not statistically different when compared at the sectoral level (Column 1 with Columns 4 and 7). Thus, possible sources of bias between our two measures of GVC trade (micro and macro) do not appear to produce any significant bias in the corresponding estimated coefficients.[26] In Columns 2–3 and 4–5, we disentangle both GVC measures into their respective backward and forward components. These results are highly consistent with those of previous studies, including the underestimation of the estimated coefficients for both backward and

[25] Notably, this empirical exercise is meant as a further empirical test to investigate the consistency of using alternative GVC indicators. Hence, we do not make any casual interpretation of the estimated relationship.

[26] The null hypothesis of equality of coefficients is not rejected with a level of confidence of 0.01 in both cases.

forward WIOD indicators. As for the firm measures, we run another test by controlling for industry fixed effects. Although these latter coefficients are lower in magnitude (as industry effects absorb the time-invariant heterogeneity of GVC participation across sectors), their relationship with firm productivity is still statistically significant. However, in both cases, the difference between the backward and forward coefficients is not statistically significant, as expected.

Table 2. Panel estimates of the relationship between firm productivity ("average firm productivity" by sector) and alternative sectoral measures of GVC participation (2001–2014)

dependent variable:									
ln labour productivity	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ln GVC trade (WIOD)	0.0533***								
	(0.00891)								
ln Back trade (WIOD)		0.0482***							
		(0.00867)							
ln For trade (WIOD)			0.0348***						
			(0.0106)						
ln GVC trade (EFIGE)				0.0689***			0.0484***		
				(0.0129)			(0.0157)		
ln dual-mode trade (EFIGE)					0.0501***			0.0240*	
					(0.0150)			(0.0149)	
ln single-mode trade (EFIGE)						0.0411***			0.0363**
						(0.00943)			(0.0160)
cons.	3.763***	3.813***	3.950***	3.281***	3.537***	3.585***	3.638***	3.978***	3.657***
	(0.127)	(0.125)	(0.131)	(0.188)	(0.227)	(0.113)	(0.228)	(0.234)	(0.211)
Obs	998	998	998	989	986	880	975	972	866
country effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
time effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
industry effects	no	no	no	no	no	no	yes	yes	yes
adj. R-sq	0.159	0.158	0.147	0.154	0.142	0.281	0.348	0.343	0.457

Notes: Coefficient is statistically significant *at the 15% level; ** at the 5% level; *** at the 1% level; no asterisk indicates that the coefficient is not significantly different from zero.
Robust standard errors in parentheses.

Table 3. Panel estimates of the relationship between firm level productivity and alternative firm level measures of GVC participation (2001–2014)

dependent variable:	sectoral level GVC trade			firm level GVC trade					
ln labour productivity	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
ln GVC trade (WIOD)	0.0439***								
	(0.00277)								
ln Back trade (WIOD)		0.0281***							
		(0.00263)							
ln For trade (WIOD)			0.0399***						
			(0.00277)						
ln GVC trade (EFIGE)				0.0638***			0.133***		
				(0.00173)			(0.00685)		
ln dual-mode trade (EFIGE)					0.0625***			0.133***	
					(0.00217)			(0.0120)	
ln single-mode trade (EFIGE)						0.0698***			0.135***
						(0.00307)			(0.0124)
cons.	3.545***	3.692***	3.608***	3.038***	3.069***	2.922***	2.153***	2.114***	2.092***
	(0.0309)	(0.0297)	(0.0295)	(0.0308)	(0.0372)	(0.0577)	(0.0944)	(0.150)	(0.153)
Obs	26,511	26,511	26,511	26,511	19,735	6,776	27,104	19,735	6,776
country effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
time effects	yes	yes	yes	yes	yes	yes	yes	yes	yes
industry effects				yes	yes	yes	yes	yes	yes
firm effects							re	re	re
adj. R-sq	0.078	0.073	0.076	0.185	0.187	0.187	0.117	0.165	0.173

Notes: Coefficient is statistically significant *at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk indicates that the coefficient is not significantly different from zero. Robust standard errors are indicated in parentheses.

