Paper to be presented at DRUID22
Copenhagen Business School, Copenhagen, Denmark
June 13-15, 2022

Knowledge-based capital for industrial upgrading in global value chains: The case of the European food sectors

Petros Dimas
National Technical University of Athens
Laboratory of Industrial and Energy Economics
petros.dimas92@gmail.com

Dimitrios Stamopoulos
National Technical University of Athens
Laboratory of Industrial and Energy Economics
dstamopoulos@mail.ntua.gr

Ioanna Kastelli
National Technical University of Athens
Laboratory of Industrial and Energy Economics
iokast@chemeng.ntua.gr

Ioanna Kastelli
National Technical University of Athens
Laboratory of Industrial and Energy Economics
ioanna.kastelli@gmail.com

Aggelos Tsakanikas
National Technical University of Athens
Laboratory of Industrial and Energy Economics
atsaka@central.ntua.gr

Abstract

This working paper explores the driving forces that lead to industrial upgrading in global value chains (GVCs) at the sector level, focusing on the effects of knowledge-based capital (KBC) and different types of GVC participation on the export sophistication of selected EU food, beverage, and tobacco (FBT) sectors. We focus on a traditional low-tech sector to empirically investigate the effects of different types of knowledge assets (that go beyond R&D) for upgrading in GVCs, through the development of a sophistication indicator that reflects each sector's specialization in terms of value-added exports. We further integrate different types and modes of GVC participation in our analysis. The main findings indicate the importance of KBC stock for FBT upgrading in GVCs and highlight the fact that the type and mode of GVC participation does matter, as forward and especially simple participation activities appear to be the most beneficial. We further identify that upgrading is mainly enhanced by branding and organizational capital, while R&D and software also contribute to sophistication despite the low-tech classification of our sectors Æ although at a lesser extent. Our results provide fertile ground for

sector-specific policy discussion regarding the importance of knowledge capital accumulation for the competitiveness of low-tech industries.

Knowledge-based capital for industrial upgrading in global value chains: The case of the European food sectors

1. Introduction

Integration into global value chains (GVCs) has been recently studied in the relevant literature as one of the driving forces affecting the ability of firms to compete more effectively in international markets. One of several lines of research covering different aspects of the GVC configuration, studies its implications in terms of firm performance and upgrading effects. The two issues are related, as the reasoning goes from upgrading, defined as a move towards activities with increasing value-added (VA) returns, to performance in terms of growth and international competitiveness (Gereffi 2005; Gibbon and Ponte, 2005). On the other hand, the knowledge content and complexity of GVCs is constantly rising (Baldwin and Evenett, 2015; Tsakanikas et al., 2022) and knowledge assets – alternatively known as intangibles – are placed in the epicenter of empirical research as promising factors for growth and competitiveness in global markets (Mudambi, 2008; Corrado et al., 2009; Jona-Lasinio et al., 2019). Early studies by Mudambi (2008) and OECD (2013) have stressed the uneven appropriation of VA in GVCs, where upstream and downstream activities secure higher shares compared to traditional manufacturing and are usually occupied by firms in developed economies. The key to this asymmetry relates with the control and accumulation of key intangible assets (Durand and Millberg, 2020). While several studies have focused on the effect of knowledge-based capital (KBC) to growth (Corrado et al., 2005;2009; Niebel et al., 2017; Roth, 2020) and more recently to specialization and GVC participation (Jona-Lasinio et al., 2019; Fu and Ghauri, 2021; Tsakanikas et al., 2022), little is known regarding the structural effects that knowledge accumulation and different types of knowledge assets pose to industrial upgrading into higher VA activities in GVCs.

This working paper aims to address certain extensions of this gap, by investigating the effects of KBC and different types of GVC participation on the export sophistication of selected EU food, beverage, and tobacco (FBT) sectors in the period 1995-2017. Despite its relatively low formal research and development (R&D) activities, the FBT sector has developed a significant knowledge base related to non-R&D activities (Robertson and Jacobson, 2011). Although R&D and innovation levels are low according to most official national statistics, different dimensions of knowledge capital and the technological change in other sectors can affect the whole sector value chain from raw materials to final consumers and also boost its upgrading potential in GVCs. To capture upgrading, we develop an adjusted specialization indicator which integrates the exports sophistication approach of Hausmann et al., (2007) with the exports decomposition frameworks of Johnson and Noguera (2012) and Koopman et al., (2014), to provide a measure of sophistication through VA exports. We further tap to Wang et al. (2017)'s production-based decomposition framework to construct GVC participation indicators that account for different types (backward and forward) and different modes (simple and complex) of integration in the global production network, using the 2021 release of OECD's inter-country input-output (ICIO) tables. To account for KBC, we turn to the 2019 release of the EU-KLEMS database, which provides capital stock for different types of knowledge assets in the period 1995-2017.

Our preliminary results indicate towards the significance of KBC stock as a driver for FBT upgrading in GVCs and highlight the importance of branding and organizational capital as the main elements that boost this process. In addition, we find that different types of GVC participation affect upgrading in different ways, as simple forward activities provide gains, but complex backward and forward activities have a negative impact. These findings provide useful policy insights regarding the importance of different types of knowledge assets for the participation of FBT sectors in GVCs and suggest that careful selection of GVC activities is warranted.

The remainder of this paper is structures as follows. In section two we discuss the theoretical background regarding upgrading in GVCs, the role of knowledge assets and the implications that relate to FBT sectors. In section 3 we present the methodology and the data of this study. In section 4 we present and discuss the empirical results and section 5 concludes the paper. Supplementary material regarding the calculations of the various indicators is provided in the Appendix.

2. Theoretical background

A value chain consists of the several production activities (design, development, mass production/fabrication/assembly, marketing, distribution and after sales services) in the development of a product/service, from its conception to its final use. Originally, these activities mostly took place within the borders of a single economy. However, increased round of trade liberalization and the rapid advances in information and telecommunications technologies (ICTs) have paved the way for a constant increase in the international fragmentation of production and the formation of GVCs, where firms and at the aggregate level countries participate based on their perceived comparative advantages (Baldwin and Robert-Nicoud, 2014; Antràs, 2020; World Bank, 2020). According to Antràs, (2020), a formal definition of a GVC indicates towards a set of production activities fragmented across the world that add value to the development of a good or a service, and each of the firms participating in the production network are engaged in at least one stage of production. This definition highlights the key conceptual distinction between trade in GVCs and traditional trade, as the former relates to trade in intermediates while the latter focuses on the trade in final products.

Since the great ICT revolution in the late 1990s and early 2000s, trade in GVCs is constantly rising, as it now roughly accounts for about one half of all trade activities (World Bank, 2020). This deepening in GVC activities has brought forward significant implications regarding the study and quantification of countries and sectors participating in GVCs, as traditional trade statistics (such as gross exports) become unreliable when challenged to capture complex production transactions across the world (Johnson and Noguera, 2012; Koopman et al., 2014; Borin and Mancini, 2019). A solution to this challenge was provided by I-O based participation indicators, which originate from the seminal work of Hummels et al. (2001) and the measurement of vertical specialization, also known as the 'import content of exports', that provided the first rough takes on backward and forward participation. Building on the Hummels et al. (2001) framework, Johnson and Noguera (2012) introduced a VA accounting framework for the measurement of VA exports and the development of the famous 'VAX ratio', which measures the VA content of trade. These seminal works were combined and extended under a common framework by Koopman et al. (2014), who provided a decomposition of gross exports into foreign value-added (FVA) components and domestic value-added (DVA) components that better depict backward and forward participation as a share of each sector-country's gross exports. In a latter work, Wang et al. (2017) further refined this framework using a production-based approach to further decompose GVC participation in simple and complex activities, which become quite important in the process of upgrading in GVCs.

The concept of upgrading was initially introduced by Porter (1990) as the process that leads to better products, more efficient production or move to more skilled activities. Kaplinsky and Readman (2005) and Humphrey and Schmitz (2002) further evolved this concept within the context of GVC, and identified four distinct types of upgrading, namely product and process upgrading that mainly reflect industrial upgrading at the firm/sector level, and functional and intersectoral upgrading that mostly relate with economic upgrading at the country level. In a more general sense, their conceptualization of upgrading in GVCs reflects the move to higher VA activities (Gibbon and Ponte, 2005) and relates to the asymmetry of VA appropriation along the value chain as depicted in the famous U-shaped smiling curve (Mudambi, 2008; OECD, 2013).

According to the smiling curve, VA in GVCs is concentrated in upstream and downstream activities, which are intangible-intensive and dominated by knowledge-intensive services, while manufacturing activities stagnate in the middle part, where traditional process and fabrication activities occur. This asymmetry is also evident at the country level, as developed economies follow a deindustrialization pattern towards activities in the upstream and downstream stages, while outsourcing industrial production to developing ones (Meng et al., 2020). This process also affects the manufacturing sectors of advanced economies *per se*, as they are constantly integrating service components and knowledge assets into their activities, in an attempt to upgrade in more lucrative production stages through an ongoing 'servicification' (Miroudot and Cadestin, 2017). The key elements that define this process is the accumulation and control of knowledge assets as a mean to secure specialization gains (Durand and Millberg, 2020; Tsakanikas et al., 2022) and the proper integration in GVCs based on a suitable selection or move to high-VA activities.[1]

This study aims to investigate these two elements, i.e., the role of knowledge assets and GVC participation in the process of upgrading, by focusing on the interesting case of the FBT sector. One motivation for the selection of this case study relates to the critical role of sector-specific characteristics in the process of upgrading. A second one is based on the significant knowledge base of FBT sectors which is usually underestimated as it encompasses non-R&D assets, whereas the related GVC literature has predominantly focused on high-tech sectors, such as ICT-related industries in Meng et al., (2020; 2022) and the famous example of the automotive sector in Timmer et al. (2015). Low-tech sectors, despite their relatively low formal R&D activity, develop a significant knowledge base related to non-R&D activities and their technological transformation is based on technological advancements of other high-tech sectors such as ICT, biotechnologies, health etc. They have been described as 'carrier' industries, in the sense that they carry into widespread use new technologies generated in high-tech sectors (Christensen et al., 1996; Robertson and Smith, 2008; Heidenreich, 2009; Robertson and Jacobson, 2011).

3. Methodology

To study the effects of KBC stock and GVC participation on upgrading, we adopt a three-stage empirical strategy. At the first stage, we develop a set of indicators that enables us to capture different types and modes of GVC participation, building on the production-based decomposition framework proposed by Wang et al. (2017). We further utilize additional decomposition frameworks from the seminal works of Jonhson and Noguera (2012) and Koopman et al. (2014) to develop an exports-oriented specialization indicator for industrial upgrading in GVCs, which focuses specifically on product upgrading. For our calculations, we turn to the newly released 2021 edition of OECD's ICIOs, which provides data for 45 2-digit NACE Rev. 2 sectors from 66 countries in the period 1995-2018. Second, we turn to the 2019 edition of the EU-KLEMS database (Stehrer et al., 2019) to retrieve KBC and fixed capital stock data and develop intensity indicators. Based on the EU-KLEMS data availability, we develop a sample that contains GVC and KBC data for 14 FBT sectors from several EU economies[2] in the period 1995-2017. At the third and final stage, we model our indicators in a set of panel regressions to empirically investigate their effects as determinants of industrial upgrading in GVCs.

