GLOBAL VALUE CHAIN PARTICIPATION AND THE TECHNOLOGY STRUCTURE OF EXPORTS: EXPERIENCE FROM THE CENTRAL AND SOUTHEAST EUROPEAN COUNTRIES

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ABSTRACT
Producing and incorporating technologically complex goods in the production process is a fundamental pillar to achieving long-term economic development. In this sense, integration into the global production and trade networks is viewed by many countries as a way to achieve this technological improvement. This paper examines the relationship between global value chain (GVC) integration and technology absorption through trade in high-tech products of Central and Southeast European countries over the period 1996-2019. We construct a GVC participation measure applying the latest Broad Economic Categories (BEC) classification that distinguishes between generic and specific intermediate goods. We also analyse the technology structure of exports at a country level and the sectoral level. Using panel data estimation techniques, we find that higher participation in GVCs enhances the export of high-tech products at both country and sectoral levels. This result is robust to different regression models including the use of lagged control variables and instrumental variables.

Keywords: *Global Value Chains, Technology Structure of Exports, Central and Southeastern European countries.*

JEL classification: *F14, F60, C23, C26.*

1. INTRODUCTION

Over the past decades, the world economy has experienced unprecedented globalization through the rise of global value chains (GVCs). This was a period of "hyperglobalisation" caused by factors like trade liberalisation, ICT development, fall of communist systems (Antrás, 2020b). It is often argued that GVCs have offered a new path towards industrial development since firms from high-technology nations are combining their specific managerial, technical, and marketing know-how with the low wages in developing nations (Baldwin, 2016). Nevertheless, the nexus of increased GVC participation in supporting the international transfer of technology to firms in developing countries has been given somewhat less attention in the literature.

10.47063/EBTSF.2024.0012
http://hdl.handle.net/20.500.12188/31960

It has long been argued that innovation and international trade are two driving forces of economic growth and development (Romer, 199). Increased innovation provides opportunities for product differentiation and reduction of production costs, which facilitates a firm's expansion to international markets (Krugman,1980; Guan and Ma, 2003; Tavassoli, 2018). On the other hand, trade with foreign countries results in technological spillovers (Coe and Helpman, 1995; Castellani and Fassio, 2019), which are beneficial for productivity growth in developing countries.

These two driving forces of innovation and international trade are best combined in the GVC-related trade. The rise of the GVC production model has altered the traditional way of industrialization where one country needed to develop the whole set of components that formed part of a final product. With the GVC production model, instead of having to build-up an entire domestic industry in order to export, countries can specialize in one or more stages of production and produce only some particular components that form part of the final product(s) of a GVC. This has allowed countries to leap-frog and shorten the industrialization process and penetrate international markets faster than was the case with more traditional industrialization processes.

Looking from a development standpoint, it is crucial for a country to engage dynamically in the process of GVC participation. This implies a strive to move up the value chain and accumulate more human and physical capital with time. Typically, developing countries enter GVC in low value-added tasks producing less technologically sophisticated products and performing labour-intensive tasks like product assembly. Nevertheless, within the GVC a foreign firm and a local supplier are part of the same supply chain, and they need to interact and coordinate to secure the proper functioning of the supply chain. With time, this facilitates the transfer of tacit knowledge, potentially increasing domestic innovative capabilities. Thus, opportunities to engage in the production of more sophisticated high-tech products or tasks emerge, allowing companies and the economy to move up the value chain ladder. The production of high-tech products is beneficial for the economy as a whole as it allows for positive spillovers in terms of technology transfer, skills upgrading, and productivity gains (depending on the absorptive capacity of the country). Thus, this new GVC-related model of development focuses on first joining and then crucially moving up the value chain towards higher technology and value-added processes.

In addition, the process of fragmentation of manufacturing within GVCs, has reduced the production complexity of high-tech products and opened-up opportunities for developing countries. Detaching production into smaller sub-components which are designed and produced separately and then assembled into final product(s) has facilitated this process of technology transfer. Inter-firm linkages in GVCs are important in the transfer of knowledge and in the promotion of innovation, influenced by internal or intra-firm sources of learning, fostering a capability accumulation process (Morrison *et al.*, 2008; Reddy *et al.*, 2021). This has allowed newcomers to the industries to be able to shorten the gap or catch-up with lead companies from advanced economies. Firms from small developing countries can also take advantage of the fragmentation of production and leverage their regional markets for scale and move up the technological and value chain spectrum. The Central and Southeast European countries (CSEE), which are of interest in this study, are following suit in this process.

In this paper we aim to look at the link between a higher participation in GVCs and a country's involvement in high-technology products trade. We focus on the Central and Southeast European countries[1]. These are economies that underwent a sizable socio-economic transformation over the past decade. They had relatively similar starting points in their

[1] The countries in this study are comprised of Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia and Slovenia, Serbia, North Macedonia, Bosnia and Herzegovina and Albania.

development after the fall of communism/socialism, but the pace of their development and technological upgrading has been different; with the CSEE countries leading the way, and the WB countries following a similar pathway, but with a lag. In our analysis we try to answer the following question: has greater integration into global value chains enhanced the technology upgrading of exports in these countries through certain sectors prone to higher technology adoption?

In our analysis, we rely on an empirical method based on panel data techniques to address this question. The potential endogeneity of the participation in global value chains and technology transfer is considered in our regressions through the inclusion of lagged explanatory variables and the use of instrumental variables. In the aggregate model, we also control for human capital as an additional regressor. In all cases, our findings confirm the impact of GVC integration on the technology structure of exports at both the country and sectoral levels.

We contribute to the existing literature on GVC and trade integration in the following ways: First, we develop a method of calculating GVC participation by applying, in a novel way, the new Broad Economic Categories (BEC) classification Rev. 5. That distinguishes between generic and specific intermediate goods which are consistent for the countries in question[2]. Moreover, as an additional contribution to the literature, we build a model to analyse the high-technology exports in the CSEE countries, something that has been scarcely investigated for these regions. Finally, we estimate this relationship using panel data through a country-level analysis, but we also drill deeper and look at the sectoral level to see the influence of different segments of the economy.

The rest of the paper is organized as follows. Section 2 provides an overview of the literature that relates the participation in GVCs with technology upgrading. The next section outlines the methodology applied in calculating the GVC participation and the benefits of using the BEC classification. Section 4 contains some relevant stylized facts about GVC participation and trade in high-technology goods for the CSEE countries. The econometric methodology and estimation results are presented in Section 5. The final section concludes.

2. RELATED LITERATURE

International trade is considered to be a channel of technology transfer. On the one hand, the level of connection to international markets brings advantages for trading firms in the form of better-quality inputs and higher revenues, which can influence productivity gains as argued by Amiti and Konings (2007), Topalova and Khandelwal (2011) and Halpern *et al.* (2015). On the other hand, this process is self-reinforcing as firms will be stimulated to invest more in upgrading their technology (Bustos, 2011; Lileeva and Trefler, 2010). Moreover, this process of technology adoption is more pronounced if GVC trade is involved and if local absorption capacity is adequate.

The empirical literature has shown the benefits for countries from GVC participation that go beyond those associated with trade in final goods (Lall, 2000; Humphrey and Schmitz, 2002; Cheng *et al.*, 2015; Baldwin and Yan, 2014; Shimbov *et al.*, 2016). As mentioned by the seminal papers of Collier and Venables (2007) and Athukorala and Yamashita (2006), the international fragmentation of production has allowed many countries to improve their competitiveness derived from the possibility to be specializing in a segment of the production process, even when they are not the most efficient producers of the final good.

From a development perspective, as shown by Hausmann *et al.* (2007), the process of the composition and sophistication of a country's export basket will be influenced by capacity building, learning, and technology adoption, which will ultimately play a vital role in

[2] Data limitations and consistencies issues limited our options of using some of the existing sources of GVC participation measures.

stimulating economic growth. This was further developed in more recent literature, arguing that a greater participation in GVCs also provides benefits for firms through access to more sophisticated intermediate inputs presenting opportunities for acquiring better technologies, stimulating technological spill-overs, and forming trade networks faster than with conventional arm's length trade (Gereffi, 2019; Shimbov *et al.*, 2016; Stöllinger, 2017; Pahl and Timmer, 2020).