Table 3 provides the estimates of Eq. 2 using firm-level productivity and firm-level EFIGE GVC variables, together with GVC WIOD measures. The empirical results do not change significantly. The estimates in Columns 4 and 5 include sector-level fixed effects to control for sectoral heterogeneity, other than country heterogeneity. Owing to the multilevel structure of our data (repeated observations over time nested within firms that are nested within industries that are then nested within countries), we cannot control for sectoral and firm fixed effects simultaneously. Thus, we opt for a multilevel random effects estimation, the outcomes of which are reported in Columns 7–9. These final estimates confirm the usual results. We believe that a proper parameter comparison is between Columns 1, 2, and 3 with the corresponding Columns 4, 5, and 6, whereas Columns 7, 8, and 9 are likely to be affected by omitted variable bias. In this respect, it should be noted that the difference between the (firm and sectoral) estimated coefficients of GVC measures (Columns 1 and 4) is now statistically significant. This is likely related to the aggregation bias in comparing parameters estimated at different levels of aggregation (firm and sectoral).

A further empirical test accounts for the so-called Melitz hypothesis, which controls for the presence of a positive correlation between firm-level productivity and exports that is independent of the actual GVC trade involvement of the investigated firms. To this end, we modify Eq. 2 by introducing an interaction variable between the total exports of all exporting firms and dummies indicating only our categories of GVC firms, as follows:

$$\phi_{ijt} = \gamma_0 + \gamma_1 x_{ijt} + \gamma_2 gvc_{ij} + \gamma_3 x_{ijt} * gvc_{ij} + \psi_c + \varphi_j + \mu_{ijt} \qquad [3]$$

where ϕ is the natural logarithm of firm labor productivity; x denotes the natural logarithms of firm-level exports; and *gvc* is a dummy indicating the modalities of GVC trade by firms. Note that owing to EFIGE time constraints, gvc is a constant. As in Eq. 2, ψ_c and φ_j are country and industry effects, respectively, and μ is the error term. γ_3 is here the coefficient of interest, as it measures the increase in firm productivity attributable to GVC participation. Table 4 presents the results of the estimates in Eq. 3. This confirms that GVC trade provides added value in terms of productivity, independent of its positive relationship with overall exports.

Table 4. Panel estimates of the relationship between firm-level productivity and GVC trade (2001–2014) by controlling for Melitz' effects

dependent variable: *ln labour productivity*	
ln exports	0.0617*** (0.00158)
gvc*ln_exports	0.00649*** (0.00228)
cons.	3.104*** (0.0251)
Obs	39,665
country effects	yes
industry effects	yes
time effects	yes
adj. R-sq	0.217

Notes: Coefficient is statistically significant *at the 10% level; ** at the 5% level; *** at the 1% level; no asterisk indicates that the coefficient is not significantly different from zero. Robust standard errors are indicated in parentheses.

Conclusions

The novelty of this study lies in its contribution to the recent stream of literature by making methodological advancements in the use of GVC trade data. To this end, we find a sound and significant relationship between sectoral-level indicators of GVCs derived from the WIOD and firm-level GVC indicators derived from EFIGE data. Specifically, we show that possible sources of bias between the macro and micro measures of GVC trade do not produce any significant bias in the corresponding estimated coefficients. This proves that using sectoral ICIO tables can be a workable strategy to overcome the current chronic scarcity of firm-level data suitable for GVC analysis. These outcomes extend to the empirical analysis of the GVC-productivity nexus, which is one of the most investigated in previous literature. They are robust to various empirical tests and specifications, as well as to controlling for firm, sectoral, and country heterogeneity.

Our results are relevant for scholars in several ways. From a methodological point of view, our empirical strategy extends the potential to carry out sound evidence-based analyses on GVCs using the available aggregate (sectoral level) ICIO data sources. We are aware and discuss in our empirical analysis that discrepancies could occur between the two data sources. However, we demonstrate with empirical evidence that due to the lack of high-quality firm-level data, we can use ICIO data to compensate for the scarcity of firm-level data because the two data sources are correlated. We are also aware that the availability of more firm-level data sources, although

highly desirable, is not a panacea. Although, in theory, they provide the best ground for measurement, in practice, because of the lack of countries' micro-data and harmonized statistics, they suffer from severe problems stemming from data availability to comparability and the lack of standard definitions.

By isolating the GVC trade, we empirically test the role of international fragmentation of production and the specialization of firms in tasks and functions rather than in final products. This helps us reformulate policy priorities in the domain of trade and industrial policies, broadening the scope of tariff and non-tariff trade policies, including softening barriers to imports to facilitate access to world-class inputs. This reflection is absent in standard empirical analyses of the "export premium" à la Melitz. Future research agenda calls for a larger effort by scholars to refine works that consider firms' heterogeneity in I–O tables. Meanwhile, our work proves that we can picture a consistent, comprehensive empirical portrait by making the most of the available statistics.

