Article

Intangible ICT and Their Importance within Global Value Chains: An Empirical Analysis Based on Longitudinal Data Regression

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Abstract: The rising global importance of global value chains was enabled by developing information and communication technologies, ICT. A correct understanding of ICT roles determines a country's global competitiveness. The study aims to examine the role of intangible ICT assets in creating domestic and foreign value added in export. Based on a sample of available longitudinal data from the EU-KLEMS database, for the period 2000–2015, 10 EU countries have been selected and analysed. We applied several panel regression models to confirm the important role of ICT capital, specific to intangible ICT, in creating domestic added value in exports and participation in the global value chains. Our results show that intangible ICT assets have a higher impact on the global value chain participation than tangible ICT assets. Moreover, the analysis at the sectoral level reveals a stronger effect of total ICT assets in the case of total business sectors.

Keywords: panel data regression; information and communication technologies; intangible assets; global value chains; productivity

1. Introduction

The changing structure and nature of the global economy have focused attention on intangible assets as a source of growth and development. It reveals that the accumulation of intangible assets has a positive effect on value added and country participation in the global value chains (GVCs), as mentioned by Jona-Lasinio et al. [1], Thum-Thysen et al. [2], or Tsakanikas et al. [3].

GVCs represent the cross-border sharing of production. It is characterised by immense flows of intermediate goods that pass as production inputs from one country to another. The literature dealing with this phenomenon is very well documented by empirical studies of the authors such as Koopman [4], Miroudot and Cadestin [5], and Timmer et al. [6].

The GVC analysis focuses primarily on tracing the origin of value added contained in exports at the national or industrial level. It tracks trade in intermediate products up to the final export level, which includes domestic added value contained in foreign exports and foreign added value in domestic exports. The country's participation in the GVC varies depending on the creation of domestic value added.

The gradual process of deregulation and liberalisation of foreign trade, accompanied by the rapid emergence and development of information and communication technologies (ICT), have put pressure on the competitiveness of countries and multinational corporations. The impact of the accumulation of specific ICT assets has been under review for decades. It is confirmed that the accumulation of intangible ICT assets has a significant impact on the whole range of the economy. According to research by Baldwin [7], the accumulation of intangible assets is an important factor in increasing value added in globally organised

production. The accumulation of intangible assets supports the country's participation in the GVCs. The structural and technological changes we have seen in recent decades have been linked to rapid progress in the field of ICT. It is primarily about increasing new business models and increasing the importance of the service sector. Accumulation of intangible assets is now a major factor driving global competitiveness, according to Jona-Lasinio, Manzocchi, and Meliciani [8]. The valuation of intangibles has also been discussed and summarised by Glova et al. [9]. Even their managerial aspect, considering own development or external purchased intangibles, is discussed in Glova et al. [10]. Specific aspects of the ICT regarding competitiveness are discussed in Abusaada and Elshater [11], whereby ICT is considered from the regional perspective of smart cities, urban planning systems and informatics as discussed in Pan et al. [12], Appio et al. [13], Pan et al. [14], and Chung et al. [15]. However, this perspective is regionally oriented, and further, we are considering investments in ICT on a macroeconomics level that affect export.

Therefore, this article examines the problem of accumulation of investments in ICT assets as an important factor in the growth of domestic value added contained in exports and the country's participation in the GVC. We focus our attention mainly on the accumulation of intangible ICT assets, which have the potential to increase domestic value added in globally organised production. The examination of the impact of intangible asset accumulation is justified in particular in the context of possible stagnation of countries expressed within the so-called Smile Curve. It describes how the value added in the production process is created. The reasons for stagnation and locking at the bottom of the smiling curve are several. For example, the quality and structure of human capital or the level of knowledge capital. By building knowledge-based economies based on the accumulation of intangible assets, we aim to create technological innovation and thus ensure the modernisation of products and industrial tasks. The purpose of the article is to analyse, through random effect panel regression, the impact of ICT (tangible and intangible) and Non_ICT assets on participation in the GVC. We also analyse the impact of ICT assets at the sectoral level. We distinguish between the industrial (C) and service sectors (TBS). Based on the fact that the European Union is the most regionalised market in the world due to the high intra-EU trade as mentioned in Tsakanikas et al. [3], in the econometric analysis, we use data for selected EU countries, depending on their availability.

There is a close link between innovation, value-added creation, and economic growth OECD [16,17]. It confirms the assumption that the innovation supported by the accumulation of intangible assets is an important driver for upgrading in the GVC. The same is proved at the industry level for the developing countries by Sampath and Vallejo [18] and Choi et al. [19].

