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Are innovation and intangible assets drivers for EU's manufacturing competitiveness in Global Value Chains?

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Keywords: intangibles, innovation, global value chains, patents, competitiveness, manufacturing, European Union

Summary

The aim of this study is to investigate the linkage between intangibles, innovation and participation in Global Value Chains and examine their effects on the performance of 19 manufacturing sectors from 27 European Union countries and Great Britain. Towards this end, we utilize data from the newly constructed GLOBALINTO Input-Output Intangibles Database that contains data on intangibles (and additional related competitiveness metrics) from 56 2-digit NACE Rev. 2 industrial sectors for 27 European Union countries and the United Kingdom and was constructed under the Horizon2020 project "GLOBALINTO: Capturing the value of intangible assets in micro data to promote the EU's Growth and Competitiveness".

The structure of this paper includes a short introduction regarding the theoretical linkage between competitiveness, innovation and Global Value Chains, a detailed description on the variables and metrics that approximate the various factors elaborated on this study and an empirical investigation on the linkage between competitiveness, Global Value Chains, intangibles and patents. The empirical analysis is conducted at the 2-digit NACE Rev.2 industry level for 19 manufacturing sectors from all EU27 countries and the United Kingdom in the period 2000-2014 and includes a statistical analysis and simple panel data regressions. The main findings of this study suggest that intangibles trade between countries and industries is on the rise, a fact that presents evidence of the formation of innovation value chains between the connected industries. Furthermore, we identify domestic intangibles as a main driver for innovation production and imported intangibles as a driver for competitive performance. Innovation production is also identified as a vital driver for successful GVC participation.

Introduction

The determinants of economic growth have constantly been in the foreground of economic and industrial research as the dynamic perception of global trade and international markets is constantly reshaping itself. Various innovative studies are adding or even changeling the already established status-quo and creating an ever-expanding, massive literature on the subject. The more recent literature streams focus on the role of innovation, the diffusion of knowledge and the participation of firms in Global Value Chains (GVCs) as various empirical analyses attempt to quantify these elements and properly assess their contribution to growth, development and firms competing in international markets.

The international fragmentation of the production process creates new opportunities for firms and sectors to capitalize on their respective competitive advantages by targeting specific stages of the production cycle (WBG, 2020). "Successful" GVC participation can be identified as a process that allows firms to build on their respective comparative advantages by undertaking selected activities which are able to perform exceedingly in order to maximize their gains and increase the accumulation of added value (VA). This process is closely related with the evolution of innovation (Lema et al., 2019), as knowledge and technology transfer have enabled advancements in innovative products, reallocation of resources, reorganization and control of complex, multinational production processes as well as introduction of innovative organizational structures and dissemination of information and data from countries and industries from all over the world.

While the constant evolution of technology is currently spiking in the era of the 4th Industrial Revolution (Industry 4.0), economic catch-up is also an important factor that is currently reshaping global trade and GVCs. More specifically, Lee and Malerba (2017) elaborate on a newly shaped reality where traditional latecomer firms – that originate mostly on developing countries – have learned their lessons by participating in lower VA activities in GVCs that were led by corporations from developed economies and selected to temporary separate themselves from the global network in order to upgrade their functions and re-enter the GVC in a more dominant, higher VA grossing position. Characteristically, this "in-out-in again" sequence is directly evident in the emerging developing economies of Eastern Asia and most notably China in the early 2000s as noted by Lee (2018), causing a shock in global markets and triggering a rearrangement in the global production networks. The "catch-up cycle" is bolstered by rapid technological advancements and knowledge flows that allow a rapid technological transformation in the already industrialized emerging economies where firms are able to upgrade their functions and re-enter or even create new, self-coordinated value chains of their own. As result, developing economies are constantly growing and the labor-cost arbitrage between them and the developed economies is constantly declining.

European economies are no strangers to GVCs. Amador et al. (2015) state that European Union (EU) members and especially the Euro Area economies are on the rise in terms of participating in GVCs. This rising participation appears to overcome the participation of the United States (US) and Japan since 2009. The EU is a diversified mixture of high income, developed economies as well as developing ones, that are historically connected in terms of trade of goods and services. As Daudin (2011) pointed out, Europe is the most regionalized region in the world as direct result of these strong interconnections of its economies via the intra-EU trade. This argument is further supported in Baldwin (2012) and Baldwin and Lopez-Gonzales (2015), where the outsourcing of industrial production from Germany to Poland is discussed. In these studies, Germany, a high income, developed country, is classified as a headquarter – intangible intensive – economy, that outsources its heavy industrial production to the factory economy Poland. The classification of headquarter economies can be expanded to the full range of Western EU economies while the newly introduced EU members from Eastern Europe are mostly classified as "factories" for their EU counterparts. This headquarter and factory economy perspective for EU members is also expanded in their manufacturing activities. Headquarter economies' manufacturing sectors undertake more knowledge intensive, up-stream and down-stream manufacturing activities such as industrial Research and Development (R&D) and marketing, while the traditional industrial production is undertaken by factory economies that provide lower labor-cost and currently lack the infrastructure and know-how in order to upgrade to more lucrative activities. However, EU's GVCs are not only regional and the dual perspective of intra-EU and extra-EU is challenged by the rearrangement of power and governance in global production chains and the emergence of the heavy industrialized factory economies from Eastern Asia and especially China.

Until recently, a common perception that dominated global trade and economic growth studies was that international trade networks are constructed by multinational corporations selecting their business strategies, partners and outsourcing locations based on the lowest possible labor cost. The decline in labor-cost arbitrage and the constant race to secure a bigger share of added value in the GVC currently reflect that GVCs have grown to be knowledge and technology intensive, a fact that highlights the importance of intangible assets in the positioning along the value chain. Several studies elaborate on the fact that big enterprises establish their dominant position on the international markets based on control of significant and valuable intangible assets (see i.e. Mudambi (2008) and WIPO (2017)). Corrado et al. (2017) argue that investment in intangible capital is currently outpacing several components of fixed capital such as investment in equipment and physical plants while Chen et al. (2017) and Fagerberg et al. (2018) note that the share of VA creation due to intangibles is on a rising trend over time.

According to the famous "smiling curve" introduced by Shih (1992), the two ends of the value chain – that include intangible-intensive activities such as the initial idea stage and the marketing stage – command higher shares in the VA appropriation than the traditional middle parts such as assembly, industrial production and fabrication. As OECD (2013) stressed out, within many industries (including traditional manufacturing sectors), value appropriation is concentrated in upstream and downstream activities while the share of value created in the actual stage of production is constantly declining. These findings constitute a challenging participation for manufacturing sectors in GVCs, especially in the case of EU industries where the declining trend of VA accumulation in traditional manufacturing stages is amplified by the external threat of the reorganized and heavy industrialized factory economies of Eastern Asia. The fourth industrial revolution has bolstered the growth of these developing economies as they are now able to coordinate a vast majority of production stages along the value chain and constantly evolving their comparative advantage by using technology evolution, knowledge and innovation in order to undertake more intangible-intensive activities and expand their incumbent role in all the stages of the GVC. As a result, the role of technology, innovation and other various intangibles is of critical significance for EU manufacturing sector's growth and competitiveness.

The scope of this study is to explore knowledge and innovation flows in the form of intangible inputs in the manufacturing sectors of 27 EU economies and the United Kingdom (UK) and their effects from an international competitiveness. Towards this end, we utilize relevant data from the newly constructed GLOBALINTO Input-Output (I-O) Intangibles Database (Tsakanikas et al., 2020a, b). An innovative element of this study is the identification of imported and domestic intangible input flows, that allows us to account for knowledge and innovation trade and identify possible participation in innovation value chains for the underlying manufacturing industries. Moreover, we empirically assess the correlation between intangible inputs and production of innovation, utilizing a relevant patent statistic as an indicator of an innovation product. In this concept, we attempt to study the intangible usage and innovation production growth in 19 EU and UK manufacturing industries in the period 2000-2014. In the second part of this study, we integrate our findings in a GVC environment by exploring the correlation between intangible inputs, patents and GVC participation using a standard GVC participation indicator, that is backward participation. In the same concept, we attempt to estimate the effects of the aforementioned variables in the competitive performance of the manufacturing sectors. To this end, we use simple panel data regressions to identify the contribution of intangibles, patents and GVC participation to a relative productivity performance indicator that is included in GLOBALINTO I-O Intangibles Database and constitutes a measure of international competitiveness.