Firms integrated into GVCs usually have relatively high import and export levels due to intra-chain trade. Thus, they can benefit from both learning by importing and exporting. On the one hand, access to world markets for intermediate goods gives firms the ability to use high-quality inputs that may not be available domestically. Developing countries can strive for a technology upgrading by incorporating high-quality intermediates, which will enable the production of new and more sophisticated products and crucially to obtain knowledge and learn about the technology embodied in the imported inputs, which may eventually enhance production efficiencies in domestic firms (Andersson *et al*., 2008; Elliott *et al*., 2016). On the other hand, exporting within GVCs allows firms to learn from markets that are more competitive and have more sophisticated consumers. Thus, they can move further up the technological and value-added lather. The outcome of both processes has positive implications for the level of technological quality of exports.

The empirical literature has shown that when entering GVCs, developing countries often integrate in low-value-added activities. While this may be a natural starting point for a developing country it may not be the desired one as developed countries are positioned either at the upstream or downstream end of the value chains, where the maximum value addition takes place. Export of high-tech goods in developing countries often can be bound to certain multinational affiliates with a few given products, while the economy remains specialized in low-tech and low-skill fragments of the global value chains (Éltető, 2018). Thus, from a development perspective, a country can have more benefits through GVC participation when it moves towards the parts of the chain where the most value is created. One of the key components for this to happen is technology adoption and innovation, which will influence the change in the trade structure of a country. This process helps firms and countries to start moving up the value chain and operate closer to the technological and value-creation frontier (Ito *et al*., 2019; Brancati *et al*., 2017).

The movement towards a more sophisticated and higher technology exports is defined by the technological capabilities and the ability of a country to absorb new technologies and adapt or reproduce them elsewhere, as argued by Morrison *et al*. (2008). As a result, local technological capabilities are crucial for shaping the production and technology structure of a country, thus influencing the technological content of its exports. Taglioni and Winkler (2016) argue that policies which strengthen, and foster innovation and capacity building are essential for expanding and strengthening the level technological content in exports and the level of GVC participation. For example, the increasing participation in GVCs has allowed countries like China to specialize in tasks with higher value-added within this international division of labour, which has led to export and import of goods with higher technological content (Ndubusi and Owusu, 2020).

A similar process was followed by the CSEE countries. According to Stehrer-Stöllinger (2015) and Shimbov *et al*. (2013), Germany became the main trade hub, forming a Central-European manufacturing core, with the southeast European countries gaining ground in more recent years, as argued by Ilahi *et al* (2019). Similarly, Grodzicki and Geodecki (2016) and Kersan-Skabic (2017) discuss the core-periphery model in Europe based on the country groups in the value chains. Both works find that in GVC participation central European countries are in a better position than the southern European. According to Mandras and Salotti (2020) the southeast European countries also increased their GVC participation significantly between

2000 and 2018, even though not at the level of the central European counterparts. Kejžar *et al*. (2020) arrive at a similar conclusion of rising GVC participation for the southeast European countries, with a relatively more pronounced backward participation. This means that they import a significant part of intermediate goods, as they are close to innovation-related activities, in particular Germany as the main global value chain production hub in Europe. This proximity is likely to have an effect on the technology transfer in these countries, which is what we set to investigate in our analysis.

As our summary of the literature highlights, despite its relevance from the point of view of modernization and economic growth in this region, studies investigating the connection between innovation, technology upgrading, and GVC participation are not many, particularly not for the CSEE countries. This paper contributes to this nascent literature by exploring the nexus between technology adoption influencing the technology upgrading of exports and the participation in GVCs for the CSEE countries. In addition, the few related studies provide a productivity or macroeconomic perspective on the subject, as can be seen in Kersan-Skabic (2019) and Amador and Cabral (2016). In contrast, as a novelty, we present here, in addition to the aggregate model, a sectoral picture of the connection between the technology content of exports and GVC participation, for the regions of CSEE countries.

3. MEASURING THE PARTICIPATION IN GVCs

The rise of global value chains has made the analytical distinction between trade in intermediates and trade in final goods more important[3]. The dynamics of contemporary trends in international trade and economic globalization have been widely analyzed by distinguishing intermediate and final goods trade. A more recent expansion in the analysis of economic interconnectedness has been made possible by the development of global input-output tables and indicators of trade in value added (TiVA, WIOD, Eora). Nevertheless, we do not use these databases in our analysis, as we do not consider the narrower term of value added in trade, but rather the participation of countries in a GVC type of trade and its effects on the structure of exports. In addition, another shortcoming that we face with these data sources is the lack of information for some of the countries in our sample. Thus, for a more accurate and complete empirical analysis, in this paper, we use the BEC classification as an alternative source.

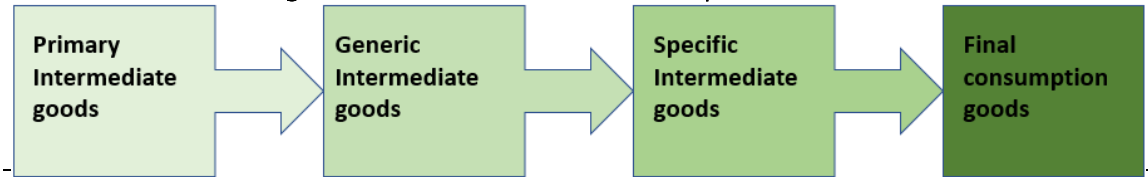
The BEC is a high-level aggregation of existing product classifications. It provides an overview of international trade based on the detailed commodity classifications in the Standard International Trade Classification (SITC), the Harmonized Commodity and Coding System (HS), and the Central Product Classification (CPC). Its comparative advantage has traditionally been the classification of goods by end-use category. This made a range of analytical applications possible in the past, and in the latest revision, it also facilitates observing the relative integration of economies in global value chains. We use the latest, fifth revision from 2016 that adds a new component defined as "specification dimension" to differentiate generic intermediates, i.e., consumed across a wide range of industries, from those that are specified, i.e., typically consumed only in certain industries. The aim of using this new dimension is to help researchers analyse countries' participation in global value chains and its diverse implications, which is precisely what we take advantage of.

Furthermore, the BEC Rev. 5 has an additional improvement as it defines broad economic categories entirely based on product specificities and does not mix intermediates with end-use categories as was the case in past revisions. This is a meaningful improvement as it provides greater international comparability. In the new BEC Rev.5 the products included in a given

[3] The literature on the analysis of global value chains refers to the broad plethora of research on similar phenomena referred to as production sharing, vertical specialization, the fragmentation or disintegration of production, offshore outsourcing, and most recently trade in value added.

economic category are in concordance with classifications agreed to internationally, such as HS and CPC. We also take advantage of this new feature in the database, which helps us to do the reclassification of products in order to go one layer below the aggregated country-level and be able to do a sectoral analysis as well.
The main purpose of the novel specification dimension in the BEC Rev. 5 is to isolate trade in primary commodities and generic intermediates from trade in highly specified intermediates. This new variable is particularly useful because global value chains most prominently involve international transactions with some level of explicit coordination, rather than the arm's-length transactions underpinning more "traditional" trade (Figure 1). While researchers have developed ad-hoc lists of differentiated and highly specified products in the past, the specification dimension of BEC Rev.5 defines an official, internationally accepted list.