---

[1] Of course, these two aspects are interrelated, as knowledge assets enhance participation in GVCs (Jona-Lasinio et al., 2019)

[2] In detail, we cover the FBT sectors from Austria (AUT), Belgium (BEL), Czech Republic (CZE), Denmark (DNK), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Italy (ITA), the Netherlands (NDL), Slovakia (SVK), Spain (ESP), Sweden (SWE), and the UK (GBR).

The following sections are devoted to the development of the indicators and the econometric application of this study. The detailed computational procedure for each of the GVC-related indicators can be found in Appendix A.

3.1 Monitoring upgrading via a sophistication indicator

As discussed above, relevant literature has proposed several indicators to capture different elements and dimensions of economic upgrading. Tian et al. (2019) discuss a large set of empirical instruments for different upgrading dimensions, ranging from traditional growth (labor and total factor productivity based) metrics, capital intensity indicators, exports growth (implying that increased exports shares/ exports unit values suggest that an upgrading is underway), skills intensity in exports, changes in the sectoral composition of exports at the country level, etc. For the purposes of this study, we develop a sector-specific case study on the industrial upgrading of EU FBT sectors in GVCs. Naturally, we are inclined to focus on product upgrading implications and embed our analysis within the context of GVC activities. To this end, a suitable candidate to monitor upgrading would be the VA exports of each FBT sector, following the framework of Johnson and Noguera (2012) with further refinements to purge pervasive double-counting implications from Koopman et al. (2014). In fact, Johnson and Noguera (2012)'s VAX ratio (i.e., the ratio of VA exports relative to gross exports) has already been utilized to proxy economic upgrading in several GVC-oriented studies (see Taglioni and Winkler, 2016, Ahmad and Primi, 2017 and Tian et al., 2019).

However, to fully capture industrial product-upgrading one must also consider a comparative perspective as well to provide a baseline that defines whether an actual upgrade into higher VA-grossing products has occurred. This can be accomplished through Ricardian comparative advantage indicators, that reflect the specialization of a sector/country's exports following the seminal work of Balassa (1965) and his revealed comparative advantage (RCA) indicator. Indeed, RCA type indicators provide useful empirical tools to capture competitiveness and sophistication implications at the sector and the country level and are frequently utilized in trade and policy studies, including recent applications within the context of GVCs as well (Koopman et al., 2014; Timmer et al., 2018; Tsakanikas et al., 2022). In the context of this study, we use the novel 2021 ICIOTs of OECD and combine the approaches of Johnson and Noguera (2012) and Koopman et al. (2014) for the calculation of the VA content of exports at the sector level with Hausmann et al. (2007)[3] exports sophistication approach on RCA, to develop an adjusted sophistication indicator that reflects product-upgrading in GVCs for the sectors of our sample, as described in eq.1:

$$xsoph_{i,t} = \frac{\dfrac{VAX_{i,c,t}}{VAX_{M,c,t}}}{\dfrac{VAX_{i,w,t}}{VAX_{M,w,t}}} \qquad (1)$$

This indicator depicts the share of each FBT sector's VA exports in its aggregate domestic manufacturing industry VA exports, relative to the average share of the world FBT sector in the corresponding world manufacturing exports.[4]

[3] To introduce the sophistication dimension in their export's specialization indicator, Hausmann et al. (2007) included country-level GDP per capita (PRODY) as a corrective factor to their RCA-type EXPY sophistication indicator. Due to availability of data at a higher aggregation (sector compared to product-specific) level, we can further refine this indicator through VA exports measures to replace the simplified country-level correction for sophistication.

[4] The VA-exports measures deployed in this study consider re-imported VA, which is an additional element to those included in the Johnson and Noguera (2012) framework and is calculated following the decomposition procedure of Koopman et al. (2014).

Details regarding the computational procedure and the integrated decomposition frameworks utilized for the quantification of this indicator are provided in Appendix A, alongside a brief intro on the basics of I-O analysis to help guide the interested reader throughout the calculations.

3.2 Simple and complex GVC activities: a production-based decomposition framework

One of the main goals of this study is to unveil the implications between sophistication and different types and modes of GVC participation for the underlying EU FBT sectors. In this line, our empirical challenge reflects the intricacies of different modes of GVC participation that remain 'hidden' in the broad indicators of backward and forward participation, as defined in the seminal work of Koopman et al. (2014). More specifically when accounting for the 'import content of exports' (i.e., vertical specialization), one remains agnostic regarding the actual number of production stages from which the imported VA originates from. In the opposite direction, the same holds for forward participation as well, as we cannot clearly distinguish between DVA in the exports of a partner that is subsequently used for production and final consumption by the third party, and which continues to be re-exported for production into other subsequent trade partners. This complexity implications become quite relevant at the country and especially the sector level, as some sectors participate in more complicated production networks than others. A relevant example is the case of manufacturing sectors, the complexity of their global supply networks is constantly rising, and different sectors present different levels of GVC integration based on the nature of their core activities (Baldwin and Evenett, 2015; Miroudot and Cadestin, 2017; Tsakanikas et al., 2022). For FBT sectors, which are traditionally oriented towards final consumption and given the constraints of their core products[5], the complexity implications that relate to both their forward and backward participation in GVCs may provide significant insights regarding their positioning and industrial upgrading in higher VA-grossing activities.

To tackle these implications, we turn to a production-based decomposition framework introduced by Wang et al. (2017), which classifies GVC and non-GVC activities based on the VA that crosses borders for production or final use. This VA-based decomposition framework tackles certain limitations of its predecessors, and namely the gross exports decomposition framework by Koopman et al. (2014)[6] as it shifts the focus from gross exports into VA and introduces additional dimensions (or modes) that disaggregate the backward and forward participation indicators into simple and complex activity modes. Following this framework, we can distinguish among the following types of VA trade:

- Domestic value chain trade, where DVA is traded between domestic sectors for production purposes and without crossing borders.
- DVA in exports for final use, the traditional trade component of VA which is sold abroad directly to final consumers.
- VA (both domestic and foreign) embodied in the imports/exports of intermediates, which corresponds to the GVC trade component of VA.

The latter dimension provides the platform for the further decomposition of embodied VA in simple and complex GVC activities:

- DVA (FVA) embodied in intermediate exports (imports) which crosses borders for production purposes only once and is consumed by the importing sector/country for production of final

[5] Quality and preservation are quite important elements in the agri-food supply chain and hinder the formation of extensive and complicated supply networks.

[6] To be concise, Wang et al. (2017) approach builds on the fundamentals of Koopman et al. (2014) and revamps the exports-oriented calculation of backward and forward participation to tackle measurement errors which were particularly persistent at the sector level. As a result, the production-based approach provides more robust metrics for sector-level applications.

products to be consumed domestically. This dimension represents the mode of simple forward (backward) GVC participation.

- DVA (FVA) embodied in intermediate exports (imports) that are re-exported (re-imported) by the partner sector/country to (from) third parties for production or final consumption. This dimension corresponds to the mode of complex forward (backward) GVC participation.

We implement this decomposition framework in the 2021 edition of OECD's ICIOTs to provide tailor-made indicators for the EU FBT sectors of our sample in the period 1995-2017. In terms of backward participation, we start from the aggregate vertical specialization indicator in eq.2 and decompose it to account for simple and complex activities in eq.3 and eq.4:

$$B_{i,t}^{GVC} = \frac{FVAinGX_{i,t}}{VA_{i,t}} \tag{2}$$

$$B_{i,t}^{simple} = \frac{FVA^{smpl}inGX_{i,t}}{VA_{i,t}} \tag{3}$$

$$B_{i,t}^{cplx} = \frac{FVA^{cplx}inGX_{i,t}}{VA_{i,t}} \tag{4}$$

Where $FVAinGX_{i,t}$ comprises the sum of FVA embodied in the gross exports of each FBT country-sector pair i, and the simple and complex components of FVA are further included in individual indicators as well. A similar approach is adopted for the forward participation indicators in the following set of equations (eq. 5, eq.6 and eq.7):

$$F_{i,t}^{GVC} = \frac{DVAinGXp_{i,t}}{VA_{i,t}} \tag{5}$$

$$F_{i,t}^{simple} = \frac{DVA^{smpl}inGXp_{i,t}}{VA_{i,t}} \tag{6}$$

$$F_{i,t}^{cplx} = \frac{DVA^{cplx}inGXp_{i,t}}{VA_{i,t}} \tag{7}$$

Where $DVAinGXp_{i,t}$ depicts the sum of DVA from the FBT sector i in the gross exports of partner sector-countries for production purposes, and the simple and complex components of this subset of DVA are further included in the respective indicators.

A detailed elaboration on the decomposition framework and the computational procedure on OECD's ICIOTs is provided in Appendix A.

3.3 Knowledge-based and other types of capital intensity

To account for the stock of knowledge of each FBT sector in our sample, we turn to the 2019 edition of the EU-KLEMS which follows the Corrado et al. (2005; 2009; 2016) classification and quantification approach on intangibles. According to them, intangibles are classified into three wide categories that include:

- Computerized information, such as software and databases.
- Innovative property, such as R&D, design, financial innovation, and other intellectual property (IPP) assets.

- Economic competencies, such as branding (advertising and marketing research), organizational capital (own and purchased) and training.

They further developed an expenditure-based approach for the quantification of these assets, which corresponds to the products of innovative activities which OECD describes in its latest edition of the Oslo manual for the measurement of innovation (OECD and Eurostat, 2018), and utilizes gross fixed capital formation (GFCF) data to capitalize KBC investment flows for assets included within the National Accounts system. This first group of KBC includes R&D, software, databases, and other types of IPP products such as mineral exploitation and artistic originals. A second group of KBC outside the National Accounts derives from supply-use data regarding advertising and market research, purchased organizational capital, and design, which are subsequently capitalized following the framework of Corrado et al. (2016).[7] Finally, a third group derives from the joint elaboration of different surveys (such as the EU Labor Costs Survey and the EU Structure of Earnings Survey) with National Accounts and supply-use data[8], and includes own account organizational capital and vocational training.

Drawing from the EU-KLEMS pool of data, we develop KBC intensity indicators per type of KBC asset as described in the following equation:

$$k_{i,t}^{KBC} = \frac{K_{i,t}^{KBC}}{EMPE_{i,t}} \tag{8}$$

where $K_{i,t}^{KBC}$ corresponds to KBC capital stock[9] per type of KBC[10], and EMPE stands for the number of employees in the FBT sector i in each country.

We further expand our capital intensity indicators to account for tangible capital components, distinguishing between ICT capital stock and the rest of fixed capital components, as described in the following equations:

$$k_{i,t}^{ICT} = \frac{K_{i,t}^{ICT}}{EMPE_{i,t}} \tag{9}$$

$$k_{i,t}^{TAN_{noICT}} = \frac{K_{i,t}^{TAN_{noICT}}}{EMPE_{i,t}} \tag{10}$$

where $K_{i,t}^{ICT}$ corresponds to ICT capital stock and $K_{i,t}^{TAN\_noICT}$ to the rest of the fixed capital stock in the FBT sector i in each country. Data regarding fixed capital stock and employment at the sector level are also drawn from EU-KLEMS.