Detailed data description

Our study builds on relevant metrics and variables that derive from the GLOBALINTO I-O Intangibles Database, that was constructed under the Horizon2020 project "GLOBALINTO: Capturing the value of intangible assets in micro data to promote the EU's Growth and Competitiveness". Furthermore, we retrieve additional data the 2016 Release of the World Input-Output Database (WIOD) (Timmer, et al., 2015) and Eurostat. Our analysis is conducted at the 2-digit NACE Rev. 2 level of industrial classification for 19 manufacturing industries from all EU27 economies and Great Britain in the period 2000-2014.

The detailed list of selected countries includes: Austria (AUT), Belgium (BEL), Bulgaria (BGR), Croatia (HRV), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Poland (POL), Portugal (PRT), Romania (ROU), Slovenia (SVN), Slovakia (SVK), Spain (ESP), Sweden (SWE) and the United Kingdom (GBR).

The list of 2-digit NACE Rev. 2 manufacturing industries alongside their standard High-Tech manufacturing industry classification by Eurostat[1] is presented in Table 1:

[1] Eurostat classifies manufacturing activities as High-tech, Medium-high-tech, Medium-low-tech and Low-tech on a basis of their share of R&D expenditures to value added. This classification captures technological intensity in each industry and is available in different NACE Rev.2 aggregation levels. In the context of this study, we use the 2-digit NACE Rev.2 level aggregation of manufacturing activities.

Table 1: 2-digit, NACE Rev.2 manufacturing sectors included in this study

Sector Acronym	Detailed description	Eurostat High-Tech classification
C10-C12	Mn.[n] of food products, beverages and tobacco products	Low-tech
C13-C15	Mn. of textiles, wearing apparel and leather products	Low-tech
C16	Mn. of wood and of products of wood and cork, except furniture; Mn. of articles of straw and plaiting materials	Low-tech
C17	Mn. of paper and paper products	Low-tech
C18	Printing and reproduction of recorded media	Low-tech
C19	Mn. of coke and refined petroleum products	Medium-low-tech
C20	Mn. of chemicals and chemical products	Medium-high-tech
C21	Mn. of basic pharmaceutical products and pharmaceutical preparations	High-tech
C22	Mn. of rubber and plastic products	Medium-low-tech
C23	Mn. of other non-metallic mineral products	Medium-low-tech
C24	Mn. of basic metals	Medium-low-tech
C25	Mn. of fabricated metal products, except machinery and equipment	Medium-low-tech
C26	Mn. of computer, electronic and optical products	High-tech
C27	Mn. of electrical equipment	Medium-high-tech
C28	Mn. of machinery and equipment n.e.c.	Medium-high-tech
C29	Mn. of motor vehicles, trailers and semi-trailers	Medium-high-tech
C30	Mn. of other transport equipment	Medium-high-tech
C31_C32	Mn. of furniture; other manufacturing	Low-Tech
C33	Repair and installation of machinery and equipment	Medium-low-tech

[n]*Manufacture*

Intangibles intensity

According to Corrado et al. (2005, 2009), intangible assets comprise computer software, ICT activities, research and development activities output, organizational capital, innovative property and economic competencies, entertainment and design, branding and marketing. The fact that these assets are intangibles, does not imply either that access to them is free, or that some of them are provided by nature. On the contrary, intangible assets are mainly provided by certain economic sectors, which are continuously developing their production methods, as well as the characteristics and the merits of these assets. As a result, intangibles can certainly be treated as intermediate products and services in the inter-industry trade. Moreover, in the globally fragmented economy, intangibles as well as other intermediates, are constantly traded between industries in different economies around the world. This sector dimension of intangible assets usage as inputs in the production process and the corresponding trade of intangibles between industries, is yet to be explored by the scientific community.

The aforementioned concept of intangibles as intermediate inputs is adopted in the construction of the GLOBALINTO I-O Intangibles Database. This database is an innovative contribution to the emerging field of quantifying the impact of intangible assets in an industry's production cycle by introducing a higher level, 2-digit NACE Rev.2 sector inputs approach based on the inter-sector (and inter-country) trade of utilities. This approach goes beyond the capital investment perspective introduced in relevant intangibles-related databases, most notably in INTAN-Invest (Corrado et al., 2016) and the most recent release of the EUKLEMS (Stehrer et al., 2019), as it presents the opportunity to treat intangible inputs as knowledge and innovation utility flows in the inter-industry and inter-country trade. This perspective also enables the tracking of knowledge and innovation transfer between industries from different countries and introduces a new dimension in intangible capital quantification as intangible inputs are quantified per origin as domestically produced and imported. This dual dimension of intangibles trade enables the identification of potential innovation value chains between the knowledge and innovation-connected industries and countries.

In order to quantify intangibles intensity in our study, we use a two-dimensional intangibles intensity indicator, accounting for domestically produced and imported intangible inputs for each manufacturing sector in EU27 plus UK from the GLOBALINTO I-O Intangibles Database. Under the theoretical approach of the database, intangible inputs are produced from four 2-digit NACE Rev.2 industry sectors[2] (or groups). Specifically, the sectors producing intangibles are:

- J62-J63 sectors: Computer programming, consultancy and related activities; Information service activities
- M72 sector: Scientific research and development
- M73 sector: Advertising and market research
- N sector: Administrative and support service activities

Intangible inputs are produced from these sectors in forty-three countries (all EU members and UK included) and the rest of the world (RoW), and used in our study by 19 2-digit NACE Rev.2 manufacturing sectors in each EU country and UK, during the period 2000-2014. In order to account for both domestic and imported intangible inputs for each manufacturing sector in each country, we use two separate indicators as described in the following equations:

$$(1)\ dIntan_{i,c} = \frac{domestic\ intangible\ inputs_{i,c}}{total\ intermediate\ consumption_{i,c}}$$

$$(2)\ iIntan_{i,c} = \frac{imported\ intangible\ inputs_{i,c}}{total\ intermediate\ consumption_{i,c}}$$

Where $dIntan_{i,c}$ stands for the share of domestically produced intangibles inputs in sector i in country c to its total intermediate consumption of utilities and $iIntan_{i,c}$ stands for the share of imported intangibles inputs respectively.

Further information regarding the construction of GLOBALINTO I-O Intangibles Database and the various data and variables included can be found in Tsakanikas et al. (2020b).

[2] Intangible assets from these sectors cover software, R&D input, organizational capital and branding.

Innovation

In order to approximate innovation in our study, we utilize a standard innovation metric that is patents. More specifically, building on available data from GLOBALINTO I-O Intangibles Database, we introduce the variable $pat_{i,c}$ as the number of patent applications to European Patent Office (EPO) by sector i in country c. Patent application data are available for the time period 2000-2013.

Backwards participation in GVCs

The constantly reshaping global production networks have challenged the credibility of standard trade statistics to provide a robust representation of the actual transactions of products and services among different economies and industrial sectors (Borin and Mancini, 2019). In this sense, studying international trade using various GVC statistics that derive from Inter-Country Input-Output (ICIO) Tables represents a more nuanced approach in order to capture complex supply and demand relationships between economies and industries at a global scale. Standard GVC participation indices build on VA trade between industries and countries, firstly introduced in the seminal framework by Hummels et al. (2001) and further expanded and established by the decomposition of gross exports by Koopman et al. (2014) into two major elements: domestic value added (DVA) and foreign value added (FVA) embodied in gross exports. Backwards participation, an alternate expression of Hummels et al. (2001) VS indicator, is approximated as the share of FVA embodied in gross exports and while forward participation metrics relate to DVA embodied in gross exports and in foreign gross exports (by a third country).