Figure 1: Value-added chain as defined in BEC Rev.5



(Source: BEC Rev.5 manual and authors' own elaboration)

Specified processed intermediates, as defined in the BEC Rev.5, are highly dependent on the industry for which the goods are made. Moreover, as specified in the BEC manual, in some cases parts and components are produced according to the specific requirements of one or a few buyers, with a single or small number of downstream uses. For instance, almost all components in the aircraft, automotive, and electronics industries can be considered as part of the GVC trade. In addition, even products that are not produced in reduced or limited lots, like pharmaceuticals, or are produced in large quantities like chemicals, can still be considered as specific, as they are almost always protected by patents required by their value chain, thus limiting the access to these products. This dimension of products as defined in BEC Rev.5 is also related to the "Products Complexity index" as defined by Harvard's Center for International Development, which uses the diversity of countries that make specific products and the average ubiquity of the other products that these countries make[4]. On the other hand, the generic intermediate goods can normally be found further upstream in the value chain (see Figure 1). These products are more linked to an arm's length type of trade, rather than related to global value chains because their generic use would normally have a broader application across industries. Thus, the generic intermediates can be associated with homogeneous and referenced priced goods, while specified intermediates with differentiated goods.
The abovementioned characteristics of the BEC Rev.5 classification are the starting point of our analysis. Namely, as mentioned we take advantage of the specification dimension to come up with the specified goods related to GVC trade and also to the interconnectedness of the BEC Rev.5 with other classifications to do the sectoral analysis. In our analysis, we use UN Comtrade data, and we look at the period 1996-2019 period (we exclude 2020 and 2021 due to the COVID-19 shock of global trade). We apply UN Comtrade gross trade data classified according to the Harmonized System (HS) and converted to International Standard Industrial Classification (ISIC) for sectoral analysis. Thus, we use the same industries as in the OECD-WTO TiVA database, for the sectoral analysis. Using this data, we construct total exports, final goods exports, intermediate exports, intermediate imports, and high-tech goods exports. We use a similar procedure as in Duval *et al*. (2014), but we use the new BEC classification. In

[4] For more detail see atlas.cid.harvard.edu/about/glossary/

addition, we do not interpolate results into the TiVA database as in Duval *et al*. (2014), but we work with absolute data for each year, country and sector[5].

Thus, before being able to use the data form UN Comtrade, we had conducted substantial rearrangements, reclassifications and calculations. A step-by-step description of the processes caried out is presented in Annex 1 at the end. Based on the conversions and reclassifications, the calculations for the high-tech goods and GVC participation are conducted. Specifically, based on concordances provided by the UN, for HS, SITC, CPC, ISIT and BEC, we first match sectoral trade statistics (at six-digit HS classification level) with the specification dimension in BEC Rev.5 (specified vs. generic and primary goods) classifications. Then, we adjust the original data to match sectoral series so that they are consistent with the ISIC Rev. 4 industries (using the CPC classification as an intermediary). Series for each industry are then estimated separately. Based on the above-mentioned reclassification we obtain the values for the dependent variable of high-tech exports per sector. Then for the sectors in which there is trade in high-tech goods we construct the share of high-tech exports, as a share of exports per sector. For the main explanatory variable of GVC participation, for each observation year, country and sector at the exporter-sector level, we calculate the share of specified intermediate imports (as defined above using the BEC Rev.5 classification) in a given sector as a share in overall exports of the same sector to create the backward participation. The same procedure is repeated for each observation year, country, and sector at the exporter-sector level to obtain the forward participation as the share of specified intermediate exports in a given sector in both total exports and in overall exports of the same sector, respectively.

4. STYLIZED FACTS: HIGH-TECH EXPORTS AND THE PARTICIPATION IN GVCS

The share of high-technology products in total exports is an indicator that is often included in international innovation and business indices. The concept is that the higher this ratio is, the more technologically advanced the export structure of a country is and thus the higher the development potential can be. As mentioned before, this can be partially true for certain countries and certain industries as not all countries and industries follow the same pattern. Table 1 provides a first glance at the share of high-tech products in exports for the CSEE countries for four years of our sample: 1996/7, 2000, 2010, and 2019.

Table 1: Share of high-tech products in total exports

	1996/97	2000	2010	2019
Albania	0.4	0.9	0.9	0.04
Bosnia and Herzegovina		1.4	1.6	4.2
Bulgaria	2.4	1.8	4.6	6.1
Croatia	6.7	6.4	7.0	8.3
Czeckia	5.8	7.8	15.5	19.5
Estonia	5.3	21.0	9.7	11.1
Hungary	3.6	22.8	21.3	15.5
Latvia	3.5	2.4	5.0	10.5

[5] A similar method is used in a recent European Central Bank publication by Cigna et al. (2022).

Lithuania	0.7	1.5	0.8	2.1
Macedonia	0.6	0.8	2.3	3.5
Poland	2.1	2.6	6.0	7.8
Romania	0.7	2.1	3.2	4.9
Serbia		1.2	1.4	1.3
Slovakia	1.7	1.8	1.1	1.5
Slovenia	1.8	2.2	2.9	4.6

(Source: own calculations based on UN Comtrade database)
Note: the countries that did not have 1996 data available the 1997 figures are used.

In general, the countries in our sample managed to increase their high-technology content of the export structure over the period, with the exception of Albania and Montenegro. Still, we can observe different patterns in terms of magnitude and in certain cases high volatility in time. In the period 1996-2019, Romania saw the highest (almost eleven-fold) increase in its high-technology exports (even though from a very low base). Lithuania and Poland increased their share of high-technology exports by over four times, while Bosnia and Herzegovina, Latvia and Slovakia managed more than a three-fold increase. The remaining countries on average doubled their share of high-tech exports.

In some cases, these dynamics are driven by some sectors in particular, which have a significant influence on the export structure. The three most dominant sectors, achieving the highest shares in overall exports are (i) computers, electronic and electrical equipment, (ii) chemicals and non-metallic mineral products, and (iii) machinery and equipment. Moreover, in some countries, this dynamic is driven by a single exporter of significant world market share. For example, Lithuania has Europe's second largest polyethylene terephthalate company[6] and its export is a very important item. The outstandingly high Hungarian figures for the period 2000-2010 was due to the local Nokia affiliate that exported mobile phones at that time, but closed later (indeed, 58% of high-tech exports were telecom equipment and this dropped to 30% in 2018). Estonia's high figure in 2000 was due to Ericsson's activity. In the Czech high-tech export computer and data processing machines and telecommunication equipment dominate. North Macedonia has a local company that is a leading European manufacturer of electronic printed circuit boards[7]. In Serbia, there have been a number of FDI investing the chemicals and non-metallic mineral products industry over the years. Poland and Slovenia have seen an increase in machinery and transport equipment high-technology products as a result of significant FDI establishing operations in these countries.

The rise of high-technology exports resulted in these products being the predominant export of certain sectors in some countries. The most obvious cases are the computers, electronic and electrical equipment from Latvia, Estonia, Czechia, Lithuania and Slovakia, where the share ranges from 39 to 68% of overall exports in the sector (Table 2). In the chemicals and non-metallic mineral products sector, high-technology products account for 14% of overall exports in the sector in Croatia and Hungary and 12% in Slovenia. In addition, this trend of rising share has been maintained though ought the period, but with different magnitudes per sector. By far the sector that most benefited from the rising exports of high-technology products was

[6] https://neogroup.eu/en/company/about-us/
[7] https://www.hitech.com.mk/en/about-us/