[7] These supplementary assets are constructed following a set of assumptions regarding their capitalization and depreciation. For more information, see Corrado et al. (2016) and Stehrer et al. (2019).
[8] For details regarding the computational procedure, see Stehrer et al. (2019).
[9] KBC stock in the 2019 EU-KLEMS is calculated from investment (GFCF) data using the Perpetual Inventory Method (PIM).
[10] We select to drop own account organizational capital and other IPP assets due to data availability for the FBT sectors of our sample.

3.4 Model specification and estimation strategy

We model the aforementioned indicators of GVC participation, KBC and fixed capital stock into simple panel regressions, to investigate their effects on exports sophistication. Our model specification is presented in eq. 11:

$$xsoph_{i,t} = \alpha_0 + \boldsymbol{X_{i,t}}\beta_1 + \lambda_i + \lambda_t + \varepsilon_{i,c,t} \qquad (11)$$

where $\boldsymbol{X_{i,t}}$ denotes a vector of sophistication explanatory variables at the sector (i), country (c) and time (t) level:

$$\boldsymbol{X_{i,t}} = \left(B_{i,t-1}^{GVC}, F_{i,t-1}^{GVC}, k_{i,t}^{KBC}, k_{i,t}^{TAN_{noICT}}, k_{i,t}^{ICT}\right) \qquad (12)$$

In detail, the GVC participation indicators are lagged by one period, following the remarks of Tsakanikas et al. (2022) and Constantinescu et al. (2019) that gains from participation in GVCs are not instantaneous. An additional motivation for the lagged terms relates to the potential simultaneity bias in the specification.[11] We further include sector/country (λ_i) and time (λ_t) fixed effects to account for unobserved country and time-specific macroeconomic, trade, and technology factors that may determine the sophistication of FBT exports. Another refinement includes taking the variable into natural logarithms for scaling purposes, to account for outliers and provide elasticity measures (Wooldridge, 2010).

For our estimation strategy, we select to deploy pooled OLS estimators with panel-corrected standard errors (PCSEs)[12], which are robust to both heteroskedasticity and panel-specific autocorrelation (Beck and Katz, 1995).[13]We further acknowledge the possible presence of endogeneity in our specification due to reverse causality (simultaneity) and omitted variable bias in our specifications. However, the unavailability of reliable instruments for KBC[14] and poor efficiency by generalized method of moments (GMM) estimators[15] prevent us from adopting a relevant estimation strategy. To mitigate the effects of reverse causality in our specification, we use lagged terms for the full set of forward and backward participation indicators and introduce a large set of fixed effects.

The full set of variables deployed in the econometric application is presented in Table 3.1:

Table 3.1: Variable definition and source.

Variable	Definition	Data source
$xsoph_{i,t}$	The ratio of the share of value-added exports of each FBT sector in its total domestic manufacturing value-added exports relative to the corresponding average world share (natural log).	OECD ICIOTs (own calculations)

[11] Accordingly, increased forward or backward participation may reflect the sophistication of each FBT sector's product.

[12] Given the presence of heteroskedasticity and first order serial autocorrelation in our sample, another option would be to adopt feasible generalized least squares (FGLS), but they tend to produce unreliable standard error estimates (Hoecle, 2007).

[13] We further tested for the presence of cross-sectional dependance (contemporaneous correlation of errors across panels), but the results of both Breusch-Pagan LM and Pesaran's diagnostic tests were negative (Breusch and Pagan, 1980; Pesaran, 2004).

[14] The identification of proper indicators to instrument intangibles' related variables is a notable problem and is also reported in the studies of Jona-Lasinio et al. (2019) and Tsakanikas et al. (2022).

[15] Both two-step system and difference GMM estimators provided unreliable results that relate with the small cross-sectional dimension of our panel (i.e., 14 FBT sectors in each year) compared to the number of lagged instruments produced in both cases.

$B_{i,t-1}^{GVC}$	The share of FVA in gross exports relative to the VA of each FBT sector (natural log – lagged by one period).	OECD ICIOTs (own calculations)
$B_{i,t-1}^{smpl}$	The share of FVA that derives from simple GVC activities in gross exports, relative to the VA of each FBT sector (natural log – lagged by one period).	OECD ICIOTs (own calculations)
$B_{i,t-1}^{cplx}$	The share of FVA that derives from complex GVC activities in gross exports, relative to the VA of each FBT sector (natural log – lagged by one period).	OECD ICIOTs (own calculations)
$F_{i,t-1}^{GVC}$	The share of DVA in partner gross exports relative to the VA of each FBT sector (natural log – lagged by one period).	OECD ICIOTs (own calculations)
$F_{i,t-1}^{smpl}$	The share of DVA in partner gross exports for simple GVC activities, relative to the VA of each FBT sector (natural log – lagged by one period).	OECD ICIOTs (own calculations)
$F_{i,t-1}^{cplx}$	The share of DVA in partner gross exports for complex GVC activities, relative to the VA of each FBT sector (natural log – lagged by one period).	OECD ICIOTs (own calculations)
$k_{i,t}^{KBC}$	Total KBC capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{R\&D}$	R&D capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{Soft\_DB}$	Software and databases capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{AdvMaR}$	Advertising and market research capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{POCap}$	Purchased organizational capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{Dsg}$	Design capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{VTrain}$	Vocational training capital stock per no. of employees for each FBT sector (natural log)	EU-KLEMS (2019 edition)
$k_{i,t}^{ICT}$	ICT capital stock per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)
$k_{i,t}^{TAN\_noICT}$	Fixed capital stock without ICT per no. of employees for each FBT sector (natural log).	EU-KLEMS (2019 edition)

4. Results and discussion

4.1 Descriptive statistics and some salient facts

The starting point of our descriptive analysis relates to the accumulation of KBC stock in each FBT sector of our sample. Fig.4.1 presents the average FBT sector-level KBC stock intensity, in terms of total output[16], per country of origin and per type of KBC asset.

[16] We resort to KBC stock per total output intensities to provide a comparable metric of the contribution of each sector's knowledge stock to its total output while purging our indicators from the size effects of the different FBT sectors of our sample, which are reflected into their respective no. of employees. On the other hand, these size effects that relate with each sector's employment are quite relevant in our econometric analysis and are discussed in the following section.

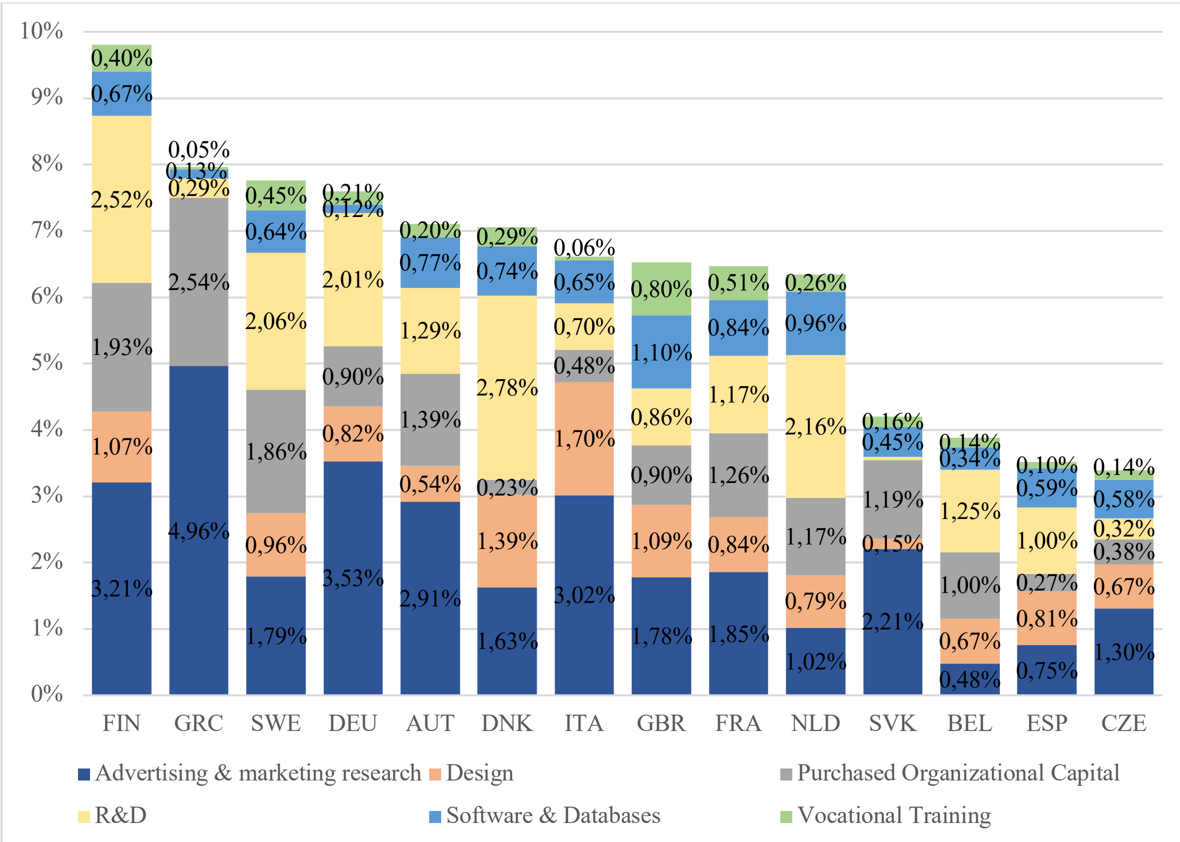

Figure 4.1: FBT sector-level KBC stock intensity shares (in terms of total output) per type of KBC asset and per country (1995-2017 series avg.)

According to Fig 4.1., Finland's FBT sector appears to be the most KBC intensive, with an average intensity at 9.8%, and followed by those from Greece and Sweden with average intensities at 8% and 7.8%, respectively. Several other FBT sectors further present average intensities above 7%, including those from Germany, Austria, and Denmark. In the middle section of the graph, we find the FBT sectors of Italy, the UK, France, and the Netherlands, with average intensities between 6% and 6.7%. In the right hand-side of the graph we observe the FBT sectors that lag in terms of knowledge intensity, with average levels well below 5% and especially in the cases of Belgium, Spain, and Czech Republic.

Another set of interesting findings relates with the type of KBC asset that the FBT sectors from each country utilize. A common trend in all the countries of our sample is that advertising and market research or branding capital is the most frequently utilized knowledge asset, as most FBT sectors present average intensities well above 2%. The leading FBT sector in terms of branding stock comes from Greece, with an average intensity of approximately 5%, and is followed by those from Germany (3.5%), Finland (3.2%) and Italy (3%). On the other hand, the lagging FBT sectors in terms of branding include those from Netherlands, Spain, and Belgium.