Among empirical literature, backward participation in GVCs is the most commonly used index of GVC participation (see i.e. Baldwin (2012), OECD (2013), Amador et al. (2015), Baldwin and Lopez Gonzalez (2015), Lee (2018)) and is hereby selected to approximate GVC participation for the purposes of this study as described in equation (3):

$$(3)\ \ gvcB_{i,c} = \frac{FVA\ embodied\ in\ gross\ exports_{i,c}}{gross\ exports_{i,c}}$$

Where FVA embodied in gross exports and gross exports are calculated at the 2-digit NACE Rev.2 sector level for each manufacturing sector i in each country c using relevant I-O data for the EU27 and UK's manufacturing sectors[3] from WIOD.

Sector Performance

To account for the competitive performance of the EU27 and UK's manufacturing sectors, we utilize a relative international competitiveness productivity performance indicator from the GLOBALINTO I-O Intangibles Database. This indicator builds on a revealed comparative advantage notion (Balassa, 1965), by introducing a relative metric for the productivity

[3] Henceforth, when referring to EU's manufacturing sectors within the main body of the study, we also include United Kingdom's.

performance of a sector in comparison to the performance of this sector globally. More specifically, the performance indicator is described in equation (4):

$$(4)\ perf_{i,c} = \frac{VA_{i,c}}{total\ output_{i,c}} \Big/ \frac{VA_{i,glob}}{total\ output_{i,glob}}$$

Where the nominator includes an efficiency metric (the ratio of VA to total output) of sector i in each country c and the denominator includes the same efficiency metric for sector i globally.

Empirical analysis

Descriptive statistics

Data for all variables are available for 19 industries (*i*) of 28 EU countries (c) for 15 years (2000-2014) (t). This results to a combined sample of 7960 observations with few exceptions for missing values due to unavailability of data. The main variables of interest in this study are intangibles intensity (domestic and imported)[4] and its relationship with patents, GVC participation and sector growth. The descriptive statistics for the full sample are presented in *Table 2*, with the intangibles intensity showing a relatively large amount of variability in proportion to their respective mean, but not as large as patenting data.

Table 2: Main descriptive statistics of variables used in this study

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Share of imported intangibles to intermediate consumption	7960	0.0000	0.6594	0.0121	0.0344	0.0010
Share of domestic intangibles to intermediate consumption	7960	0.0000	0.3235	0.0337	0.0338	0.0010
Share of intangible inputs to total intermediate consumption	7960	0.0000	0.6691	0.0458	0.0517	0.0030
Sector productivity; Performance relative to sector globally	7975	-0.3098[5]	4.9212	1.0752	0.3575	0.1280
FVA share in Gross Exports to total Gross Exports	7980	0.0000	0.8600	0.3413	0.1283	0.0160
No. Patents (thousands scale)	5911	0.00	6337.87	126.59	455.37	207360.20

The data in this analysis cover the period 2000-2014. We divide this period into three separate time frames for comparative reasons, with respect to the economic crisis (in 2008) as a common axis in our analysis. The separate time frames are identified as the

[4] The sector level statistics of intangibles intensity in this study are cumulative statistics at the sector level with respect to each sector's country of origin. The domestic dimension refers to intangibles produced domestically in each EU economy that are provided as inputs for the respective country's manufacturing sectors. Imported intangibles refer to imported intangibles from outside each sector's specific economy. In this sense, imported intangibles encompass both intra-EU and extra-EU intangible imports for each manufacturing sector.
[5] This specific negative value is unique and refers to the petrochemicals sector of the Bulgarian economy for 2014 – other values are zero or grater.

pre-crisis period (2000-2007), followed by the crisis years (2008-2010) and by the ensuing ''stagnation period'' (2011-2014). In the following figures, we present the evolution of intangibles intensity growth rate with respect to each time frame in our analysis.

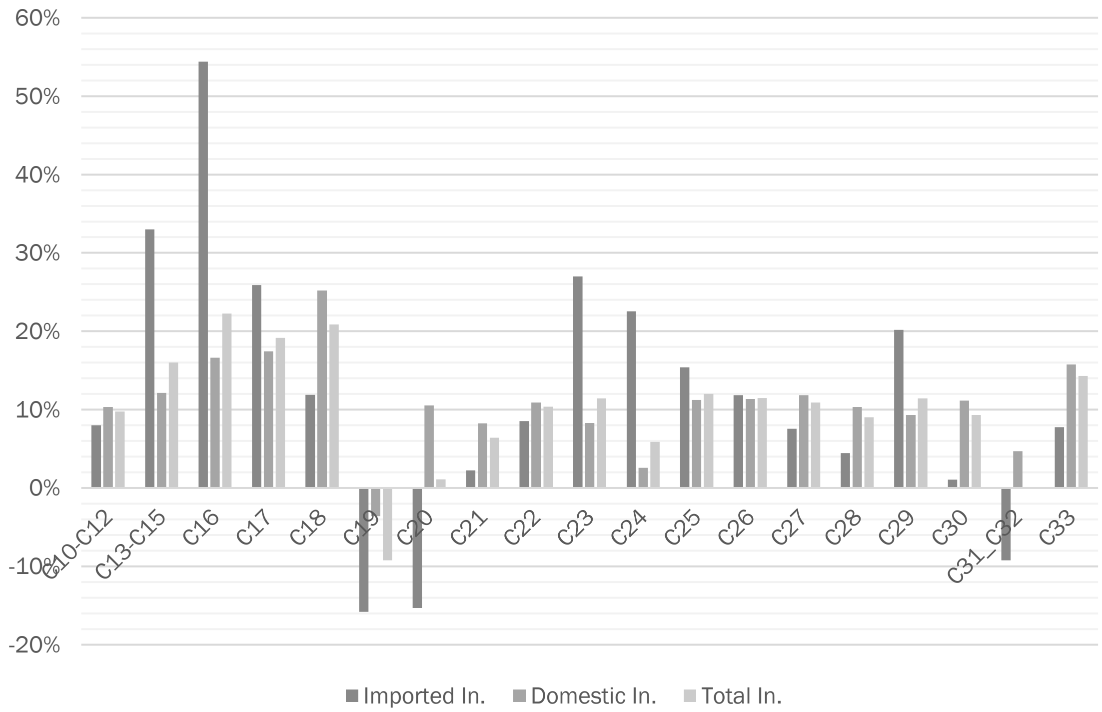

Figure 1: Rate of growth of inter-industry Intangibles flows for EU economy pre-crisis, 2000-2007 (source: authors' calculations based on GLOBALINTO I-O Intangibles Database)

In the pre-crisis time period, there is an increasing trend in the growth of imported intangible assets for the majority of EU's manufacturing sectors. Most notably, traditional low-tech sectors such as textiles, apparel and leather products (C13-C15), wood and products of wood (C16) and paper and paper products (C17) appear to increase their imported intangible flows. Manufacture of coke and refined petroleum products (C19) and chemicals and chemical products (C20) follow an opposite pattern in terms of imported intangibles intensity. Domestic intangibles intensity also follows a rising pattern with relatively lower growth terms in contrast with the imported ones. Overall, intangibles intensity is on the rise for the majority of manufacturing industries with coke and refined petroleum products being the only outlier with a decreasing trend in current time span.