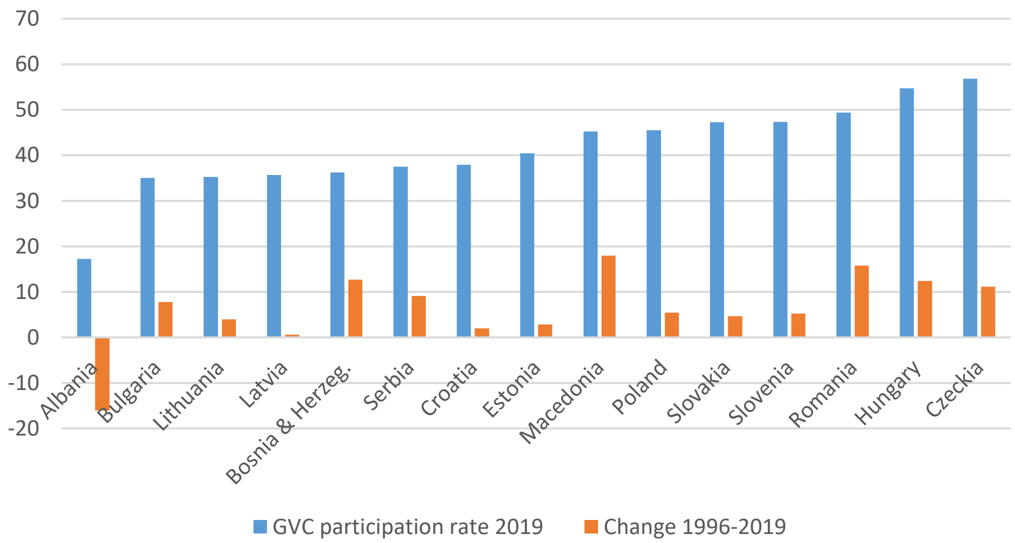
computers, electronic and electrical equipment, but also sectors like chemicals and non-metallic mineral products and machinery and equipment had significant gains (Figure 2).

Table 2: Share of high-tech products exports per manufacturing sector, 2019

	Chemicals & chemical prod.	Computer electronic & optical prod.	Electrical equipment	Fabricated metal prod.	Machinery & equipment	Other transport equip.	Pharmac., medicinal chem. & botanical prod.	Other manufacturing n.e.c.
Albania	4.0	93.4	1.0	0.0	0.3	0.0	0.0	0.0
Bosnia and Herzegovina	13.5	77.3	10.4	0.6	9.5	0.2	0.9	0.3
Bulgaria	3.3	66.7	12.7	0.0	5.2	5.2	24.4	0.8
Croatia	6.8	66.1	8.4	4.7	13.3	5.5	49.1	1.4
Czeckia	3.1	87.5	10.1	3.7	14.8	37.6	23.2	1.1
Estonia	3.0	86.5	16.3	0.7	7.1	32.8	23.8	0.9
Hungary	10.7	66.0	17.5	0.0	18.0	9.8	38.3	1.8
Latvia	7.3	85.9	12.2	0.0	14.7	30.4	12.2	1.2
Lithuania	19.9	81.6	9.6	0.1	6.5	10.1	33.0	1.7
Macedonia	0.3	65.4	15.9	0.0	2.5	0.3	25.2	0.2
Poland	2.9	59.9	4.1	0.2	9.5	41.4	29.9	0.6
Romania	8.1	61.8	23.4	0.0	10.7	6.3	17.8	0.7
Serbia	2.7	60.5	1.6	0.4	10.8	12.4	16.1	0.5
Slovakia	1.8	54.1	9.0	1.0	6.9	4.6	21.4	1.6
Slovenia	10.2	55.9	4.7	0.0	7.2	42.3	19.8	1.5

(Source: own calculations based on UN Comtrade database)
Note: the countries that did not have 1996 data available the 1997 figures are used.

Figure 2: Change in the share of high-tech products exports per manufacturing sector (difference between 2019 and 1996)



(Source: own calculations based on UN Comtrade database)
Note: the countries that did not have 1996 data available the 1997 figures are used

Throughout the past two decades, the CSEE countries have also considerably increased their participation in GVCs, as part of their development strategy. As mentioned, they became increasingly connected to the main GVC hubs in Europe, in particular Germany and integrated themselves in the manufacturing core. In general, all of the CSEE countries have relatively high GVC participation rates, even though variations among countries exists.

Looking at the sectoral level we observe variations among countries, but also among sectors. The four main sectors with the highest GVC participation are i) computers, electronic and electrical equipment, ii) chemicals and non-metallic mineral products, iii) machinery and equipment, and iv) other manufacturing products. These have been the sectors that observed the fastest growth in GVC participation and also the ones that achieved the highest integration in the European manufacturing hub[8]. Sectors like textile and apparel and wood and paper, show smaller GVC participation in all countries. The higher weight of sectors that contain technologically more advanced products places the CSEE countries on the right track, as they can benefit more from the possible technological spill-overs.

Table 3: GVC participation per sector (period average 1996-2019)

	Albania	Bosnia and Herzegovina	Bulgaria	Croatia	Czeckia	Estonia	Hungary	Latvia	Lithuania	Macedonia	Poland	Romania	Serbia	Slovakia	Slovenia
Basic metals	19.7	23.8	12.2	20.0	17.0	46.9	14.2	21.0	27.9	10.0	13.1	23.5	10.6	14.3	16.3
Chemicals & chemical prod.	26.0	38.5	39.4	31.4	39.1	18.5	39.1	34.0	27.4	51.4	36.0	35.7	32.3	41.1	38.9
Coke & refined petroleum	3.9	5.5	1.8	5.5	5.4	79.7	5.0	2.7	1.7	7.1	6.5	4.5	5.1	5.3	4.4
Computer electronic & optical prod.	81.7	82.2	86.0	85.4	89.2	69.3	87.5	78.7	81.2	87.3	77.6	89.5	82.8	74.9	88.5
Electrical equipment	73.9	72.1	78.8	77.4	89.5	56.9	83.7	73.9	73.0	77.3	76.9	88.1	76.0	87.7	72.2
Fabricated metal prod.	73.3	69.9	60.5	67.4	66.9	35.5	64.6	63.3	65.0	66.7	64.4	62.5	61.3	64.0	62.6
Machinery & equipment	1.0	0.0	0.5	0.2	0.3	36.7	1.2	0.6	0.2	0.2	0.3	0.5	0.2	0.6	0.2
Food, beverages & tobacco	0.2	47.5	45.8	51.1	53.7	42.1	62.8	49.0	46.1	33.9	53.2	52.2	46.5	59.0	50.5
Motor vehicles	38.0	58.1	47.4	42.4	57.5	25.3	70.4	49.5	44.9	51.3	66.0	66.7	49.5	49.0	40.8
Other non-metallic mineral prod.	54.2	64.7	67.9	66.4	67.1	72.4	76.3	62.4	67.3	71.3	69.1	62.2	71.3	62.5	71.8
Other transport equip.	63.8	76.9	83.7	95.7	87.5	91.0	67.3	89.8	85.6	51.9	96.4	96.3	91.3	90.0	84.3
Pharmac.,& medicinal chem. Prod.	99.2	99.6	99.2	99.3	99.2	98.8	99.2	99.0	99.3	99.6	98.5	98.4	98.8	99.3	99.6
Rubber & plastics	34.0	23.4	28.2	28.1	29.8	29.3	39.5	28.1	36.9	33.5	25.8	30.4	20.0	26.4	22.6
Textiles, wearing & leather	38.6	32.1	34.1	20.5	29.8	27.4	31.6	27.2	32.8	27.5	29.0	35.4	28.6	27.3	24.1
Wood, papper & printing	52.9	30.6	47.1	37.3	43.8	30.3	56.9	22.1	41.2	50.1	53.6	36.6	51.5	46.3	45.4
Other manuf.	47.3	52.2	51.7	47.2	54.7	37.2	61.6	43.4	46.3	60.9	42.4	41.6	54.2	57.0	62.4

(Source: own calculations based on UN Comtrade database)