When accounting for FBT R&D intensity, we find that for most countries, the average intensity is above 1%. Notable leading R&D FBT sectors come from the Nordic economies (Denmark, Finland, and Sweden) and the Netherlands. Conversely, although knowledge-intensive in terms of non-R&D KBC assets, Greece's FBT sector presents the lowest R&D intensity at approximately 0.3%, on par with the FBT sector from Czech Republic, which is the least knowledge-intensive FBT sector of our sample. This interesting finding highlights the significance of monitoring non-R&D knowledge assets when accounting for the knowledge base of each sector, as other KBC components may compensate the lack of R&D activities. Furthermore, our findings indicate that monitoring only R&D activities to conduct generalized conclusions regarding knowledge intensity may be misleading. Another relevant example is that of the Dutch FBT sector, were R&D intensity is relatively high (2.2%), but other types of knowledge assets are seldomly used.

In terms of organizational capital[17], we observe that the FBT sector of Greece is by far the most intensive, with an average intensity of 2.5%. The Finnish and Swedish FBT sectors follow, with average intensities at approximately 1.9%. On the other hand, the FBT sectors that lag in terms of organizational capital originate from Italy, the Czech Republic and Spain. Another notable laggard is the otherwise knowledge intensive Danish FBT sector, with an average intensity of 0.2%.

Computerized information in the FBT sectors, proxied by software and databases capital stock, presents a similar pattern of low average intensity in most of the countries of our sample, an expected outcome based on the core processing activities of FBT industries, with UK leading the way (1.1%) and Netherlands (1%) and France (0.8%) following. On the contrary, the German and Greek FBT sectors appear to be the least software intensive sectors of this sample (both at 0.1%).

The last two components of KBC capital stock are design and vocational training stocks. For the former, we observe that the FBT sectors of our sample seldomly engage in design activities, with average intensities ranging between 1.1% to 0.6%. Notable exceptions to this pattern are the leading design intensive FBT industries from Italy (1.7%) and Denmark (1.4%), the lagging Slovakian FBT sector (0.2%) and the peculiar case of the Greek FBT industry where no design stock is recorded in the time frame of our analysis.[18]For the vocational training stock, we observe that it is the least used KBC asset by the sectors of our sample, as the largest intensity share is at 0.8% and is attributed to the UK's FBT sector.

An overview of our KBC intensity descriptive statistics presents interesting insights regarding the actual knowledge intensity of the otherwise known as low-tech FBT sectors. Specifically, we find that R&D intensity, the technology classification metric that OECD and Eurostat use for their tech-classification, is not the most frequently utilized knowledge asset in FBT industries, as we document significant intensity in the use of branding and organizational capital stock. These two assets enhance the knowledge base of the FBT industries and are also critical for their GVC participation, as the former reflects organizational capabilities needed for integration in the global production network and the latter unlocks modes of participation which are linked with higher VA-grossing activities in the downstream segment of the smiling curve, which are particularly relevant for a final consumption-oriented sector such as the FBT.

The above findings point to the importance of investigating other types of intangibles especially when looking in specific sectors as not all sectors are the same in terms of learning and innovation processes. They also reflect the fact that the type of intangibles used might differ according to the positioning of firms in the value chain, that is either firms are mainly positioned at the upstream and/or downstream parts of the smiling curve or mainly at the production part.

Stepping into the implications of FBT participation in GVCs, Fig.4.2 presents the overall time series of different types of participation for all the FBT sectors of our sample. A first observation is the FBT GVC

---

[17] Henceforth, we refer to advertising and market research capital as branding capital and to purchased organizational capital as organizational capital for abbreviation purposes.
[18] This finding constitutes a motivation for further research as it relates to two possible explanations: unavailability of data/measurement problems or country-specific intricacies that need thorough examination.

participation – both backward and forward – has increased in the period 2000-2008, following the great deepening in GVC activities in the same period (Antrás 2020; World Bank 2020). The 2008 financial crisis severely tampered this increasing trend, with a significant drop in all types and modes of participation evident in 2009, followed by an immediate recovery in 2010. FBT sectors appear to be persistently more backward-oriented, as both simple and complex backward participation activities are consistently on higher levels compared to their respective forward-oriented counterparts. Simple backward participation appears to be the main mode of FBT GVC participation, with a significant drop in 2009, a recovery at lower levels in the period 2010-2014, and a declining pattern in the period 2014-2017. At the same time, complex backward activities – although with a more severe drop in 2009 – appear to be significantly rising in our time frame. In fact, they appear to converge with simple backward activities in the 2014-2017, following an opposite growth pattern and presenting evidence of more complex backward integration for the FBT sectors of our sample. On the other hand, both simple and complex forward participation activities present smoother trends, with patterns of growth in the post-crisis period and a slight convergence in the 2014-2017 period. Combining these observations, we monitor a deepening in complex GVC activities for the EU's FBT sectors, which contrasts with the established perception of short production chains and final consumption orientation of FBT sectors in general and indicates towards the integration of different activities (and possibly more in-house support services) in the core business of the sector.

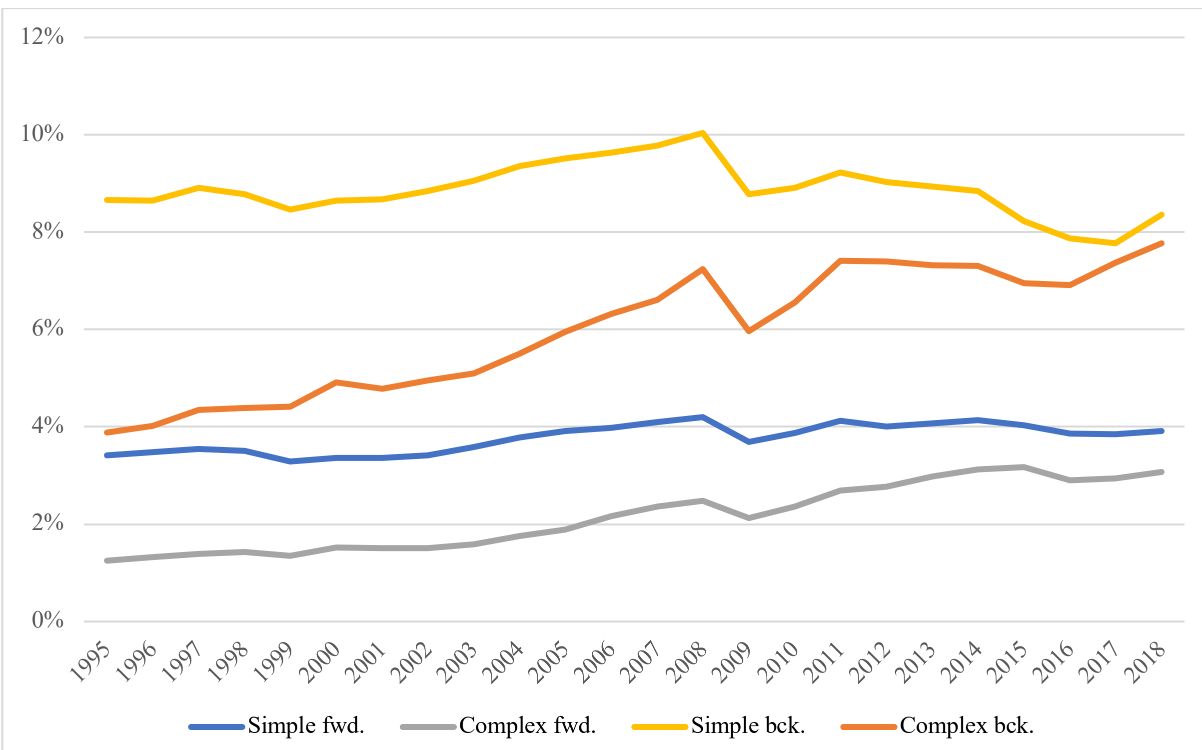

Figure 4.2: The evolution of GVC participation per type (backward and forward) and mode (simple and complex) for selected EU FBT sectors in the period 2000-2017.

The increasing integration of FBT sectors in the global production network and thus in international trade and globalization is further depicted in the decomposition of their VA, as presented in Fig.4.3. Accordingly, we observe that the share of domestically consumed VA, while dominant in the early 1990's (at approximately 80%), is constantly declining and the share of VA in traditional trade is constantly rising, which indicates a significant rise in the gross exports for final consumption for the FBT sectors of our sample. At the same time, VA in exports for both simple and complex GVC activities appear to be increasing in the most recent years, with complex activities gradually further increasing their respective shares from 2009 and onwards.

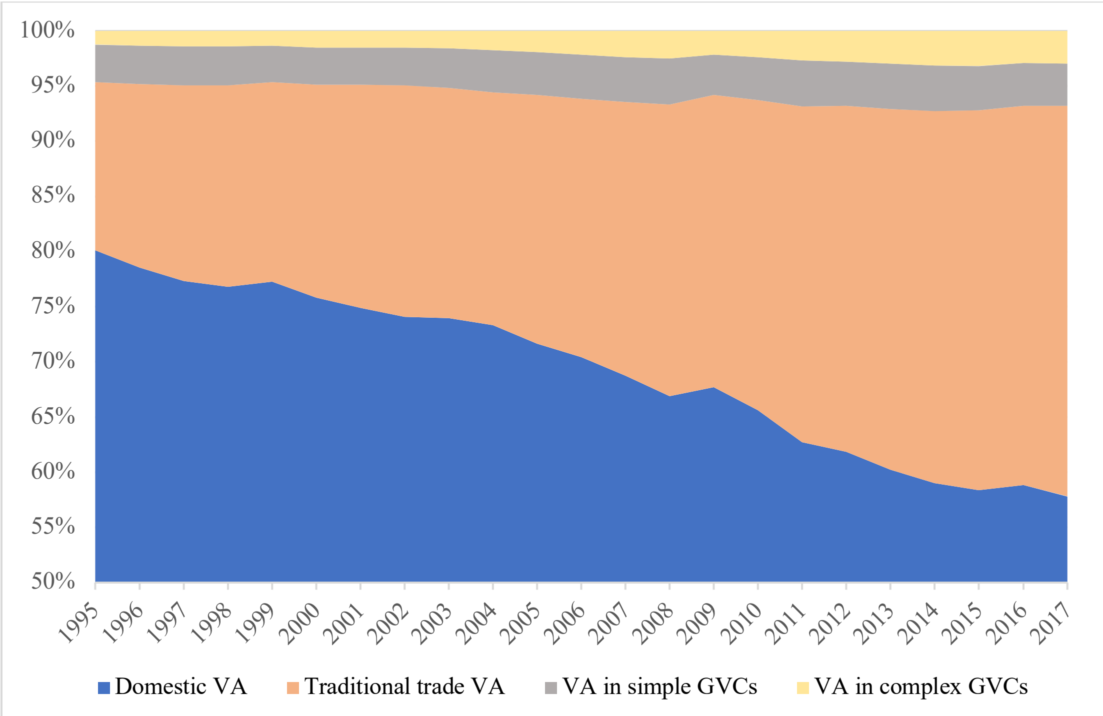

Figure 4.3: Decomposition of VA in (per type of consumption) for the selected EU FBT sectors in the period 1995-2017. Note that the vertical axis is shortened.