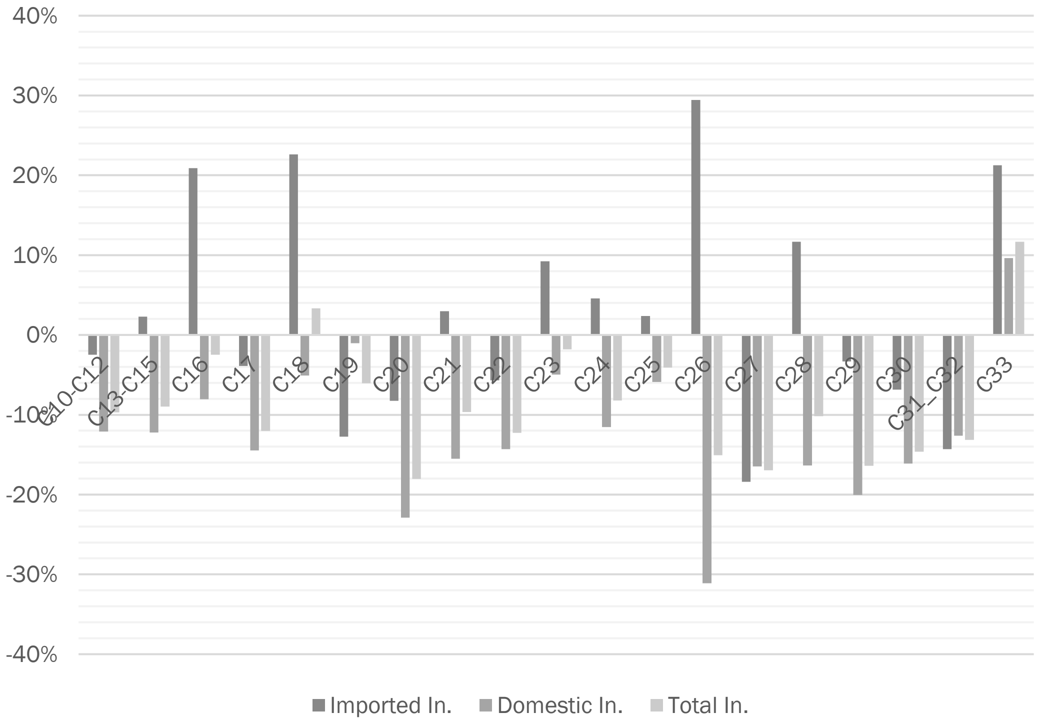

Figure 2: Rate of growth of inter-industry Intangibles flows for EU economy during the crisis, 2008-2010 (source: authors' calculations based on GLOBALINTO I-O Intangibles Database)

The economic crisis that saturated the EU economies since 2008 has made a significant negative impact in overall intangibles intensity. It is evident from Fig.2 that all manufacturing sectors experienced a decreasing sock in intangibles intensity growth in the current period with domestic intensity constantly decreasing from 2008 to 2010 and imported intensity following a similar pattern. However, in certain industry cases, different trends emerge. When focusing on computer, electronic and optical products (C26), a high-tech manufacturing sector, we observe a significant increasing trend in imported intangibles intensity (approximately 29% growth) that is paired with a similar-magnitude drop in domestic intensity (approximately 31%). The overall intangibles intensity for this sector decreased in 2008-2010 as domestic intangible inputs outweigh the imported in absolute value terms. A similar overall trend is also observed in machinery and equipment n.e.c. (C28), wood and products of wood and cork (C16), printing and reproduction of recorded media (C18) and several other medium-tech manufacturing sector. These findings present a different dimension in intangibles intensity during the crisis period (in our study, 2008-2010) as we identify a constantly increasing trade in intangibles despite the decrease in domestic and overall intangibles usage in this period.

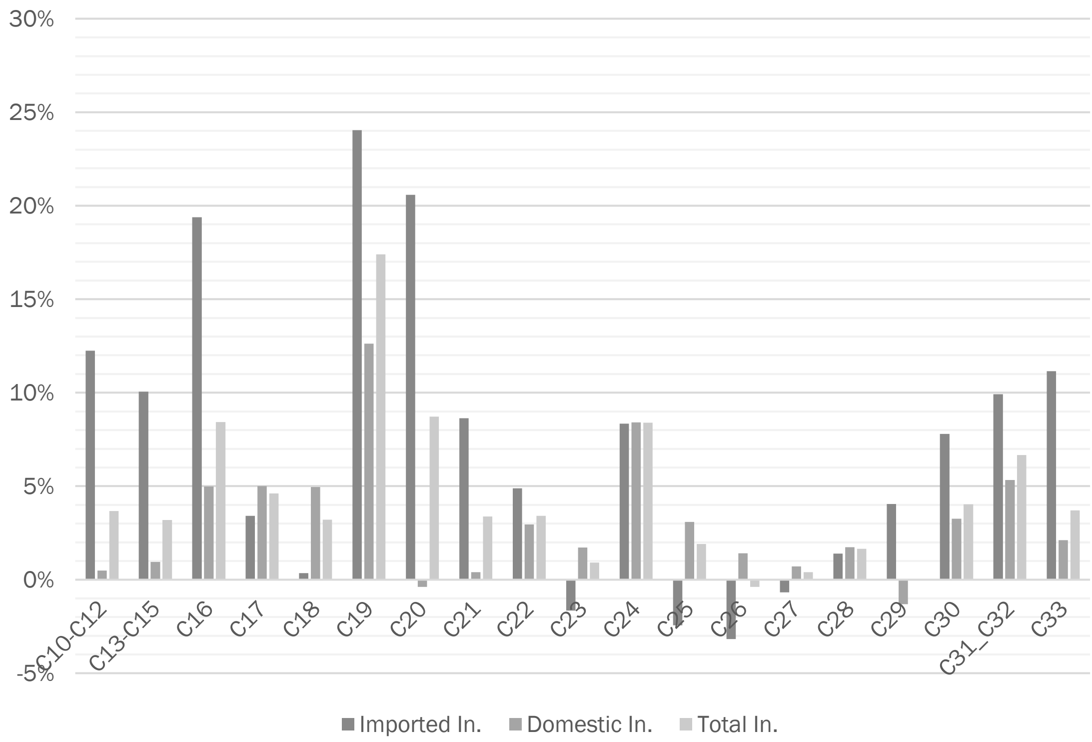

Figure 3: Rate of growth of inter-industry Intangibles flows for EU economy in the "stagnation period", 2011-2014 (source: authors' calculations based on GLOBALINTO I-O Intangibles Database)

The "stagnation period" that followed the economic crisis did not have a specific time frame for all EU economies[6], as most of Western European economies had a more rapid adjustment to the new environment compared to Southern and Eastern Europe economies. According to Fig.4, intangibles intensity is on the rise again during 2011-2014, as the economic recovery of economies and industries is underway. Domestic and imported intangible inputs are experiencing significant growth in the majority of the manufacturing sectors. More specifically, coke and refined petroleum products (C19) and chemicals and chemical products (C20) demonstrate the most significant increase in imported intangibles intensity, a fact that indicates that these specific sectors have adjusted their strategies towards intangible inputs after the crisis compared to their behaviour in the pre-crisis period (Fig.1).

An overall overview of the descriptive statistics regarding intangibles intensity during the 2000-2014 period indicates that intangibles intensity in the EU's manufacturing sectors is sensitive towards parameters of the general macroeconomic environment. However, imported intangibles growth appears to be unaffected by the economic recession and constantly rising, indicating towards the establishment of inter-industry and inter-country trade of intangibles as the domestically (in terms of intangible inputs) oriented manufacturing industries constantly integrate a larger amount of imported intangible

[6] One could argue that the economic recession had a different time frame for each economy in the EU, as more developed economies experienced a relative shorter pitfall compared to lagers. For example, the financial collapse that took place in 2008 affected the German economy in a much less severe manner that the Greek one and also for a significantly shorter time period. We selected 2008-2010 as the crisis period in order to best approximate the period that all EU economies jointly experienced financial turmoil. We define 2011-2014 as a "stagnation period" on a similar common base with respect to data availability and also taking into account that "stagnation" is a relative term as some economies already recovered and took the first steps forward during that period, while others struggled to overcome their difficulties.

inputs in their activities. The overall rising trend of intangibles intensity in EU's manufacturing also constitutes a vestige towards the upgrading of traditional activities and the overall technological transformation of the manufacturing sectors. This rising trend is also related with the production of innovation, as the number of patent applications to EPO for each manufacturing sector is constantly rising in the period 2000-2013 (Figure 4).