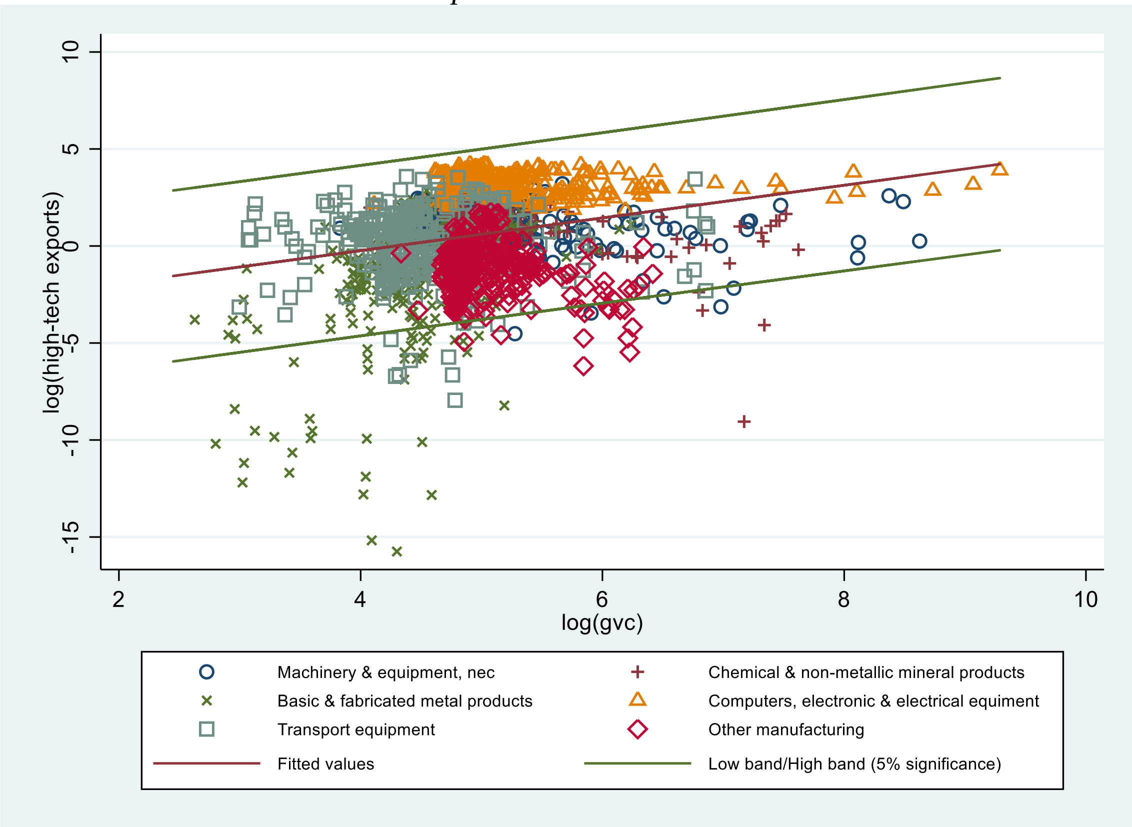
The foregoing stylized facts reveal that, on the one hand, the weight and the structure of exports vary across countries and sectors, although, in general, there is a clear tendency of rising high-technology exports in total exports. On the other hand, figures about GVC participation show different patterns along countries, but with computer, electronics and electrical equipment sector clearly emerging as dominant in most of them. Other sectors that show relatively high participation rates are machinery and equipment, other manufacturing and chemicals and non-metallic mineral products.

As a first approximation to the nexus between GVC participation and the technological composition of exported goods, we next plot the share of high-tech exports across different levels of GVC participation by sectors. As can be seen in Figure 4, most of the sample observations are contained within the significance bands of the regression line, confirming thus the positive link between the participation in global value chains and high-technology exports. Looking at different sectors, we appreciate that this positive relationship is more pronounced

[8] In general, 2/3 and more of overall gross trade of the CSEE countries is done with the European Union countries, or with other WB countries.

in industries such as machinery & equipment, computers, electronic & electrical equipment, and chemical & non-metallic mineral products. This is in line with the observed dynamics of the two variables, which are more noticeable in these sectors as highlighted in the above tables.

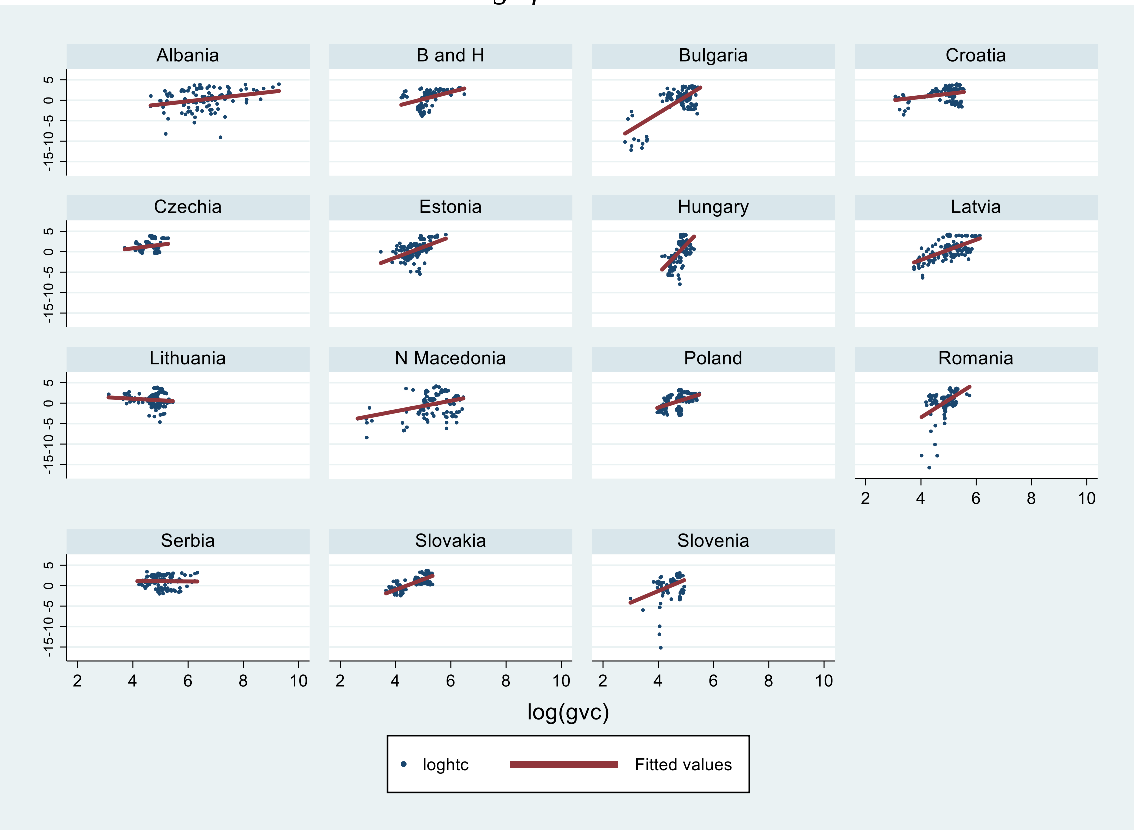
Figure 3: Correlation between high-technology trade and GVC participation, average for the period 1996-2019



(Source: own calculations using UN Comtrade data)

The positive connection between GVC participation and high-tech exports holds, in general, when the correlation between both variables is studied country by country (Figure 4). Except for the case of Lithuania and Serbia, the line representing the fitted values of the log of the high-tech exports concerning GVC participation has an upward slope in the rest of the countries. This can be seen as the first evidence of our hypothesis about the gains in terms of higher technology adoption in exported goods from greater involvement in the international division of production. However, we cannot ignore that in the above plots other factors may influence this relationship, as they might affect both variables simultaneously, or the potential measurement errors are not being taken into account. To deal with these issues, in the following section, we carry out a complete regression analysis, considering other covariates, and possible endogeneity problems or measurement errors.

Figure 4: Correlation between high-technology trade and GVC participation by country, average for 1996-2019



(Source: own calculations using UN Comtrade data)

5. IMPACT OF GVC PARTICIPATION ON THE TECHNOLOGICAL INTENSITY OF EXPORTS

As previously mentioned, a proper causal study of the effects of GVC participation on the technology structure of exports in the CSEE countries requires resorting to regression analysis. However, for the countries under study, this is not an easy task given the lack of data. As previously mentioned, to make up for this deficiency we have built our database using information from UN Comtrade which by substantial reclassification and calculation has allowed us to carry out the study at the country and sectoral level for the period 1996-2019.