In Fig.4.4 we introduce the country level in our analysis and present the shares of backward and forward participation (both simple and complex) in the beginning (1995) and the end (2017) of our time frame. We observe that for most of the countries, the backward participation of their FBT sectors has significantly risen between 1995 and 2017. Notable increases are documented for the FBT sectors of Austria, Greece, Denmark, and Finland. The same holds for forward participation as well – although at lower levels. In this case, it is the German and Spanish FBT sectors that have significantly increased their forward participation between 1995-2017, while the highest levels of forward participation are recorded in Denmark and the Netherlands. An overall inspection of the graph indicates that several sectors are clearly oriented towards either domestic (both intermediate and final) or traditional trade (final but abroad) activities, such as the Spanish, the French, the English, the Greek and the Italian FBT sectors. On the other hand, the Belgian, Dutch, Danish, Cech and Slovakian FBT sectors appear to be more engaged in GVC trade while the German, Finnish and Swedish sectors exhibit a more balanced orientation in their activities.

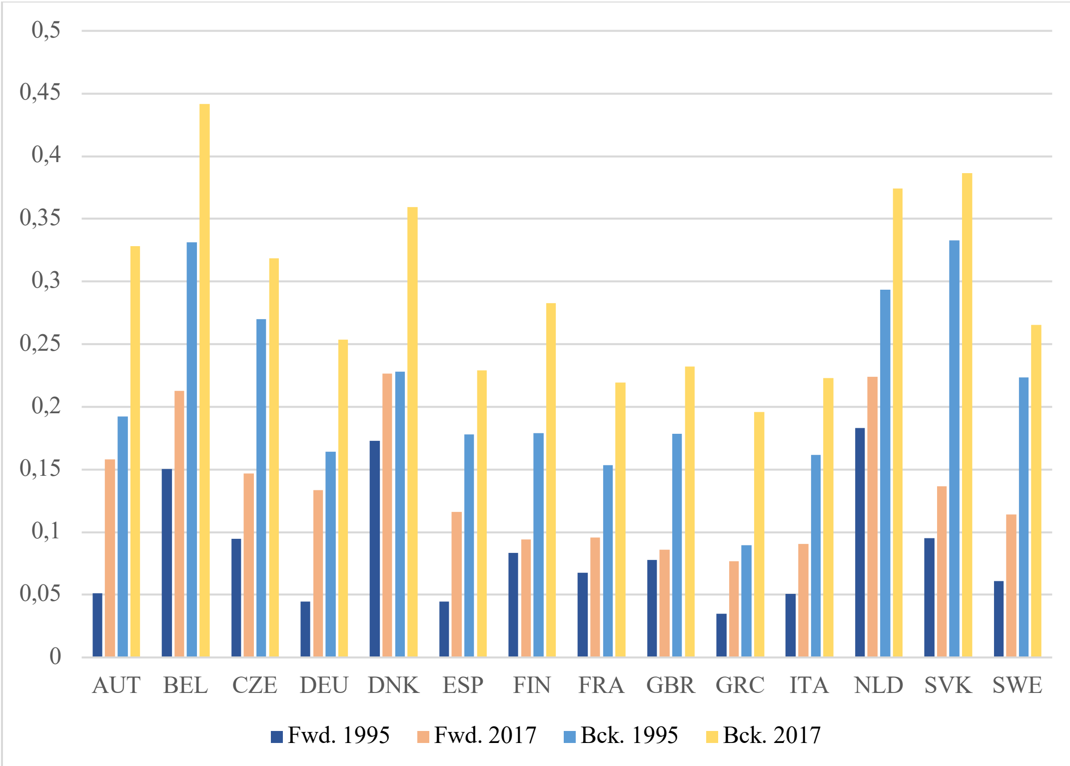

Figure 4.4: FBT participation (backward and forward) in GVCs in 1995 and 2017.

Before we explore the link among KBC stock intensity and the different types and modes of participation with upgrading in GVCs, the final step in our descriptive analysis includes a study of the evolution of each FBT sector's exports sophistication in the period 1995-2017 and is depicted in Fig. 4.5.

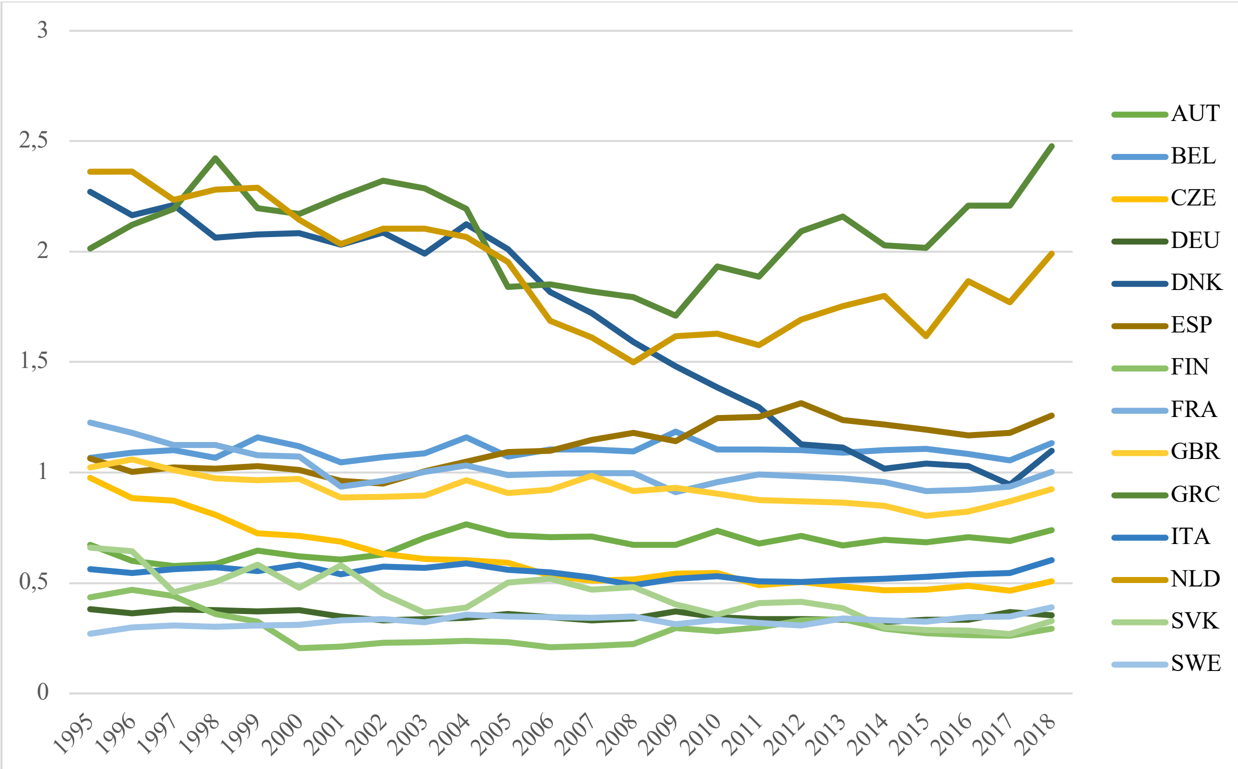

Figure 4.5: Evolution of FBT product upgrading (sophistication) in the period 1995-2017.

A first observation relates with the status of sophistication in the exports of the various FBT sectors in our sample. Using the unit as a threshold, we observe that the Greek, Danish, Dutch and Belgian FBT industries persistently demonstrate the higher sophistication in value-added exports compared to their domestic aggregate manufacturing industry.[19]On the other hand, FBT sectors from the Czech Republic, Austria, Germany, Italy, Slovakia, Finland, and Sweden appear to be consistently less sophisticated in their value-added exports. A third group which includes the FBT sectors from France, the UK and Spain are converging in the unit threshold, with the British sector falling marginally below the unit from 1997 and onwards, the Spanish sector surpassing the threshold in 2004 and the French falling just below the unit in 2000 and remaining at this level in the rest of the time frame. A notable case is the Danish FBT sector, which although well above the unit from 1995 to 2016, it exhibits a declining trend which was severely amplified in the period between 2006 and 2012. In fact, in 2017, the sophistication of the Danish FBT sector fell below the unit. One possible explanation relates with its significant deepening in backward participation activities, as the Danish FBT sector documents one of the higher shares and corresponding increases in backward participation from 1995 to 2017, as depicted in Fig.4. This fact may as well hinder the sector's own contribution in its gross exports, as it could possibly integrate disproportionate shares of FVA.

[19] A different interpretation of these results reads that Greek, Danish, Dutch and Belgian FBT sectors present a comparative advantage in terms of value-added exports.

4.2 Econometric results

To provide a more coherent interpretation of our econometric results, first we provide a set of panel regressions that account for the different types of aggregate backward and forward participation activities and the set of KBC and fixed capital assets and their contribution to industrial upgrading exports sophistication in Table 4.1. Our benchmark specification includes backward and forward GVC participation, fixed capital stock and (aggregate) KBC capital stock in column 1. Subsequently, we decompose fixed capital to ICT capital stock and tangible assets excluding ICT in column 2. Then, we introduce each type of KBC asset in different specifications to account for their individual effects on sophistication.[20]

Table 4.1: The determinants of product-upgrading per type of GVC participation and KBC stock.

Dependent variable: $xsoph_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$B_{i,t-1}^{GVC}$	-.035	-.037	-.015	-.114	-.059	-.038	-.023	-.016
	(.119)	(0.119)	(.118)	(.118)	(.118)	(.119)	(.118)	(.117)
$F_{i,t-1}^{GVC}$	.245***	.243***	.259***	.252***	.248***	.255***	.229***	.232***
	(.064)	(.066)	(.068)	(.065)	(.066)	(.070)	(.069)	(.070)
$k_{i,t}^{TAN}$	-.384***							
	(.075)							
$k_{i,t}^{KBC}$	.148***	.149***						
	(.060)	(.060)						
$k_{i,t}^{TAN\_noICT}$		-.390***	-.330***	-.276***	-.349***	-.357***	-.268***	-.236***
		(.070)	(0.061)	(.059)	(.070)	(.066)	(.063)	(.068)
$k_{i,t}^{ICT}$		.005	.003	.002	.001	.002	.002	.002
		(.030)	(.030)	(.029)	(.030)	(.031)	(.031)	(.030)
$k_{i,t}^{R\&D}$			.063***					
			(.024)					
$k_{i,t}^{Soft\_DB}$				.058***				
				(0.21)				
$k_{i,t}^{AdvMaR}$					.101**			
					(0.042)			
$k_{i,t}^{POCap}$						.121**		
						(.052)		
$k_{i,t}^{Dsg}$							-.004	
							(.061)	
$k_{i,t}^{VTrain}$								-.047***
								(.044)
constant	1.68***	1.69***	1.83***	1.45***	1.69***	1.84***	1.49***	1.32***
	(0.341)	(.314)	(.315)	(.299)	(0.333)	(.335)	(0.321)	(.346)
Sector/Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	301	301	299	301	301	301	301	301
No. of groups	14	14	14	14	14	14	14	14
R^2	.938	.938	.947	.940	.940	.931	.931	.931

[20] The different types of KBC stock are complementary to each other (Corrado et al., 2009; Jona-Lasinio et al., 2019) and thus are included in different specifications to avoid multicollinearity.

Notes: *, **, *** correspond to significance at the 10%, 5% and 1%, respectively. Panel-corrected standard errors recorded in parentheses. FE= fixed effects.