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Appendix A

Table 1A – List of manufacturing sectors used in the empirical analysis

ISIC rev4	Industry name
C10_C12	Food products, beverages and tobacco products
C13_C15	Textiles, wearing apparel and leather products
C16	Wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Paper and paper products
C18	Printing and reproduction of recorded media
C19	Coke and refined petroleum products
C20	Chemicals and chemical products
C21	Basic pharmaceutical products and pharmaceutical preparations
C22	Rubber and plastic products
C23	Other non-metallic mineral products
C24	Basic metals
C25	Fabricated metal products, except machinery and equipment
C26	Computer, electronic and optical products
C27	Electrical equipment
C28	Machinery and equipment n.e.c.
C29	Motor vehicles, trailers and semi-trailers
C30	Other transport equipment
C31_C32	Furniture; other manufacturing
C33	Repair and installation of machinery and equipment

Figure 1A

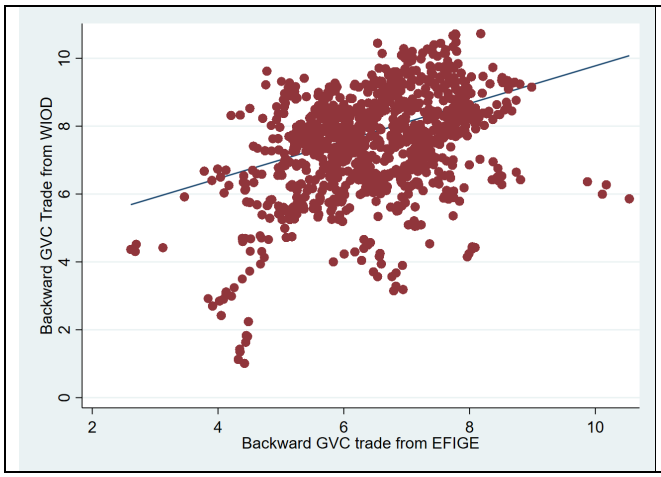

Figure 1B

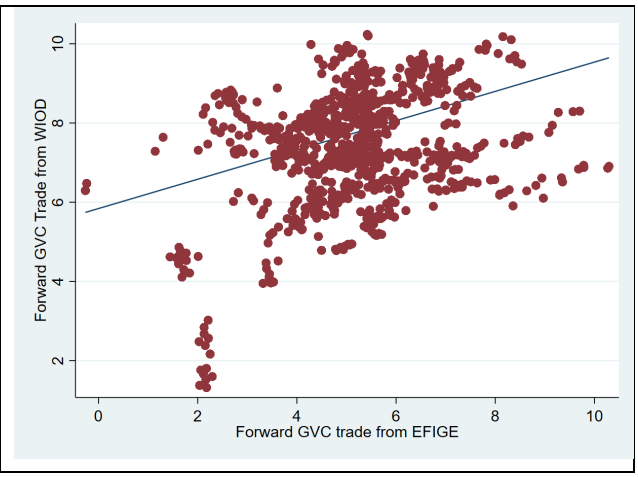

Figure 2A

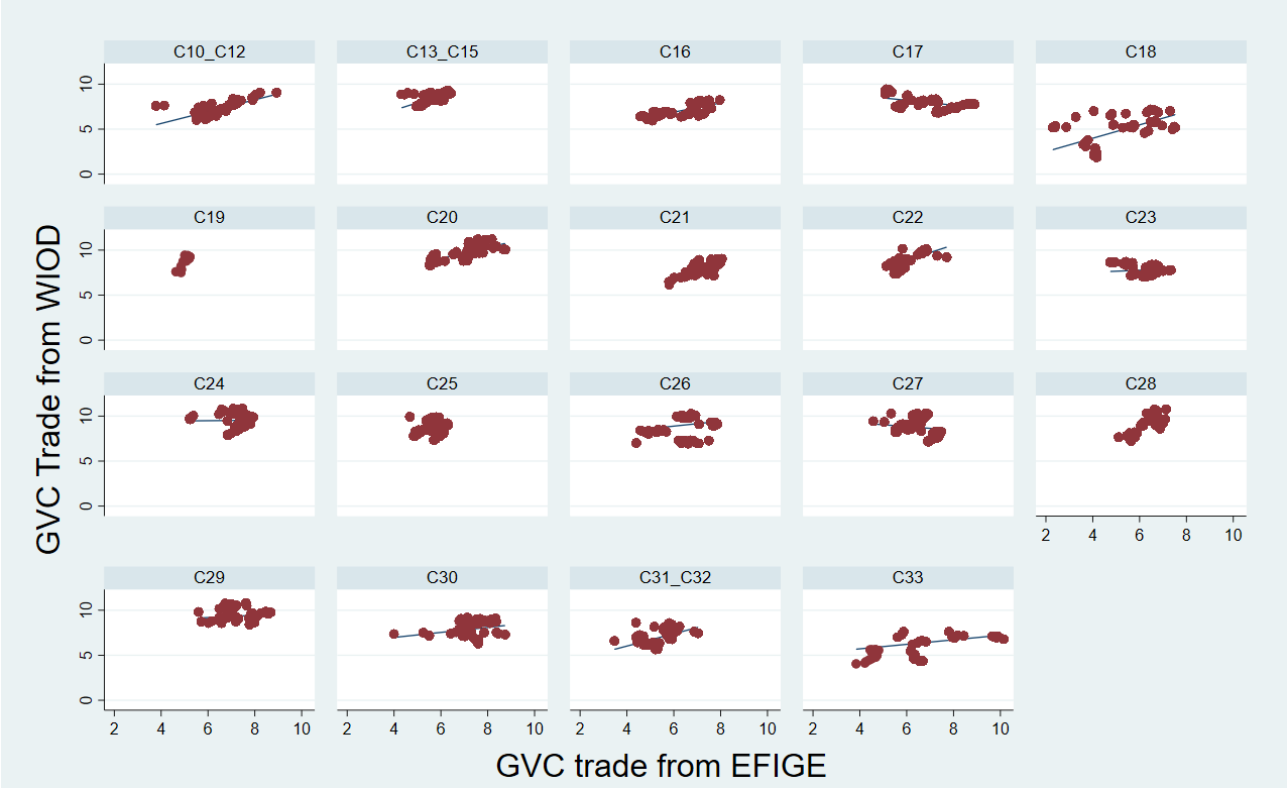

Figure 3A

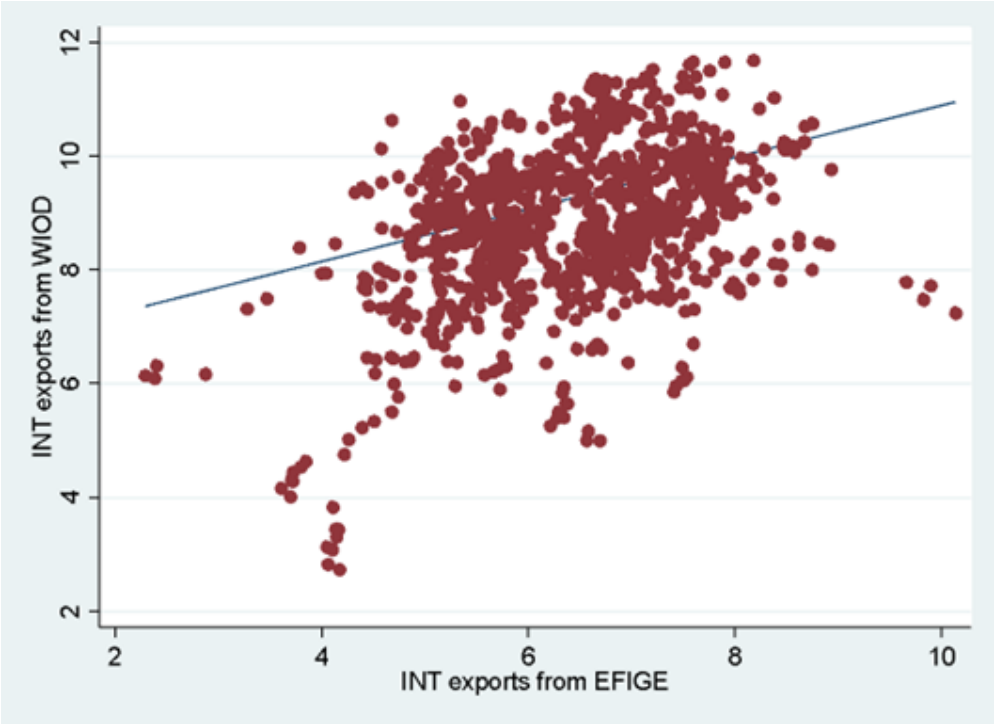

Figure 4A. Shares of GVC trade by sector (WIOD vs EFIGE measures) - Percentage of total export in intermediates (average values, 2001–2014)

Source: Authors' elaboration

Notes: The shares of GVC trade for the WIOD are computed as % of total exports in intermediates. The shares of GVC trade for EFIGE are computed as percentages of exports of the selected GVC firms (single- and dual-mode categories).