The econometric analysis here is reported under two subsections: first, we define the empirical model, and the regression methodology employed. Next, we discuss the results obtained for both the aggregate model and the regressions using sectoral data.

5.1. Econometric approach

To examine the influence of a greater participation of countries in GVC on the quality of their exports we consider here the following regression model,

$$lnHTExports_{c,s,t} = \alpha_0 + \alpha_1 lnGVC_{c,s,t} + x'_{c,t}\beta + \gamma_{c,s} + \delta_t + \varepsilon_{c,s,t}$$

Where the dependent variable is the share of high-technology products in total exports of country c in sector s and time t, in logs ($HTExports_{c,s,t}$).[9] The main explanatory variable here is the logarithm of the GVC participation index of country c in sector s and time t ($lnGVC_{c,s,t}$). As in Harding and Javorcik (2012) and Ndubuisi and Owusu (2020), we consider country-sectors specific effects ($\gamma_{c,s}$) to capture time-invariant characteristics and time effects ($\gamma_{c,s}$). In the aggregate model, we further control for other factors related to human capital ($x'_{c,t}$). In the sectoral model, we could not estimate this extended model due to the unavailability of data on human capital and innovation for these countries at the sectoral level. Finally, u is a regression disturbance term, which is assumed to be strongly independent across countries and sectors. Data sources and descriptions of variables are presented in Appendix II. The decision as to whether to consider unobserved sector-country-specific effects as fixed or random is made based on the Hausman test.

The plausibility of both the potential positive impact of an increase in the degree of participation in GVCs on technology acquisition through exports and the possibility of sectors with a higher technology composition on export level attracting more GVC activities leads us to consider in the regressions of the endogeneity or reverse causality problem. As Ndubuisi and Owusu (2021) pointed out, GVC participation in a sector or region may be correlated with other characteristics of the sector or region that also affect the quality of its exports. This phenomenon would imply that the degree of participation in global value chains could not be considered an exogenous variable, or independent of the technology upgrading process.

To mitigate this potential reverse causality, we proceed first to estimate the model using the lag value of the GVC participation index as our main explanatory variable. Despite this regression strategy indeed controls for a causal link in the opposite direction, it does not totally prevent us from endogeneity biases that stem from the omission of additional explanatory variables or possible measurement errors. (Wooldridge, 2020). The quality of exports depends on many unobserved factors that may be correlated with GVC participation, which could give rise to simultaneous changes in both variables, explanatory and regressor, due to alterations in third external factors rather than to a causal relationship. Therefore, to properly address the endogeneity concern, we next resort to two-stage regression techniques with instrumental variables (IV). This regression strategy has been carried out both in the aggregate model and in the sectoral estimates, as can be seen below.

4.2. Main results

4.2.1. Aggregate GVC participation and technological composition of exports

The estimation results at the country level are depicted in Table 4. The coefficients in this table are shown sequentially for the different estimation methodologies. First, we estimate Eq. (1) through fixed effects (Model 1). As can be seen at the bottom of the table, the Hausman test suggests that the fixed effect (FE) estimation model is preferred to the random effects (RE) model. Next, under the assumption that time will not significantly alter the impact of GVC participation on the technologic composition of exports, at least at short to medium term, and to control for potential reverse causality, we re-estimate the model including the lagged valued of the regressor instead (Model 2). Again, the FE model appears as a better option to the RE estimation. The coefficients on the GVC participation index obtained in both cases (Model 1 and Model 2) are positive and significant, confirming the existence of a technology adoption and technological upgrading of exports from of a greater integration in GVC. They are also of similar magnitude. Specifically, our estimates imply that, on average, an increase in the GVC

[9] Note that for the estimations with aggregate data, the s subscript disappears, and the fixed effects are country specific.

index of 1% leads to a rise in the share of high-technology products in total exports between 1.15% and 1.26%, *ceteris paribus*.

However, as previously mentioned, the above outcomes should be taken with caution as they may suffer from a problem of endogeneity or measurement errors. Even when FE estimation is capturing the time-invariant characteristics, it might be country shocks across time affecting both the participation in GVC and the technological composition of exports. Moreover, according to Reed (2015) and Bellemare *et al*. (2017), the use of lagged explanatory variables is appropriated to escape from simultaneity biased only under very restrictive assumptions, which entail, among other things, assuming the absence of serial correlation among the unobserved sources of endogeneity. This empirical strategy does not take into account possible measurement errors.

Accordingly, to address potential endogeneity issues and to identify the source of the technological upgrading of exports that arises exclusively due to the influence of greater participation in GVC, we next estimate the model using two-stage regression techniques with an instrumental variable (IV), considering GVC as an endogenous regressor. Following Banh *et al*. (2020), we built our instrumental variable using the average GVC measured at the EU level.[10] Concretely the IV is obtained as the total GVC participation rate in the EU by the GVC index by country lagged one period. The validity of this instrument is confirmed through the weak identification and under-identification test (see Table 4 at the bottom).

The results obtained from the two-stage fixed effect with the mentioned instrumental variable (2SFE_IV) estimation are shown in Model 3 (Table 4). In this regression, the coefficient on GVC index is positive and highly significant ratifying thus the beneficial impact on the technological structure of exports from a greater participation in global value chains found before. Moreover, its value confirms an elasticity greater than one, as in previous regressions. Our estimates are also consistent with previous literature (Ndubuisi and Owusu, 2020) delving into the hypothesis that a higher participation in GVC provides an opportunity to adopt new technologies and to incorporate more sophisticated inputs.

Table 4: Estimation results for high-tech exports (in logs). Period: 1996-2019

	Model 1	Model 2	Model 3
VARIABLES	FE	FE with lags	2SFE IV
$\log\,(GVC\ index)_t$	1.264**		1.556**
	[0.587]		[0.743]
$\log\,(GVC\ index)_{t-1}$		1.146*	
		[0.599]	
$Constant$	-4.290*	-3.692	-5.126*
	[2.535]	[2.594]	[0.816]
Country effects	YES	YES	YES
Year effects	YES	YES	YES
Wald χ^2 test year-effects	207.15	816.42	270.42
	(0.000)	(0.000)	(0.000)
Hausman test	18.33	18.62	

[10] Specifically, we have obtained the average value of the GVC index for the EU countries before the 2004 enlargements (excluding the UK, Malta and Cyprus). In concrete, these countries are France, Italy, Belgium, Luxembourg, the Netherlands, Germany, Ireland, Denmark, Greece, Spain, Portugal, Austria, Finland, and Sweden. In the case of Luxembourg and Belgium, we have included the value of their GVC indexes only from 1999 on, as no information is available before this period.

	(0.006)	(0.005)	
Weak ident. test – CD F stat.			345.713
Stock-Yogo critical value (5%)			16.85
Stock-Yogo critical value (10%)			10.27
Underident. test – Anderson LM stat.			223.854
			(0.002)
Observations	329	312	279
Number of countries	15	15	15

*Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. The dependent variable and the GVC participation index are expressed in logs. The figures reported for the Wald tests year-effects in parenthesis are the p-values. The instrumental variables used in the IV-FE regressions are the total GVC participation rate in the EU and the GVC index by country lagged three periods,* $GVC\ index_{t-1}$, $GVC\ index_{t-2}$ *and a* $GVC\ index_{t-3}$. *The figures reported for the weak identification and the underidentification tests are the p-values.*

Table 5 below presents the regression results including human capital, $HK1$, as an additional covariate influencing the technological composition of exports. $HK1$ is defined here in such a way that a high value of this variable shows a greater degree of participation in tertiary education by students of all ages of a country in a specific year (see Appendix II). In line with the related literature, the estimated coefficients on $HK1$ are positive (although only significant in the two-stage FE regressions), suggesting that human capital abundant countries are also those with a greater weight of their high-tech exported goods (Ndubuisi and Owusu, 2021) and thus in a better position to absorb the technology spill-overs.
Regarding the influence of the GVC index on the technology upgrading of exports, this main regressor remains significant in the explanation of our dependent variable considering both its current or past value (Model 1 and Model 2, respectively), and when it is treated as an endogenous regressor (Model 3). In concrete, a 1% increase in the GVC participation index result in an increase of 1.17% to 1.45% increase in high-technology exports (from Model 1 to Model 3). In addition, the appropriateness of the IV is confirmed in the first stage regression and in tests of both under-identification and weak identification shown at the bottom of Table 5.