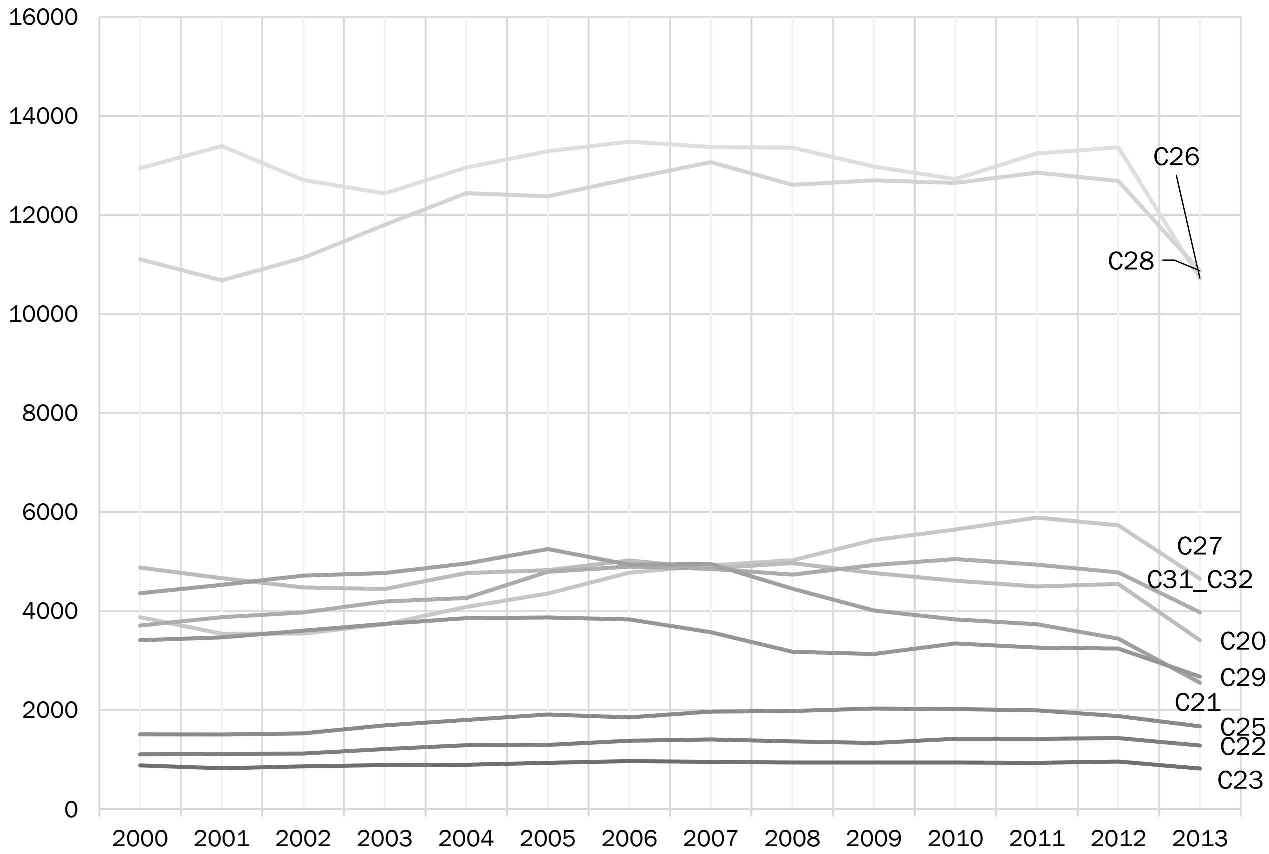

Figure 4: Patenting activity (applications to EPO) of top ten patenting sectors of EU economy for 2000-2013 (source: authors' calculations based on GLOBALINTO I-O Intangibles Database)

This similarly increasing trend in intangibles intensity and patent activity is further explored in the following sections of our analysis.

Correlations

The initial stage of the empirical investigation of the linkage between all variables of interest (intangibles intensity, patents, GVC participation and sector performance) included simple correlation statistics to identify the sign and significance of the correlation between the variables.

We adopt a two-dimension approach that includes that correlations of intangibles intensity (domestic, imported and total) and correlations of patents. This approach is organized as follows:

- Pearson correlations of domestic, imported and total intangibles intensity for each EU manufacturing sector (*Table 3*) with:
  - ✓ Patent applications to EPO per sector
  - ✓ Sector performance
  - ✓ Sector backward participation to GVCs
- Pearson correlations of patent applications to EPO from each EU manufacturing sector with (*Table 4*):
  - ✓ Sector performance
  - ✓ Sector backward participation to GVCs

We also empirically investigate the linkage (via correlation statistics) of intangibles intensity and patent applications with the exporting activity of each EU manufacturing sector using the share of total exports to total output as our exports proxy. This relative exports indicator is also retrieved from GLOBALINTO I-O Intangibles Database and is included in the descriptive analysis for comparative purposes.

Overall, imported intangible flows to be strongly correlated (both in terms of strength and (positive) direction) with exports for all industries than the respective total intangibles intensity. Domestic intangible inputs are not correlated with sector exports. On the contrary, patenting activity is positively and strongly correlated with domestic intangibles but appears to not be affected by imported intangibles in any significant way, either in the total nor in each sector individually. This fact is thoroughly reversed in the case of exports, where we observe a positive and statistically significant correlation. Sector performance is positively correlated with both intangibles intensity as well as patent activity. In terms of participation in GVCs, there is a positive correlation with imported intangibles and a negative with domestic ones. This was an anticipated finding as backward participation is associated with foreign (i.e. imported) VA instead of domestic.

At the industry-specific level, we observe significant heterogeneity regarding the effects of intangible inputs per origin and across different sectors, both in terms of direction as well as correlation strength. For example, the correlation between imported intangibles and sector performance is strongly positive for petrochemicals (C19) but strongly negative for non-metallic mineral products (C23); the association between patenting intensity and imported intangibles is non-significant for almost all sectors, while the relationship with domestic intangibles is significant and positive for all but one (C33) sectors. This heterogeneity in terms of strength and correlation direction per intangibles origin is also evident in the case of exports. For example, domestic intangibles appear to be strongly and positively correlated with exports in the food, beverages and tobacco products industry (C10-C12) while in the case of transport equipment (C30) the direction of this relationship is reversed.

Our results highlight the importance of thoroughly examining intricacies of each correlation on sector level basis, with respect to sector specific characteristics across EU countries, since important sector-specific differences can be obscured in the overall aggregated view.