According to Table 4.1, it is forward participation in GVCs that provides a positive and statistically significant contribution to the export sophistication of the FBT sectors, while the effects of backward participation are rather negligible. This is a rather interesting finding, as FBT sectors appear to be more backward-oriented, and our results imply that deepening in backward participation activities does not translate into upgrading gains in GVCs. Another notable finding relates with the effects of fixed capital stock, which is found to have a negative and statistically significant effect on upgrading. Based on the concept of the smiling curve, increasing stock of fixed capital may reflect accumulation of machinery and other types of equipment which are related with traditional, low-VA manufacturing activities that lie on the middle of the U-shaped curve, and thus appear to have adverse effects on the transition towards more sophisticated activities of the FBT sectors.[21] This is further supported by the status of the economies that the FBT sectors originate from, as developed economies (such as the EU) undertake knowledge intensive segments in manufacturing supply-chains and leave traditional large-scale production for developing economies (Mudambi, 2008; OECD, 2013; Meng et al., 2020). Our results add further empirical evidence to this argument, as KBC stock presents a positive and statistically significant contribution to industrial upgrading, signaling that deepening in KBC enables the transition to more knowledge intensive activities that provide higher VA-gains. Furthermore, this result aligns with the expanding literature on the effects of intangibles to growth (Corrado et al., 2005; 2009; Roth, 2020) and manufacturing specialization in GVCs (Tsakanikas et al., 2022).

When accounting for different types of KBC, we find that the most significant driver of industrial upgrading for the EU's FBT sectors in GVCs is organizational capital, followed by branding (columns 5 and 6). These results highlight the significance of organizational capital for proper integration, coordination, and governance in GVCs (Gerrefi et al., 2005; Jona-Lasinio et al., 2019) and branding is an important asset for higher gains from final consumption-oriented activities such as the core business of the FBT sectors. Furthermore, both organizational capital and branding present higher contribution to upgrading than R&D – which is also positive and statistically significant but at a lesser extent. This result reflects the nature of the non-R&D knowledge base of FBT sectors, but also presents evidence that R&D is a key for upgrading even in low-tech sectors, as it unlocks higher VA-grossing upstream stages in the production chain. On the other hand, branding is mainly related with upgrading in downstream stages which also result in higher VA gains. Another set of results relates with the ICT-related assets, represented by ICT stock and software and databases. In detail, we find that deepening in ICT capital does not appear to boost the industrial upgrading of the EU's FBT sectors, a result that reflects the low importance of ICTs for FBT activities (mainly process activities) but contradicts the established importance of ICTs for proper integration in the global production network (Gereffi et al., 2005; Jona-Lasinio et al., 2019; Antràs, 2020; World Bank, 2020). However, software and databases provide upgrading gains in the sectors of our sample, hinting that the deepening in intangible, data-driven technologies is linked with higher VA gains even in the case of low-tech industries.

[21] Another line of reasoning relates with the negative effects of the depreciation of old tangible assets, such as outdated machinery and plant equipment. However, for this reasoning to stand, investment flows (GFCF) should also be tested in future empirical applications.

At a second stage, we provide the results of two panels where different modes of backward and forward participation in GVCs are introduced in the specifications. These results are presented in Tables 4.2 and 4.3, respectively.[22]

Table 4.2: The determinants of exports sophistication per mode of backward participation and KBC stock type.

Dependent variable: $xsoph_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$B_{i,t-1}^{smpl}$	-.147	-.147	-.196**	-.182**	-.162	-.163	-.143	-.145
	(.098)	(.098)	(.097)	(.094)	(.096)	(.098)	(.095)	(.097)
$B_{i,t-1}^{cplx}$	.253***	.253***	.285***	.234***	.244***	.237***	.236***	.235***
	(.057)	(.057)	(.054)	(.057)	(.059)	(.066)	(.058)	(.061)
$k_{i,t}^{TAN}$	-.350***							
	(.076)							
$k_{i,t}^{KBC}$	.142***	.146***						
	(.058)	(.058)						
$k_{i,t}^{TAN\_noICT}$		-.365***	-.345***	-.261***	-.326***	-.336***	-.277***	-.240***
		(.071)	(.064)	(.062)	(.072)	(.068)	(.065)	(.068)
$k_{i,t}^{ICT}$		.009	.010	.005	.008	.014	.012	.009
		(.029)	(.028)	(.028)	(.029)	(.030)	(.030)	(.029)
$k_{i,t}^{R\&D}$			.071***					
			(.027)					
$k_{i,t}^{Soft\_DB}$				.050**				
				(.024)				
$k_{i,t}^{AdvMaR}$					.087**			
					(.040)			
$k_{i,t}^{POCap}$						.101**		
						(.051)		
$k_{i,t}^{Dsg}$							.007	
							(.061)	
$k_{i,t}^{VTrain}$								-.032
								(.040)
constant	1.32***	1.39***	1.61***	1.16***	1.370***	1.46***	1.31***	1.10***
	(.357)	(.341)	(.328)	(.318)	(.359)	(.364)	(.331)	(.352)
Sector/Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	301	301	299	301	301	301	301	301
No. of groups	14	14	14	14	14	14	14	14
R^2	.945	.946	.956	.947	0.946	.938	.942	.943

Notes: *, **, *** correspond to significance at the 10%, 5% and 1%, respectively. Panel-corrected standard errors reported in parentheses. FE= fixed effects.

[22] We introduce the simple and complex modes of backward and forward participation in different specifications due to severe multicollinearity between the two complex modes. Multicollinearity issues further prevent us from including the GVC variables divided per no. of employees.

Table 4.3: The determinants of exports sophistication per mode of forward participation and KBC stock type.

Dependent variable: $xsoph_{i,t}$	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$F_{i,t-1}^{smpl}$	.495***	.491***	.542***	.501***	0.479***	.553***	.523***	.519***
	(.095)	(.096)	(.097)	(.106)	(0.106)	(.096)	(.105)	(.109)
$F_{i,t-1}^{cplx}$	-.272***	-.271***	-.306**	-.292***	-.259**	-.296***	-.307***	-.302***
	(.101)	(.102)	(.102)	(.108)	(.111)	(.106)	(.110)	(.114)
$k_{i,t}^{TAN}$	-.368***							
	(.077)							
$k_{i,t}^{KBC}$	.140**	.143**						
	(.063)	(.063)						
$k_{i,t}^{TAN\_noICT}$		-.380***	-.354***	-.289***	-.331***	-.363***	-.325***	-.271***
		(.073)	(.065)	(.063)	(.074)	(.067)	(.060)	(.073)
$k_{i,t}^{ICT}$		.008	.009	.010	.006	.008	.015	.008
		(.030)	(.030)	(.031)	(.032)	(.031)	(.031)	(.031)
$k_{i,t}^{R\&D}$			.063**					
			(.028)					
$k_{i,t}^{Soft\_DB}$				.050**				
				(.024)				
$k_{i,t}^{AdvMaR}$					.071*			
					(.043)			
$k_{i,t}^{POCap}$						.110**		
						(.048)		
$k_{i,t}^{Dsg}$							.016	
							(.059)	
$k_{i,t}^{VTrain}$								-.031
								(.044)
constant	1.38***	1.42***	1.62***	1.29***	1.43***	1.67***	1.45***	1.18***
	(.399)	(.368)	(.370)	(.362)	(.402)	(.379)	(.356)	(.386)
Sector/Country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	301	301	299	301	301	301	301	301
No. of groups	14	14	14	14	14	14	14	14
R^2	.936	.936	.941	.933	.935	.936	.929	.929

Notes: *, **, *** correspond to significance at the 10%, 5% and 1%, respectively. Panel-corrected standard errors reported in parentheses. FE= fixed effects.

Our results indicate that the disaggregation of backward and forward activities into simple and complex modes does in fact provide meaningful insights regarding the structural mechanisms that support industrial upgrading in GVCs. In detail, we find that the insignificant effects of aggregate backward participation mainly reflect the negligible contribution of the simple mode, which is statistically insignificant in all but two (Table 4.2, columns 3 and 4) specifications. On the other hand, complex backward participation provides a positive and statistically significant contribution to FBT upgrading, which remains 'hidden' and overpowered by the disproportionate shares of simple backward participation in the specifications containing the aggregate indicator (Table 4.1). The common characteristic in the two specifications that break this pattern is the presence of two specific types of knowledge assets, namely R&D and software and databases, which relate to more upstream production stages.[23]In these cases, increasing shares of simple backward participation hinders industrial upgrading. To interpret these intriguing findings, we use the smiling curve as the platform for our thought process. Accordingly, FBT sectors from the EU (developed) economies are expected to be oriented towards the upstream and (mainly) downstream segments of the value chain to secure higher gains from GVC participation. In this line, increased complex backward participation shares relate to the accumulation of FVA from multiple preceding production stages in partner economies and hint at an upgrading towards a downstream positioning for the underlying FBT sectors, which in turn favours exports sophistication. Conversely, increased simple backward participation relates to the accumulation of disproportionate FVA from a single upstream trade partner, which is naturally engaged in higher VA-grossing activities and 'pushes' the underlying FBT sector into the stagnating middle part of the smiling curve to process-related manufacturing activities. A similar reasoning can be developed for simple and complex forward participation activities in Table 4.3. In this case, we find that the positive contribution of forward participation to upgrading reflects the effects of simple forward activities, i.e., the integration of significant shares of VA to the final products of a single trade partner, which in turn relates to a downstream positioning of the FBT sector at the final stages before final consumption. On the other hand, increased complex forward participation shares indicate towards several succeeding production stages, which are naturally downstream to the FBT sector and place it in middle of the smiling curve. However, when accounting for aggregate forward participation, the negative effect of complex activities is overpowered by the larger shares of simple activities, which in turn hint that the FBT sectors of our sample are mainly preoccupied in downstream stages of the smiling curve.

Lastly, a common finding in all three panels is that design and vocational training do not affect FBT upgrading in GVCs.

5. Conclusions

As the knowledge content of global trade is constantly rising, firms participating in global value chains pursue to engage or re-position themselves in the lucrative intangible-intensive stages to secure higher gains from the value appropriation along the value chain. The key to this upgrading process is the accumulation and control of knowledge-based assets, and although their contribution is widely recognized for high-tech industries and knowledge-intensive services, little is known regarding their significance for low-tech sectors. This working paper sheds light to this latter dimension, as it investigates the effects of different knowledge assets and different types and modes of GVC participation to the industrial upgrading of a sample of food, beverage, and tobacco sectors from selected EU economies in the period 1995-2017. Our contribution can be summed up to the following key points.

First, we identify that knowledge capital is indeed a significant driver for product upgrading in GVCs even in the case of a low-tech sector such as the FBT. This finding extends the benefits of the accumulation of intangibles from knowledge-intensive to traditional manufacturing activities, as intangibles are critical for upgrading into downstream and upstream stages of the production. A second contribution relates to the type

[23] One could argue that software and databases exhibit a more horizontal application in the various production stages and are not concentrated in the upstream stages of product development. However, given the nature of the core activities of the FBT sectors, we argue that computerized information is more likely to be found in the early stages that relate to research, product innovation and quality control, that precede the large-scale processing activities.

of knowledge assets that boost this process. We find that it is branding and organizational capital that provide the major benefits to product upgrading for the EU's FBT sectors. This expected outcome relates to the established knowledge base of FBT sectors, which rely on advertising and marketing knowledge to enhance their competitiveness and reflects the benefits of organizational capital for proper integration in the global production network. R&D and computerized information further enhance FBT upgrading, although at a lesser extent.