Table 5: Estimation results for high-tech exports (in logs). Period: 1996-2019. Extend

	Model 1	Model 2	Model 3
VARIABLES	FE	FE with lags	2SFE IV
$\log\ (GVC\ index)_t$	1.302**		1.450***
	[0.599]		[0.198]
$\log\ (GVC\ index)_{t-1}$		1.173*	
		[0.611]	
$\log\ (HK)_t$	0.830	0.677	0.556***
	[0.530]	[0.600]	[0.161]
$Constant$	-8.071**	-6.757*	-7.313***
	[3.607]	[3.561]	[1.134]
Country effects	YES	YES	YES
Year effects	YES	YES	YES
Wald χ^2 test year-effects	127.76	351.18	127.79

	(0.000)	(0.000)	(0.000)
Hausman test	29.03	30.41	
	(0.000)	(0.000)	
Weak ident. test – CD F stat.			350.210
Stock-Yogo critical value (5%)			16.85
Stock-Yogo critical value (10%)			10.27
Underident. test – Anderson LM stat.			223.714
			(0.000)
Observations	324	308	278
Number of countries	15	15	15

Robust standard errors in brackets. *** p<0.01, ** p<0.05, * p<0.1. The dependent variable and the GVC participation index are expressed in logs. The figures reported for the Wald tests year-effects in parenthesis are the p-values. The instrumental variables used in the IV-FE regressions are the total GVC participation rate in the EU and the GVC index by country lagged three periods, $GVC\ index_{t-1}$, $GVC\ index_{t-2}$ and $a\ GVC\ index_{t-3}$. The figures reported for the weak identification and the underidentification tests are the p-values.

In Appendix III, we perform similar regressions including as additional control variable the proportion of skilled people doing scientific or technological tasks ($INNOV$). This covariate can be considered a proxy of the degree of innovation of the different economies. In this case, the human capital variable has been redefined to avoid multicollinearity problems. Concretely, $HK2$ depicts the percentage of total working-age population with advanced education. In general, the estimates confirm the positive influence of a higher integration into global trade networks on technology adoption and the technological composition of exports. Although now, the estimated coefficients on the lags of GVC is not significant (Model 2), the current value of GVC participation significantly influences high-tech exports as shown in Model 1 and 3. Regarding the innovation tasks, the estimated coefficients confirm the expected positive impact on the technological upgrading of exported goods. This variable is positive and statistically significant in all models. Similarly, a greater availability of human capital leads to a higher technological upgrading of exports. The statistics of over-identification and weak-identification tests shown at the bottom of Table 5 ratify that the IV used in this case is also appropriate[11].

4.2.2. Sectoral GVC participation and technological composition of exports

Having obtained conclusive results on the aggregate level as presented above, in the next section we attempt to drill deeper and shed new light on the sectoral level. We aim to explore to what extent the technological improvement of exports occurs in the same sector in which firms experience a greater participation in global value chain. Despite the limitations imposed on this analysis due to lack of data for the CEE&WB countries, in this section we carry out a similar regression analysis, but at a more disaggregated level. Specifically, and as a novelty in the related literature, we estimate our regression model with sectoral data, including the following sectors: i) textiles, wearing apparel, leather and related products, ii) wood and paper products; printing, iii) chemicals and non-metallic mineral products, iv) basic metals and fabricated metal products, v) computers, electronic and electrical equipment, vi) machinery and equipment, vii) transport equipment, and viii) other manufacturing; repair, and installation of machinery and equipment.

[11] The statistics of over-identification and weak-identification tests shown at the bottom of Table 5 ratify that the IV used in this case is also appropriate.

The outcomes obtained from sectoral data are shown in Table 6. In line with previous results, the coefficient on $log(gvc)$ are positive and highly significant in all cases. Since the study of causality is limited to the same sector, it is not surprising that the impact of this effect is smaller than in the case of the aggregate model. Specifically, according to our estimates, when the GVC participation index increases by ten percentage points, we predict, on average, a rise in the share of high-tech exported goods around 3.6% and 5.3%, *ceteris paribus*. As in the previous regressions, we find that this result is robust to the use of lags or instrumental variables. For the 2SFE regressions and following the same reasoning as in the aggregate model, we employ as instrumental variable the average GVC measure at the EU level at the sector level and the lags of the sectoral $log(gvc)_t$.

At the bottom of Table 6, we report the Anderson canonical correlation LM statistic of underidentification and the Cragg-Donald statistic (1993) to test the null hypothesis that the model instruments are weak. A rejection of the null of the under-identification test indicates that the matrix is full column rank, i.e., the model is identified. Moreover, the result of the Cragg-Donald F statistic rules out the possibility that the model be weakly identified as we reject the null that our instruments are weak.

Table 6: Estimation results for high-tech exports (in logs). Period: 1996-2019. Sectoral model

	Model 1 FE	Model 2 FE with lags	Model 3 2SFE with IV
$log(gvc)$	0.417**		0.531*
	[0.192]		[0.286]
$log(gvc)_{t-1}$		0.359**	
		[0.164]	
Constant	-1.235	-1.623*	-2.360*
	[1.104]	[1.125]	[1.419]
Country-sector effects	YES	YES	YES
Year effects	YES	YES	YES
F-test year-effects /Wald test year-effects	61.87	62.59	61.07
	(0.001)	(0.000)	(0.001)
Hausman test	7.29	87.10	
	(0.007)	(0.000)	
Weak ident. test - CD F stat.			465
Stock-Yogo critical value (5%)			16.85
Stock- Yogo critical value (10%)			10.27
Underident. test – Anderson LM stat.			863.411
			(0.000)
Observations	1,925	1,861	1,911
Number of id	90	90	90

*Robust standard errors clustered at the country-sector level in squared brackets. *** p<0.01, ** p<0.05, * p<0.1. To test the significance of year effects, we use an F-statistic in Models 1 and 2 and a Wald chi-squared statistic for Model 3. The instrumental variables used are the log of the average GVC measured at the sectoral level of the European Union countries, France, Italy, Belgium, Luxemburg, Netherland, Germany, Ireland, Demark, Greece, Spain, Portugal, Austria, Finland, Sweden; and three lags of* $log(gvc)$ *at sectoral* *level. The figures reported for the weak identification and the underidentification tests are the p-values.*

6. CONCLUDING REMARKS

Literature argues that long-term sustainable growth cannot be achieved without technology development allowing for an upgrade in the technological structure of a country's export basket. This process has further been highlighted by the recent rise of GVCs, which allowed countries to participate in the global production and knowledge-sharing process. In this paper, we analyse the nexus between GVC participation and the technology structure of trade (the share of high-tech exports). We perform our analysis for the regions of CSEE countries for the period 1996-2019.

We construct a GVC participation measure applying the latest BEC Rev.5 classification that distinguishes between generic and specific intermediate goods. In addition, we match this with a list of high-tech products (involving a high intensity of research and development). In the calculations of both variables, we reclassify various product nomenclatures including HS, SITC, CPC, ISIC, and BEC.

Our analysis indicates that in general, there is a clear tendency of rising high-technology exports in total exports. GVC participation also shows a rising trend, although with different patterns along countries, but with a clear dominance in certain sectors. In a first approximation, the analysis of the nexus between these two variables indicates a positive connection between the GVC participation and the technological upgrading of exports in the CSEE countries.