Table 3: Correlations between imported, domestic and total intangibles intensity and variables of interest for each EU manufacturing sector in 2000-2014

	Intensity type	C10-C12	C13-C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31_C32	C33	Total
% exports to S.O.	*iIntan*	.598***	-.125***	.307***	.208***	.518***	.183***	.303***	.239***	.554***	.327***	.385***	.343***	-.021	.201***	.155***	.039	-.374***	.295***	.355***	**.156*** **
	dIntan	.044	.100**	-.119**	-.155***	-.0640	.136***	.143***	.104**	.097**	.097**	-.052	-.095**	-.149***	-.016	-.064	-.173***	-.066	-.047	-.396***	**-.007**
	T.I.	.521***	.0140	.038	-.031	.397***	.209***	.313***	.267***	.316***	.226***	.066	.053	-.123**	.079	.025	-.146***	-.174***	.203***	-.274***	**.098*** **
Sector Performance	*iIntan*	.115**	-.228***	-.173***	.049	-.182***	.359***	.316***	-.0202	.159***	-.289***	-.117**	-.073	-.168***	-.0201	-.089*	.143***	.113**	.238***	.061	**.041*** **
	dIntan	-.143***	-.293***	.050	-.069	.084*	.124**	.256***	.094*	.289***	-.150***	-.152***	.214***	.113**	.188***	-.117**	-.25***	-.175***	.211***	-.075	**.038*** **
	T.I.	.009	-.365***	-.035	-.035	-.110**	.338***	.372***	.035	.320***	-.253***	-.173***	.154***	-.004	.147***	-.144***	-.182***	-.123**	.324***	-.053	**.053*** **
Patents (no.)	*iIntan*	-.075	-.101**	-.088*	-.153***	-.097**	-.101**	-.064	-.097**	-.075	-.064	-.0450	-.090*	.0440	-.102**	-.088*	-.08*	-.026	-.077	-.036	**.002**
	dIntan	.586***	.505***	.389***	.429***	.385***	.115**	.547***	.425***	.604***	.661***	.440***	.463***	.458***	.392***	.360***	.379***	.554***	.521***	-.042	**.297*** **
	T.I.	.291***	.362***	.282***	.295***	.104**	-.018	.183***	.155***	.501***	.518***	.386***	.361***	.366***	.279***	.258***	.321***	.491***	.272***	-.049	**.196*** **
GVCs partic.	*iIntan*	.471***	.478***	.638***	.493***	.441***	-.077	.066	.464***	.282***	.527***	.423***	.358***	.144***	.332***	.365***	.298***	.058	.294***	.218***	**.132*** **
	dIntan	-.304***	-.243***	-.149***	-.344***	-.321***	-.149***	-.437***	-.212***	-.423***	-.264***	-.165***	-.388***	-.409***	-.447***	-.319***	-.220***	-.281***	-.390***	-.318***	**-.343*** **
	T.I.	.207***	.058	.159***	-.054	.210***	-.135***	-.133***	.284***	-.254***	.0160	-.026	-.190***	-.228***	-.217***	-.081*	-.106**	-.235***	-.016	-.238***	**-.136*** **

*Notes: Pearson r-values for each correlation. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level, T.I.: Total intangibles intensity,*

Table 4: Correlations between patenting activity and variables of interest for each EU manufacturing sector in 2000-2014

		C10-C12	C13-C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30	C31_C32	Total
Patents	% of exp. To S.O.	.174***	.098**	-0.198***	-.035	-.128***	-.100**	.049	.146***	-.117**	-.089*	-.178***	-.181***	.073	-.193***	-.046	-.150***	.204***	-.104**	.103***
	Sector Performance	.187***	-.295***	-.070	-.099**	.100**	-.187***	.026	.203***	.195***	.001	-.057	.22***	.155***	.179***	.046	-.077	-.117**	.206***	.073***
	GFCF to T.O.	.134***	.105**	.695***	.034	-.037	.067	.043	.081*	.049	.022	.112**	.033	-.023	-.043	.041	.014	.044	.196***	.026**
	Sector Size (T.O.)	-.153***	-.090*	-.138***	.223***	-.039	-.055	.274***	-.041	.026	-.216***	.019	.043	.052	.194***	.331***	.338***	.410***	-.114**	.086***
	FVA share in GrExp to total GrExp	-.217***	-.238***	-.178***	-.340***	-.296***	.143***	-.256***	-.285***	-.399***	-.38***	-.188***	-.376***	-.335***	-.372***	-.325***	-.289***	-.123**	-.376***	-.141***

*Note: C33 is excluded due to absence of relevant patenting data. Pearson r-values for each correlation. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level, T.O.: Total Output, GrEx: Gross Exports, S.O.: Sector Output*

Model specification

In order to corroborate the previously elaborated empirical results, we attempt a series of simple panel regressions to test the joint effect of intangible inputs, GVC participation and patents on sector performance. Our set of explanatory variables also includes a sector investment variable alongside control variables for industry and country specific effects. Based on the data regarding patent applications to EPO, we construct a sample that includes eighteen manufacturing industries (omitting C33 due to lack of patent applications filed from this sector) from eighteen EU economies including UK[7] for the period 2000-2013.

The relationship between intangibles, innovation and GVC participation with growth has been an area of interest in the state-of-the-art literature streams. The approximation of innovation using patent statistics dates back to Griliches (1990) and his implications of a strong and positive relationship between patents and growth. More recently, various studies have attempted to assess the effects of GVC participation in, most notably, productivity growth, using different approaches and measures and supporting the view of a positive effect (see i.e. Constantinescu et al. (2019), Pahl and Timmer (2020)). Another focus point of recent empirical efforts is in the linkage between intangible assets and productivity growth (i.e. Corrado et al., (2016), (2017)) with significant academic interest drawn in the relationship between intangibles and GVCs as well (i.e. Chen et al. (2017), Tajoli and Felice (2018), Jona-Lasinio et al. (2019)).

The motivation behind our model specifications stems from Lee et al. (2018) and Tsakanikas et al. (2020a), in an attempt to investigate the linkage as well as the combined effects between the variables of interest. In our specifications, we use the natural logarithm (ln) of the respective variables in order to scale the size of the estimated coefficients. Our baseline model specification is set in equation (1) as follows:

$$(1)\quad \ln(perf)_{i,c,t} = \alpha_0 + \alpha_1 \ln(dIntan)_{i,c,t} + \alpha_2 \ln(gvcB)_{i,c,t} + \alpha_3 \ln(gfcfTO)_{i,c,t-2} + \alpha_4 \ln(size)_{i,c,t} + \alpha_5 \ln(pat)_{i,c,t} + \alpha_6 \ln(\Delta GDPpc)_{c,[t-1,t]} + \lambda_t + \varepsilon_{i,t}$$

where $perf_{i,c}$ refers to sector performance for sector i in country c, $dIntan_{i,c}$ stands for the domestic intangibles intensity of sector i in country c, $gvcB_{i,c}$ refers to backward participation in GVCs for sector i in country c and $pat_{i,c}$ refers to the patent applications of sector i in country c to EPO. The list of explanatory variables also includes an approximation for sector investment, $gfcfTO_{i,c}$, that is defined as the ratio of Gross Fixed Capital Formation (GFCF) to total output of sector i in country c. The variable is calculated using relevant sector-level data from WIOD. Under the System of National Accounts (SNA) 2008 standards, expenditures on R&D are recognized as production of an asset instead of intermediate consumption and thus contributing to a sector's gross fixed capital formation. As a result, our investment approximation encompasses investment in both physical (fixed) and R&D capital. Investment in physical (fixed) capital is mostly related with long-term effects on sector performance, while R&D investment is considered to have a more immediate impact. We use a two-period time lag for medium-term returns on performance in order to balance the different time frame of return for all the kinds of

[7] Our sample comprises 18 2-digit NACE Rev.2 manufacturing sectors from: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Poland, Portugal, Romania, Slovenia, Spain, Sweden and the United Kingdom

investment embodied in GFCF. Furthermore, we control for sector size as the magnitude of a specific manufacturing industry's activities relative to its total domestic manufacturing sector. This variable differentiates between the same manufacturing industries (e.g. C10-C12) between different countries on a basis of each country's total manufacturing sector. Our proxy variable $size_{i,c}$ is defined as the total output of sector i in country c divided by the total manufacturing output of country c and is calculated using sector-level data from WIOD. We also control for country-specific, general macroeconomic and business environment factors by introducing $\Delta GDPpc_c$, that is Gross Domestic Product (GDP) per capita growth from year $t-1$ to year t in purchasing powered standards (PPS) for country c, with relative country level data retrieved from Eurostat. Lastly, $\varepsilon_{i,t}$ represents the error term and we also introduce year fixed effects, λ_t, to account for unidentified time-related factors that affect sector performance.