A third set of results relates to the type and mode of GVC participation deepening for the FBT sectors. We find that forward oriented activities enhance FBT product upgrading, and especially simple forward participation. On the other hand, complex forward participation hinders product upgrading as it reflects the existence of several downstream production stages that succeed the FBT sector, and thus places him into lower value-added activities. Conversely, simple backward participation in GVCs does not affect FBT product upgrading. This finding reflects the negligible effects of higher shares of simple backward activities, as complex activities signal the existence of multiple preceding production stages, placing the FBT sectors in downstream segments and thus favouring upgrading.

Overall, our results present significant policy implications regarding the participation of FBT and in general low-tech sectors in GVCs, highlighting the significance of enhancing their knowledge base to secure competitiveness gains. They further elucidate the importance of considering different knowledge assets with respect to the sector at hand, as R&D statistics do not univocally address the approximation of knowledge accumulation in international trade, especially in the so-called low-tech sectors. In addition, GVC participation should be considered as a rather complex process and policy interventions should target to facilitate and enhance participation in specific modes and not an openness to GVC activities in general. These policy extensions present an intriguing motivation for extended research in the future steps of this working paper.

Appendix A

A.1 Brief overview on the basics of I-O analysis.

I-O analysis is regularly utilized for the development of quantitative applications and frameworks that monitor the production interdependencies of economic entities and was firstly introduced by Leontief (1936). I-O models generally treat an economy as a set of interconnected sub-components, each requiring inputs of goods and services from the other components and producing goods and services that are then consumed by the other components for their own production or are consumed by final users. Their implementation relies on three main assumptions about the nature and structure of the economy, namely that it is completely internal (all output is eventually consumed), with no effects of production scaling, and finally, that every industry corresponds to a single product and vice versa (i.e., no substitute products exist).

While I-O tables are usually compiled by the relevant authorities on a national level (one country with its industries) based on its supply and use tables, there exist differences in currency, accounting practices, trade balances and sectoral definition that often pose difficulties in drawing meaningful comparisons. To overcome such issues, Inter-Country Input-Output tables (ICIOTs) have been developed, with the most prominent ones being the World Input-Output Database (Timmer et al., 2015) and OECD's Inter-Country Input-Output (ICIO) Tables. Assuming a hypothetical world economy with N countries with K industries each, the following ICIOT can be obtained:

Table A.1: Input-Output table framework for an international economy of N partner countries with K industries per country

	Intermediate Consumption					**Final Uses**			**Total Output**
	Country	$\boldsymbol{C_1}$	$\boldsymbol{C_2}$	[...]	$\boldsymbol{C_N}$	$\boldsymbol{C_1}$	[...]	$\boldsymbol{C_N}$	
Intermediates Supply	$\boldsymbol{C_1}$	$X_{1,1}$	$X_{1,2}$	[...]	$X_{1,N}$	$F_{1,1}$	[...]	$F_{1,N}$	Y_1
	$\boldsymbol{C_2}$	$X_{2,1}$	$X_{2,2}$	[...]	$X_{2,N}$	$F_{2,1}$	[...]	$F_{2,N}$	[...]
	[...]	[...]	[...]	[...]	[...]	[...]	[...]	[...]	[...]
	$\boldsymbol{C_N}$	$X_{N,1}$	$X_{N,2}$	[...]	$X_{N,N}$	$F_{N,1}$	[...]	$F_{N,N}$	Y_N
Value Added		VA_1	[...]	[...]	VA_N				
Total Input		I_1	I_2		I_N				

Where X is the global matrix of intermediate consumption, with each sub-matrix $X_{i,j}$ being a $K \times K$ sized block containing the flows of intermediate goods and services from the sectors of country C_i to the sectors of country C_j for intermediate consumption. $F_{i,j}$ is a $K \times D$ matrix regarding the consumption of the D final users from the production of country C_i to country C_j, VA_i is a $1 \times K$ vector of the value added per sector of production from country C_i, and Y_i, I_i are $K \times 1$ and $1 \times K$ vectors containing the total gross output and the total requirements for inputs per sector and country pair. Following the core assumptions of the framework, total output must equal total input: $Y_i = I_i'$. The global coefficients of production can then be estimated[24] as $A = X\hat{Y}'^{-1}$ resulting in a $NK \times NK$ matrix. Following these formulations, total output of the economy can be written as $Y = AI' + F$, or as $Y = (I_{id} - A)^{-1}I$, with $(I_{id} - A)^{-1} = L$ being the familiar Leontief inverse matrix for the global economy and I_{id} an $NK \times NK$ identity matrix.

[24] The apostrophe (A') denotes the transpose matrix of A and the hat accent ($\hat{A}$) the diagonal matrix of vector A.

A.2 A production-based decomposition approach for the quantification of GVC participation

In an ICIOT, the flows of goods and services between the different sectors and countries are immediately identifiable and can be traced along production chains. However, information about the traded value added that is incorporated in those flows requires further elaboration. This section is dedicated to the presentation of the metrics we used based on the formulation and notation of the presented ICIO framework.

First, we estimate the share of value added to the total output of each sector and country (sometimes referred to as 'direct VA share':

$$VA_{to} = VA\widehat{Y^{-1}} \tag{13}$$

Multiplying VA_{to} by the global Leontief matrix and the vector of gross final uses per industry (oi) and country (oc) of origin, the global matrix of value-added traded by partner industry-country pair can be formed:

$$VA_{tr}^{oc,oi\rightarrow pc,pi} = \widehat{VA_{to}}L\widehat{F_{to}} \tag{14}$$

This matrix can then be further decomposed to form the country-industry network of value-added flows by country-sector of destination/origin and by type of use (for intermediate or for final uses). The present paper follows the decomposition method described by Wang et al. (2017), which utilizes the domestic and foreign submatrices of production coefficients and final demand due to bilateral trade from the ICIOTs to separate VA that is consumed in its country of origin from VA that is exported and then consumed abroad or is further embodied in other partner countries exports.

The first origin-to-destination dimension that can be obtained from $VA_{tr}^{oc,o\rightarrow pc,pi}$ is related to non-GVC related production activities, as it contains the VA that meets final use within the boundaries of its country of origin and is described in eq. 3

$$\boldsymbol{VA}_{d\rightarrow d,i}^{cons} = \widehat{\boldsymbol{VA}_{int,\iota}^{n,k}}(\boldsymbol{I}_{id} - \boldsymbol{A}_{dom}^{tot})^{-1}\widehat{\boldsymbol{F}_{dom}^{tot}} \tag{15}$$

Another related non-GVC type of VA flows are those embodied in the exports of domestic goods from a country-sector pair directed for final use in a foreign country.[25] This corresponds to traditional trade and comprises goods and services that are consumed immediately after they are imported:

$$\boldsymbol{VA}_{d\rightarrow f,i}^{cons} = \widehat{\boldsymbol{VA}_{int,\iota}^{n,k}}(\boldsymbol{I}_{id} - \boldsymbol{A}_{dom}^{tot})^{-1}\widehat{\boldsymbol{F}_{for}^{tot}} \tag{16}$$

These first two terms differentiate with respect to the final-use destination of the product of a country-sector pair. However, VA can also cross-national borders for use as an intermediate input to the production process, which can be estimated as:

$$\boldsymbol{VA}_{d\rightarrow f,i}^{int} = \widehat{\boldsymbol{VA}_{int,\iota}^{n,k}}\boldsymbol{L}_{dom}^{tot}\boldsymbol{A}_{for}^{tot}\boldsymbol{L}\widehat{\boldsymbol{F}} \tag{17}$$

This type of use (as production input of a certain country-sector pair abroad), can in turn be either consumed in the destination country for final use or be further re-exported into third countries. In the first case, each flow for intermediate use crosses national borders for production only once before it is absorbed (simple GVC participation activity):

---

[25] The expression $(\boldsymbol{I}_{id} - \boldsymbol{A}_{dom}^{tot})^{-1}$ that is used in the last two equations is the total domestic Leontief inverse matrix, or $\boldsymbol{L}_{dom}^{tot}$.

$$\boldsymbol{VA}_{d\to f,i}^{smpl} = \widehat{\boldsymbol{VA}_{int,i}^{n,k}}\boldsymbol{L}_{dom}^{tot}\boldsymbol{A}_{for}^{tot}\boldsymbol{L}_{dom}^{tot}\widehat{\boldsymbol{F}_{dom}^{tot}} \tag{18}$$

The last component comprises of flows that cross borders from their home country and are subsequently either utilized for production or consumption purposes by the importer or further re-exported as intermediates to other partner countries. Wang et al. (2017) refer to this type of international factor trade as complex cross-country production sharing and provide an exact computation method. It can be expressed in the following form (eq. 11):

$$\boldsymbol{VA}_{d\to f\to f\to\cdots,\ i}^{cplx} = \widehat{\boldsymbol{VA}_{int,i}^{n,k}}\boldsymbol{L}_{dom}^{tot}\boldsymbol{A}_{for}^{tot}\left(\boldsymbol{L}\widehat{\boldsymbol{F}} - \boldsymbol{L}_{dom}^{tot}\widehat{\boldsymbol{F}_{dom}^{tot}}\right) \tag{19}$$

To account for participation in GVCs and construct relevant indices corresponding to backward and forward participation at the country level, we adopt the net trade concept (Wang et al., 2017) with the necessary modifications to account for the higher aggregation level and the number of VA components. The aggregate share of a country-sector's pair total VA that consists of domestic VA that originates through downstream activities (forward participation in GVCs) can be written in the following form (I_c is a $KN \times 1$ unit vector):

$$\boldsymbol{VA}_{GVC,\ FOR}^{oc,oi\to world} = \{[(\boldsymbol{VA}_{d\to f,i}^{smpl} + \boldsymbol{VA}_{d\to f\to f\to\cdots,\ i}^{cplx})I_c]'\widehat{VA}^{-1}\}' \tag{20}$$

While the share of its own production for final uses that is embodied in them as a result of its imports of partner VA in its intermediate imports (backward participation in GVCs) is given in the country level by (I_r is a $1 \times KN$ unit vector):

$$\boldsymbol{VA}_{GVC,\ BCK}^{world\to pc,pi} = [I_r(\boldsymbol{VA}_{d\to f,i}^{smpl} + \boldsymbol{VA}_{d\to f\to f\to\cdots,\ i}^{cplx})]'\{(I_r\widehat{VA_{tr}^{oc,oi\to pc,pi}})'\}^{-1} \tag{21}$$

This formulation also allows for the separation of simple and complex modes of GVC participation by omitting either the simple or the complex VA matrix from the sum expressed inside the brackets.