We further examine this result with an econometric model using panel data. The main findings from the different regression models confirm our hypothesis that higher participation in GVC improves the technological structure of exports, possibly by providing an opportunity to adopt new technologies and incorporate more sophisticated inputs. These results hold even when we treat a potential endogeneity issue using a two-stage fixed effect estimation. Furthermore, in line with the related literature, we test the effect of human capital and find that human capital-abundant countries are also those with a greater weight of their high-tech exported goods and thus in a better position to absorb the technology spill-overs.

Finally, as a novelty for the literature on CSEE countries, we drill deeper into the issue and perform a sectoral analysis. This confirms our previous findings of a positive relationship between higher GVC participation and rising technology levels of exports. This is particularly true for the sectors of chemicals and non-metallic mineral products; computers, electronic and electrical equipment; machinery and equipment, and transport equipment, as also indicated by the qualitative analysis.

The lack of sectoral-level data on human capital impeded the use to drill even deeper into the analysis. As further research lines, it would be interesting to use approximations for human capital, as well as to analyse the granular characteristic of exporting firms, and the weight of sectoral champions in the CSEE countries. In addition, another research direction can be the examination of the trade patterns in the post-pandemic era and the possible changing organisation of GVCs and their impact on technology transfer and adoption.

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APPENDIX I: THE PROCESS OF DATA RECLASSIFICATION FOR THE CALCULATION OF GVC PARTICIPATION AND HIGH-TECH GOODS

- We started with the BEC classification Rev.5. Out of this classification, from the specification dimension, we have selected the product codes that are intermediate specific goods (as per the defined specification in BEC no final products are listed in this selection, only intermediate ones). Then as there are some products related to capital formation or consumption, we have further purified the selection, by omitting them.
- Next, we used the UN correspondence tables to obtain the corresponding product codes in the HS 2017 classification. The BEC includes all sub-headings of the HS Classification, so the total trade in terms of HS equals the total trade of the goods side of the BEC.
- As the data downloaded from the UN Comtrade required a further reclassification, to be able to download the full series from 1996 to 2019, we reconciled the HS 2017 classification with the one from 2016.
- Next, in order to be able to conduct a sectoral analysis, which is of main interest in our research, we had to classify the HS product codes into sectors. This was done both for the intermediate goods as well as for final goods, as we need a classification of the overall manufacturing trade per sector. For this, we used the link between the HS classification and the Central Product Classification as a first step and the International Standard Industrial Classification of All Economic Activities (ISIC) as a second step.
- The sectors as defined in the System of National accounts are related to the ISIC, but there are no direct correspondence tables between the HS and ISIC, so we had to use the CPC as an intermediary. Thus, we mapped the HS product codes as per the CPC classification.
- In the next step we mapped these CPC codes with the corresponding ones in the ISIC to obtain the sectors as defined in the System of National Accounts (SNA). This is made possible by the fact that the relationship between ISIC, on the one hand, and the HS and CPC, on the other, is based on the fact that the product classifications in principle combine in one category goods or services that are normally produced in only one industry as defined in ISIC. Thus, we were left with an HS classification per product code that is mapped by sector.
- At the end we were left with 2092 HS classification product codes for intermediate specific goods (as per the BEC Rev.5 definition), out of a total of 5300 product codes. These codes had been classified per sector, which allows us to delve into the sectoral analysis later on.
- A similar procedure was followed for obtaining the high-technology products. We used a Eurostat list based on the OECD definition that contains technical products for which the manufacturing involved a high intensity of research and development. The list uses a product approach that looks at the level of technological intensity of products of manufacturing industries and similarly identifies the trade in high-tech products[12]. In order to ensure consistency with the data on intermediate-specific goods, as outlined above, here we also had to conduct similar re-arrangements, reclassifications and calculations before getting the final data. A step-by-step description of the processes carried out is presented in continuation.
- The high-tech product list is provided on the basis of the Standard International Trade Classification Rev.4 and contains 71 product groups defined at the basic heading level

[12] For more detail, please see https://ec.europa.eu/eurostat/cache/metadata/Annexes/htec_esms_an5.pdf

(five-digits). As the data was provided in the SITC Rev.4 format, we had to convert it to SITC Rev.3 to be able to use the correlation tables with the HS classification.

- Next, we have mapped the high-tech products obtained in the SITC Rev.3 with the corresponding product codes in the HS classification. As the products in the SITC five-digit level may have multiple corresponding products in the HS classification at six-digits, the conversion requires substantial inputs.
- As the data downloaded from the UN Comtrade required a further reclassification, to be able to download the full series from 1996 to 2019, we had reconciled the HS 2017 classification with the one from 2016.
- Next, in order to be able to conduct a sectoral analysis, we had to classify the HS product codes into sectors. This was done in the same way as described above for the intermediate specific goods. For this we used the link between the HS classification and the Central Product Classification as a first step intermediary classification to the International Standard Industrial Classification of All Economic Activities (ISIC) as a second step to obtain the sectors as defined in the System of National Accounts.
- At the end we were left with 311 high-tech products in the HS classification at six-digit level (out of a total of a total of 5300 product codes). As was the case with the intermediate specific goods, these high-tech product codes had been classified per sector, which allows us to delve into the sectoral analysis latter on.

APPENDIX II: SOURCE AND DEFINITIONS OF DATA

Abbreviation	Definition	Data Source
$High\ tech\ exports$	High-tech products share in total exports	Own elaboration based on UN Comtrade data and using a Eurostat list based on the OECD definition
$GVC\ index$	GVC participation index calculated as, $(intermediate\ goods\ imports\ /gross\ exports) * 100) + (intermediate\ goods\ exports\ /gross\ exports) * 100)$	Own elaboration based on UN Comtrade data
$HK1$	Labor force with advanced education (% of total working-age population with advanced education)	World Bank – World Development Indicators
HK 2	Labor force with advanced education (% of total working-age population with advanced education)	World Bank – World Development Indicators
INN	Persons (25-64 age) with terciary education (ISCED) and employed in science and technology, share of total population of 25-64 age (in logs)	Eurostat

APPENDIX III: ADDITIONAL REGRESSIONS

VARIABLES	Model 1 FE	Model 2 FE with lags	Model 4 2SFE IV
$\log\,(GVC\ index)_t$	0.609**		0.849***
	[0.238]		[0.278]
$\log\,(GVC\ index)_{t-1}$		0.300	
		[0.224]	
$\log\,(HK)_t$	0.436*	0.444**	0.266
	[0.192]	[0. 190]	[0.015]
$\log\,(INNOV)_t$	0.567*	0.304**	1.300***
	[0.294]	[0.200]	[0.295]
$Constant$	-0.009**	2.835	3.288
	[0.008]	[1.836]	[2.088]
Country effects	YES	YES	YES
Year effects	YES	YES	YES
Wald χ^2 test year-effects	14.74	12.22	17.88
	(0.9037)	(0.953)	(0.595)
Hausman test	65.37	14.80	
	(0.000)	(0.0965)	
Weak ident. Test – CE F stat.			159.53
Stock-Yogo critical value (5%)			16.85
Stock-Yogo critical value (10%)			10.27
Underident. test – Anderson LM stat.			172.645
			(0.000)
Observations	265	261	243
Number of id	90	90	90

*** p<0.01, ** p<0.05, * p<0.1. Standard errors in brackets. The dependent variable and the GVC participation index are expressed in logs. The figures reported for the Wald tests year-effects in parenthesis are the p-values. The instrumental variables used in the IV-FE regressions are the total GVC participation rate in the EU and the GVC index by country lagged three periods, $GVC\ index_{t-1}$, $GVC\ index_{t-2}$ and $a\ GVC\ index_{t-3}$. The figures reported for the weak identification and the underidentification tests are the p-values.