The baseline model specification in (1) is then adjusted to include imported intangibles intensity ($iIntan_{i,c}$) instead of domestic for sector i in country c (equation (2)) and then augmented to account for total intangibles intensity both domestic and imported (equation (3)):

(2) $$\ln(perf)_{i,c,t} = \beta_0 + \beta_1 \ln(iIntan)_{i,c,t} + \beta_2 \ln(gvcB)_{i,c,t} + \beta_3 \ln(gfcfTO)_{i,c,t-2} + \beta_4 \ln(size)_{i,c,t} + \beta_5 \ln(pat)_{i,c,t} + \beta_6 \ln(\Delta GDPpc)_{c,[t-1,t]} + \lambda_t + \varepsilon_{i,t}$$

(3) $$\ln(perf)_{i,c,t} = \gamma_0 + \gamma_1 \ln(dIntan)_{i,c,t} + \gamma_2 \ln(iIntan)_{i,c,t} + \gamma_3 \ln(gvcB)_{i,c,t} + \gamma_4 \ln(gfcfTO)_{i,c,t-2} + \gamma_5 \ln(size)_{i,c,t} + \gamma_6 \ln(pat)_{i,c,t} + \gamma_7 \ln(\Delta GDPpc)_{c,[t-1,t]} + \lambda_t + \varepsilon_{i,t}$$

In the final model specification, we introduce an interaction term to account for the combined effect of backward GVC participation and patent applications to sector performance. According to Brambor et al. (2006), Bali and Sørensen (2013) and Heinmueller et al. (2019), the introduction of an interaction term in an empirical model specification should be implemented under a conditional hypothesis and not to indicate a causal relationship between the variables of the constitutive term. In this sense, we introduce an interaction term between our proxy for GVC backward participation $gvcB_{i,c}$ and patent applications to EPO $pat_{i,c}$ to test the hypothesis that the production of an innovation outcome (in this case approximated as a patent applications) is associated with an increase in sector performance when the sector is participating in GVCs. The final model specification is presented in equation (4) below:

(4) $$\ln(perf)_{i,c,t} = \delta_0 + \delta_1 \ln(dIntan)_{i,c,t} + \delta_2 \ln(iIntan)_{i,c,t} + \delta_3 \ln(gvcB)_{i,c,t} + \delta_4 \ln(gfcfTO)_{i,c,t-2} + \delta_5 \ln(size)_{i,c,t} + \delta_6 \ln(pat)_{i,c,t} + \delta_7 \ln(\Delta GDPpc)_{c,[t-1,t]} + \delta_8 [\ln(gvcB)_{i,c,t} * \ln(pat)_{i,c,t}] + \lambda_t + \varepsilon_{i,t}$$

Empirical results and discussion

Table 5 presents the descriptive statistics for the adjusted sample and variables used in the panel regressions.

Table 5: Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
i_intan	4536	0.000	0.603	0.014	0.040
d_intan	4536	0.000	0.324	0.043	0.036
gvc_b	4536	0.097	0.864	0.316	0.120
gfcf_to	4536	-86.34	1.018	0.039	2.057
size	4536	0.000	0.461	0.054	0.050
pat	4286	0.000	6337.87	173.36	527.28
ΔGDPpc	4536	-0.163	0.186	0.041	0.056

The selected method of estimation is Random Effects (RE) estimators[8] with robust (clustered by industry) standard errors to account for heteroskedasticity and serial autocorrelation. The results are presented in *Table 6*.

Table 6: Effects of intangibles, innovation and GVC participation on sector performance: RE panel regressions with clustered standard errors for EU27 and UK's manufacturing sectors.

	Model specifications			
perf	(1)	(2)	(3)	(4)
dIntan	-0.029		-0.042	-0.038
	(0.028)		(0.026)	(0.025)
iIntan		0.020	0.030**	0.033***
		(0.015)	(0.013)	(0.013)
gvcB	-0.692***	-0.672***	-0.701***	-0.905***
	(0.058)	(0.060)	(0.059)	(0.082)
$gfcfTO_{t-2}$	0.056***	0.055***	0.054***	0.048***
	(0.020)	(0.019)	(0.020)	(0.020)
size	-0.096***	-0.090***	-0.091***	-0.103***
	(0.029)	(0.028)	(0.028)	(0.016)
pat	0.001	-0.001	0.001	0.082***
	(0.006)	(0.005)	(0.006)	(0.016)
ΔGDPpc	0.012***	0.012***	0.011**	0.015***
	(0.005)	(0.004)	(0.005)	(0.005)
*gvcB*pat*				0.067***
				(0.014)
constant	-1.126***	-0.867***	-1.012***	-1.263***
	(0.159)	(0.123)	(0.170)	(0.169)
Year dummies	Yes	Yes	Yes	Yes
Observations	2964	2964	2964	2964
R^2	**0.304**	**0.325**	**0.322**	**0.317**
Number of groups	321	321	321	321

Notes: Clustered standard errors in parentheses. *Significant at 10% level. **Significant at 5% level. ***Significant at 1% level

[8] Fixed Effects (FE) and Pooled Ordinary Least Squares (OLS) estimators were also implemented alongside Breusch-Pagan (1980) Langragian multiplier test and Sargan (1958)/Hansen (1982) test of overindentifying restrictions, which indicated towards the use of RE as the most suitable and efficient estimation method.

The estimation results indicate that imported intangibles intensity has a positive and statistically significant effect on sector performance when domestic intangible inputs are present, as it is evident in model specification (3). These results highlight the importance of knowledge and technology intensive inputs (approximated by the share of domestic and imported intangible inputs to total intermediate consumption) in the competitive performance of an EU manufacturing sector. Backward participation in GVCs and sector size have negative and statistically significant effect while GDP per capita growth and investment approximated by the ratio of GFCF to total output identify as drivers of performance with positive and statistically significant effects in all model specifications. Patent applications to EPO have an insignificant effect on performance in specifications (1)-(3).

These results present an intriguing interpretation, as they indicate a decoupling between backward participation in GVCs and competitive performance for the EU manufacturing sector industries. This negative effect is closely related with the type of GVC participation and the nature of the manufacturing activities that the EU and UK industries undertake. Using the "smiling curve" figure as the center of our analysis, manufacturing activities are placed in the middle part of the curve where the VA appropriation is rather limited compared the two ends of the curve where intangible intensive activities take place. Higher backward participation for manufacturing sectors is closely related with up-stream activities. Supply and production oriented backward linkages in this study are separated from intangible intensive up-stream activities via the introduction of the intangible's intensity variable. However, this separation needs to be revised in order to approximate the true impact of knowledge intensive, up-stream activities, in terms of value added.

When we introduce the interaction term in model specification (4), we observe a positive and statistically significant combined effect of backward participation in GVCs and patent applications to sector performance while the individual effect of patent applications is also positive and significant. These results are in line with the assumption that the production of an innovation – such as a patent application – is in fact a driver for sector performance when the sector is participating in GVCs. The negative sign of $gvcB_{i,c}$ can be thus interpreted as a vestige that backward participation in GVCs has a negative effect on sector performance in the absence of an innovative outcome. Coherently, the results of this study indicate at the importance of technology transfer, knowledge flows (in the form of intangible inputs) and innovation in the competitive performance of a manufacturing sector when the sector is participating in GVCs.

Conclusions and Policy Implications

This paper investigates the linkage between intangibles, patents, participation to GVCs and sector performance in 19 manufacturing sectors of 27 EU economies and the UK. Data and variables derive from the newly constructed GLOBALINTO I-O Intangibles Database, WIOD and Eurostat.

The novelty of this study is the introduction of an innovative approach in the quantification of intangibles, by treating them as intermediate inputs in the inter-industry and inter-country trade of utilities. This approach enables the tracking of knowledge and innovation flows in EU's manufacturing sectors in the form of intangible inputs intensity (i.e. the share of intangible inputs to total intermediate consumption). Intangibles intensity appears with a dual perspective in this study, based on intangibles production origin, as we are able to identify between domestically produced and imported intangible assets. This origin perspective introduces different layers of analysis that were previously unexplored in relevant literature streams. The joint empirical investigation of intangible inputs and patent applications to EPO can provide a solid representation of each sector's innovation activities as it provides evidence for both knowledge and innovation input in the form of intangibles as well as innovation output in the form of patents.