In accordance with Wang et al., (2017), other GVC metrics from the relevant literature can be derived from the elements of this decomposition. The domestic value-added (DVA_f) embodied in the gross exports of a country-sector pair, which expands the concept of VA exports of Johnson and Noguera (2012) with a corrective term to capture re-imported domestic VA *a la* Koopman et al., (2014) can be obtained as:

$$DVA_f = \{[(\boldsymbol{VA}_{d\to f,i}^{cons} + \boldsymbol{VA}_{d\to f,i}^{smpl} + \boldsymbol{VA}_{d\to f\to f\to\cdots,\ i}^{cplx})I_c]'\widehat{VA}^{-1}\}' \tag{22}$$

References:

Ahmad, N. & Primi, A. (2017). From Domestic to Regional to Global: Factory Africa and Factory Latin America? in: *Measuring and Analyzing the Impact of GVCs on Economic Development*. Washington, World Bank, 69-89.

Antràs, P. (2020). Conceptual Aspects of Global Value Chains. *The World Bank Economic Review*, *34*(3), 551–574. https://doi.org/10.1093/wber/lhaa006

Balassa, B. (1965). Trade Liberalisation and “Revealed” Comparative Advantage. *The Manchester School*, *33*(2), 99–123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x

Baldwin, R. E., & Evenett, S. J. (2015). Value creation and trade in 21st century manufacturing. *Journal of Regional Science*, *55*(1), 31–50. https://doi.org/10.1111/jors.12175

Baldwin, R., & Robert-Nicoud, F. (2014). Trade-in-goods and trade-in-tasks: An integrating framework. *Journal of International Economics*, *92*(1), 51–62. https://doi.org/https://doi.org/10.1016/j.jinteco.2013.10.002

Beck, N., & Katz, J. N. (1995). What to do (and not to do) with Time-Series Cross-Section Data. *The American Political Science Review*, *89*(3), 634–647. https://doi.org/10.2307/2082979

Borin, A., and Mancini, M. (2019). Measuring what matters in global value chains and value-added trade. *Policy Research Working Paper; No. 8804.* World Bank, Washington, DC.

Breusch, T. S., & Pagan, A. (1980). The Lagrange Multiplier Test and its Applications to Model Specification in Econometrics. *Review of Economic Studies*, *47*(1), 239–253. https://econpapers.repec.org/RePEc:oup:restud:v:47:y:1980:i:1:p:239-253.

Christensen J.L., R. Rama, N. G. von Tunzelmann, 1996, “The European Food and Beverages Industry”, European Information Monitoring System, EU, Luxembourg.

Corrado, C., Hulten, C. and Sichel, D. (2005). Measuring Capital and Technology: An Expanded Framework, in: C. Corrado, J. Haltiwanger and D. Sichel (eds) *Measuring capital in the new Economy*: University of Chicago Press, pp. 11–46.

Corrado, C., Hulten, C. and Sichel, D. (2009). Intangible Capital and U.S. Economic Growth, *Review of Income and Wealth*, 55(3): 661–685.

Corrado, C., J. Haskel, C. Jona-Lasinio, and M. Iommi, (2016). Intangible investment in the EU and US before and since the Great Recession and its contribution to productivity growth, in: European Investment Bank (ed.) *Investment and Investment Finance in Europe: Report, November 2016*, 73–102.

Constantinescu, C., Mattoo, A., & Ruta, M. (2019). Does vertical specialisation increase productivity? *World Economy*, *42*(8), 2385–2402. https://doi.org/10.1111/twec.12801

Durand, C., & Milberg, W. (2020). Intellectual monopoly in global value chains. *Review of International Political Economy*, *27*(2), 404–429. https://doi.org/10.1080/09692290.2019.1660703

Fu, X., & Ghauri, P. (2021). Trade in intangibles and the global trade imbalance. *World Economy*, *44*(5), 1448–1469. https://doi.org/10.1111/twec.13038

Gereffi, G. (2005). The Global Economy: Organization, Governance and Development. in N.J. Smelser and R. Swedberg (eds.). *Handbook of Economic Sociology*. New York, Princeton University Press, 160-182.

Gereffi, G., Humphrey, J., & Sturgeon, T. (2005). The governance of global value chains. *Review of International Political Economy*, *12*(1), 78–104. https://doi.org/10.1080/09692290500049805

Gibbon, P., & Ponte, S. (2005). *Trading Down: Africa, Value Chains, and the Global Economy*. Philadephia, Temple University Press.

Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of Economic Growth*, *12*(1), 1–25. https://doi.org/10.1007/s10887-006-9009-4

Heidenreich, M., 2009, 'Innovation in European Low- and Medium- Technology Industries', Research Policy, 38, 483–494.

Hoechle, D. (2007). Robust standard errors for panel regressions with cross-sectional dependence. *The Stata Journal*, *7*(3), 281-312.

Hummels, D., Ishii, J., & Yi, K.-M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics*, 54(1): 75–96. https://doi.org/10.1016/S0022-1996(00)00093-3

Humphrey, J., & Schmitz, H. (2002). How does insertion in global value chains affect upgrading in industrial clusters? *Regional Studies*, *36*(9), 1017–1027. https://doi.org/10.1080/0034340022000022198

Johnson, R. C., & Noguera, G. (2012). Accounting for intermediates: Production sharing and trade in value added. *Journal of International Economics*, 86(2), 224–236. https://doi.org/10.1016/j.jinteco.2011.10.003

Jona-Lasinio, C., Manzocchi, S., & Meliciani, V. (2019). Knowledge based capital and value creation in global supply chains. *Technological Forecasting and Social Change*, 148(July), 119709. https://doi.org/10.1016/j.techfore.2019.07.015

Kaplinsky, R., & Readman, J. (2005). Globalization and upgrading: what can (and cannot) be learnt from international trade statistics in the wood furniture sector? *Industrial and Corporate Change*, *14*(4), 679–703. https://doi.org/10.1093/icc/dth065

Kastelli I., & Y. Caloghirou, Y., (2014). The impact of knowledge-intensive entrepreneurship on the growth and competitiveness of European traditional sectors. in Hirsch-Kreinsen H. and I. Schwinge (eds). *Knowledge-Intensive Entrepreneurship in Low-Tech Industries*. Edward Elgar.

Kastelli, I., Tsakanikas, A., & Caloghirou, Y. (2018). Technology transfer as a mechanism for dynamic transformation in the food sector. *The Journal of Technology Transfer*, *43*(4), 882–900. https://doi.org/10.1007/s10961-016-9530-3

Koopman, R., Wang, Z., & Wei, S. J. (2014). Tracing value-added and double counting in gross exports. *American Economic Review*, *104*(2), 459–494. https://doi.org/10.1257/aer.104.2.459

Leontief, W. W. (1936). Quantitative Input and Output Relations in the Economic Systems of the United States. *The Review of Economics and Statistics*, *18*(3), 105. https://doi.org/10.2307/1927837

Meng, B., & Ye, M. (2022). Smile curves in global value chains: Foreign- vs. domestic-owned firms; the U.S. vs. China. *Structural Change and Economic Dynamics*, *60*, 15–29. https://doi.org/10.1016/j.strueco.2021.10.007

Meng, B., Ye, M., & Wei, S. J. (2020). Measuring Smile Curves in Global Value Chains. *Oxford Bulletin of Economics and Statistics*, *82*(5), 988–1016. https://doi.org/10.1111/obes.12364

Miroudot, S. and C. Cadestin (2017), 'Services in Global Value Chains: From Inputs to Value-Creating Activities', *OECD Trade Policy Papers*, No. 197, OECD Publishing, Paris.

Mudambi, R. (2008). Location, control, and innovation in knowledge-intensive industries. *Journal of Economic Geography*, *8*(5), 699–725. https://doi.org/10.1093/jeg/lbn024

Niebel, T., O'Mahony, M., & Saam, M. (2017). The Contribution of Intangible Assets to Sectoral Productivity Growth in the EU. *Review of Income and Wealth*, *63*(February), S49–S67. https://doi.org/10.1111/roiw.12248

OECD (2013). *Interconnected Economies: Benefiting from Global Value Chains*, OECD publishing.

OECD, & Eurostat. (2018). Oslo Manual 2018. In *Handbook of Innovation Indicators and Measurement*.

Pesaran, M.H., (2004). General diagnostic tests for cross section dependence in panels. *Cambridge Working Papers in Economics No. 0435(1229)*, Cambridge University, Cambridge.

Porter, M. (1990). *The Competitive Advantage of Nations*. New York. Free Press.

Robertson P., D. Jacobson (2011). *Knowledge transfer and technology diffusion*. Cheltenham : Edward Elgar

Robertson, P. L., & K. Smith, (2008). Distributed knowledge bases in low-and medium technology industries, in H. Hirsch-Kreinsen (ed.), *Innovation in Low-Tech Firms and Industries*. Edward Elgar: Cheltenham, pp. 93–117.

Robertson, P., Smith, K., & von Tunzelmann, N. (2009). Innovation in low- and medium-technology industries. *Research Policy*, *38*(3), 441–446. https://doi.org/https://doi.org/10.1016/j.respol.2008.10.019

Roth, F. (2020). Revisiting intangible capital and labour productivity growth, 2000–2015: Accounting for the crisis and economic recovery in the EU. *Journal of Intellectual Capital*, *21*(5), 671–690. https://doi.org/10.1108/JIC-05-2019-0119

Stehrer, R., Bykova, A., Jäger, K., Reiter, O., & Schwartzhappel, M., (2019). Industry Level Growth and Productivity Data with Special Focus on Intangible Assets. *Report on methodologies and data construction for the EU KLEMS Release 2019 (Contract No. 2018 ECFIN-116/SI2.784491 Deliverable 3)*. Vienna Institute for International Economic Studies (Wiener Institut für Internationale Wirtschaftsvergleich – wiiw), Vienna.

Taglioni, D. & Winkler, D. (2016). *Making Global Value Chains Work for Development*. Trade and Development, Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/24426

Tian, K., Dietzenbacher, E., & Jong-A-Pin, R. (2019). Measuring industrial upgrading: applying factor analysis in a global value chain framework. *Economic Systems Research*, *31*(4), 642–664. https://doi.org/10.1080/09535314.2019.1610728

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & de Vries, G. J. (2015). An Illustrated User Guide to the World Input-Output Database: The Case of Global Automotive Production. *Review of International Economics*, *23*(3), 575–605. https://doi.org/10.1111/roie.12178

Timmer, M. P., Miroudot, S., & de Vries, G. J. (2018). Functional specialization in trade. *Journal of Economic Geography*, *0*, 1–30. https://doi.org/10.1093/jeg/lby056

Tsakanikas, A., Caloghirou, Y., Dimas, P., & Stamopoulos, D. (2022). Intangibles, innovation, and sector specialization in global value chains: A case study on the EU's and the UK's manufacturing industries. *Technological Forecasting and Social Change*, *177*, 121488. https://doi.org/https://doi.org/10.1016/j.techfore.2022.121488

Wang, Z., Wei, S-J., Yu, X., & Zhu, K. (2017). Measures of Participation in Global Value Chains and Global Business Cycles. *NBER Working Paper Series*, No. 23222, National Bureau of Economic Research.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*, MIT press.

World Bank (2020). *World Development Report 2020: Trading for Development in the Age of Global Value Chains*. World Bank Publications, The World Bank, no. 32437.