In this context, we are able to identify that total intangibles intensity is on the rise in the majority of EU's manufacturing sectors during the 2000-2014 period. Using the crisis as a time mark in the examined period, we are able to observe different patterns of intangibles intensity from different manufacturing industries in the pre-crisis period (2000-2007), during crisis (2008-2010) and the after-crisis "stagnation period" that followed. When accounting for origin, we find that trade in intangibles (in the form of imported intangible inputs) is experiencing a significant increase in its growth rates during 2000-2014, while domestic intangibles intensity is severely affected by the impact of the economic crisis. Several manufacturing sectors (most notably Mn. of coke and refined petroleum products (C19) and mn. of chemicals and chemical products (C20)), appear to rearrange their strategies towards intangibles utilization after the crisis, a fact that is also strongly connected with an ongoing technological transformation that is reshaping traditional manufacturing activities.

In the second stage of this study, we attempt to empirically assess the linkage between intangibles intensity, patents, GVC participation and sector productivity performance. We consider patents as an innovation metric and utilize data regarding patent applications to EPO from GLOBALINTO I-O Intangibles Database for the period 2000-2013. Firstly, we study the individual relationship between intangibles intensity, patents with exporting activity, sector performance and GVC participation. We focus on backward participation to GVCs using a relevant indicator that is the ratio of the share of FVA in gross exports to gross exports. The performance indicator in this study is a RCA-type indicator that accounts for sector productivity performance relative to the world, using the ratio of VA to gross output at the industry-country and industry-world level respectively. Furthermore, we investigate the joint effect of intangibles, patents and GVC participation to sector performance via the introduction of simple RE panel regressions. We account for domestic and imported intangibles both separately and jointly and also introduce an interaction term between backward participation to GVCs and patent application in order to test the hypothesis that the production of innovation is associated with an increase in sector performance when the sector is participating in GVCs.

Our empirical findings in terms of correlations highlight the significance of intangibles origin when accounting for intangibles effects into different variables of interest. More specifically, imported intangibles are positively correlated with sector performance and backward participation to GVCs. Domestic intangibles are positively correlated with patent applications but have a negative correlation with backward participation in GVCs. Overall, intangibles intensity is strongly and positively correlated with exports. On the other hand, patent applications to EPO are positively correlated with exports and sector performance but their correlation with backward participation is dominated by sector specific characteristics for each industry.

The empirical results from our model specifications indicate that imported intangibles are a driver for sector performance when domestic intangibles are present while patent applications appear to be statistically insignificant. Furthermore, we identify a possible decoupling between backward participation in GVCs and competitive performance for the EU manufacturing industries. This finding is related with the nature of activities (mostly up-stream and production related, as knowledge intensive activities are separated via the introduction of imported intangible inputs intensity in our analysis) that our selected measure of GVC participation (backward participation) encompasses. Patents become a driver for sector performance with the introduction of the interaction term, which is also positive and statistically significant. These results support the claim that the production of an innovation – such as a patent application – is in fact a driver for sector performance when the sector is participating in GVCs. Under this conditional hypothesis, the negative effect of backward GVC participation can be thus interpreted as a hint that backward participation in GVCs has a negative effect on sector performance in the absence of an innovation outcome.

Summing up, the basic conclusions of this study are presented below:

i. The identification of intangible inputs per origin is vital key for better understanding the relationship between intangibles and different variables of interest such as exports, sector performance and GVC participation.
ii. Imported intangibles growth is explicitly rising in the period 2000-2014. Intangibles-producing industries in each country appear to be increasingly connected with various manufacturing industries from different countries as trade in intangibles is constantly rising.
iii. Domestic intangible inputs appear to be more sensitive to general macroeconomic conditions as the economic recession in 2008 severely damaged their respective growth in the upcoming years.
iv. Imported intangible inputs are a driver for sector performance while domestic intangible inputs appear to be a driver for innovation.
v. Backward participation in GVCs has a negative effect on sector performance in the presence of intangibles-related input variables.
vi. Innovation is vital for successful backward participation in GVCs.
vii. Each manufacturing sector presents a different behavioral pattern regarding intangibles intensity and its connection with various other growth and performance indicators.

The continuous rise in imported intangibles intensity can be interpreted as a vestige of the formation of innovation value chains between industries and countries. However, relevant metrics with respect to trade in VA must be properly constructed in order to accurately identify knowledge flows between the inter-connected industries that participate in GVCs.

This study identifies the role of intangibles – especially the imported ones – as drivers for competitive performance in the context of GVCs. These empirical findings at the industry level consolidate a basis for a discussion resolving around industrial policy and relevant implications regarding intangibles, a point first elaborated in Tsakanikas et al. (2020a). Industrial policies that enable the production, accumulation and development of intangible assets appear to be pivotal for EU's manufacturing industries competing in GVCs. However, according to Lampel et al. (2020), intangibles policies are currently incomplete and highly differentiated across different countries, without a common EU-oriented guideline that encompasses relevant legislations and directories both at the country as well as the industry level. Tsakanikas et al. (2020a) proposed the construction of a unified EU industrial policy framework regarding intangibles, that includes the harmonization of national agendas regarding intangibles development and diffusion policies towards common growth and competitiveness targets based on the concept of the regionalized EU value chain where all member states can benefit from. This study further contributes to this idea through the introduction of sector level analysis that highlights the importance of intangibles trade in the competitive performance of EU's manufacturing sectors. The heterogeneity of results across different sectors indicates the importance of sector specific characteristics in industrial policy making and pinpoints the different layers of analysis that need to be taken into account – first at the national and then at the EU level – towards the construction of concrete policy frameworks that promote industry and country cooperation in terms of intangibles trade.

Limitations and future research

The present study focuses on relevant data that derive from GLOBALINTO I-O Intangibles Database and cover the time period 2000-2014. The unavailability of updated data (2014 is the most recent year of available from WIOD ICIO tables), prevents the authors from empirically investigating the effects of the rapid technological and digital transformation that stems from the 4^{th} Industrial Revolution in intangibles utilization from EU's manufacturing industries and the respective evolution of trade in intangibles.

Furthermore, this study focuses on the effects of backward participation in GVCs in the EU's manufacturing sectors' performance and finds a possible decoupling between GVC participation and sector performance. However, this result may be biased towards the direction of GVC participation. Backward participation quantifies the share of VA from foreign imports that EU's manufacturing sectors incorporate to their exports. The negative relationship between the share of FVA in a manufacturing sector's exports with sector performance may simply be related with sector size and the nature of each sector's economy as several European economies base their production and manufacturing activities on domestic trade of utilities rather that participating in international networks. The empirical investigation of forward participation in GVCs (that is the share of domestic VA incorporated into foreign industry's exports) for the EU's manufacturing sectors may present different results and will be explored in future research attempts.

This study underlines the importance of imported intangibles in sector performance and discusses the vestige of the formation of innovation value chain and the trade of intangibles between industries. In order to properly identify this kind of inter-industry and inter-country connections and directly study the various knowledge flows that are traded between industries, future research should aim towards the construction of trade in VA related metrics that are able to quantify the amount of VA produced by sectors producing intangibles (based on the GLOBALINTO I-O Intangibles Database framework) that is consequently incorporated into other industries' exports and is traded between different industries across the world.

Another important aspect of this study is the identification of different patterns between different manufacturing industries. This finding indicates towards the need for industry-specific case studies that focus on a specific industry (or groupings of them) and study the effects of intangible inputs on the basis of its characteristics and other sector-specific variables of interest across different countries.

The authors would also like to acknowledge possible endogeneity and reverse causality issues that may derive from the econometric estimations implemented in this study and may result in estimation bias. Proper treatment and exploration of alternative and robust estimation methods is to be implemented in future work.

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