The impact of intangible asset accumulation on labour productivity growth appears to be similar. The positive relationship between the accumulation of intangible assets and labour productivity growth is confirmed by Roth and Thum [20] using panel data for selected EU countries and Niebel [21] on the principle of sectoral data. Thum-Thysen et al. [2] confirm that intangible assets contribute more to gross value added generation than tangible assets. Similar results are verified by research at the microlevel. Marrocu et al. [22] link the micro and macrolevel analysis. Based on the expanded Cobb Douglas production function, they show that the growth of the company's productivity is caused by knowledge capital. However, the availability of intangible assets in the region (human and technological capital) is also important for growth.

Central and Eastern European countries (CEE) are fully integrated into organised production at the EU level. We are following the positive progress of these countries in the GVC. This is empirically confirmed for specific countries by Vrh [23] and Vlčková et al. [24]. The accumulation of intangible assets plays an important role by having a positive impact on the country's participation in the GVC Jona-Lasinio et al. [1].

Countries characterised by high-quality innovation performance can benefit more from participating in globally organised production Pekarčík and Ďurčová [25]. Fagerberg et al. [26] also confirm that the share of intangible assets in value added is growing, and

therefore, countries that have a robust innovation environment can benefit more effectively from their GVCs' participation. The impact of intangible assets, namely business R&D, on domestic value added is examined by Vrh [23]. She verified the existence of a strong and positive effect of R&D expenditure on domestic value added in exports.

As discussed in Constantinescu et al. [27], the vertical specialisation of countries positively impacts productivity. The same is demonstrated in the case of the intangible asset accumulation by Tsakanikas et al. [3]. The effect is even stronger when the country participates in the GVC and in the euro area countries. This relation may be related to the assumption of Durand and Milberg [28], who use the term "Intellectual monopoly". Intellectual monopolies are those countries where multinationals are headquartered. They remain in a high position in the GVC, i.e., they create a high volume of domestic value added in third country exports and a high volume of intangible assets. The intellectual monopolies may limit the development of middle and low-income economies as GVC tasks intensive to intangible assets are mainly concentrated in high-income countries.

The impact of ICT asset accumulation on productivity has been the subject of economic research for decades. A significant step forward is the work of Solow [29], who introduces the so-called Solow Paradox—thus confirming that the accumulation of investments in ICT does not have a positive impact on productivity. He observed the slowdown in the US productivity growth, as opposed to the rapid rise in ICT investment over the same period. This paradox is explained, among other things, by incorrect ICT measurement and delayed effects.

Thus, the accumulation of ICT investment can positively affect productivity within a period. Therefore, it is important to correctly analyse the long-term impacts of ICT investment. A short-term analysis can lead to incorrect results (inefficient marginal costs and benefits) as the positive effect of ICT investment can only occur within a period. First of all, these new technologies may be complex, so their effect will be felt with delay Brynjolfsson [30]. The problem of insufficient measurement and reporting of intangible assets, including intangible ICT assets within national accounts, is addressed by Corrado et al. [31,32]. As part of the current industrial revolution, Industry 4.0 Brynjolfson et al. [33] link the accumulation of intangible assets and productivity growth with artificial intelligence (AI). It confirms that the full use of labour productivity gains benefits from AI is possible through an increase in the accumulation of complementary intangible assets, including intangible ICT assets.

There are two different possibilities of how to investigate the role of intangible ICT asset accumulation—the macroeconomic and the microfirm approach. From the macroeconomic point of view, Kim et al. [34] confirm that ICT is a determinant of productivity. They analyse ICT externalities and intangible assets based on the BFOS model. They find that the accumulation of ICT assets positively impacts the country's output growth and the spillover effect in other sectors whose production is not primarily focused on ICT. This relationship is not contained within the traditional production function. Corrado et al. [35] analyse the role of intangible asset accumulation in growth and examine the complementarity between ICT and intangible assets. Pieri et al. [36] confirm that ICT assets effectively reduce productivity inefficiencies and ensure industry knowledge spillovers. Vu [37] verifies that ICT assets positively impact a country's economic growth. Jona-Lasinio et al. [1] show, at the sectoral level of certain EU countries, the positive impact of intangible ICT assets on the country's participation in the GVC and value creation. They confirm the higher impact of ICT assets in the service sector than in the industrial sector. More detailed analyses of the intangible asset accumulation effect are possible at the industry level. Dal Borgo et al. [38], based on a sectoral analysis of the GB industry, demonstrate that the industrial sectors and the service sector, mainly financial services, are intangible-intensive. They also confirm that the accumulation of intangible assets significantly impacts labour productivity growth.

At the micro-economic (firm) level of German companies, Marrocu et al. [22] confirm that the accumulation of intangible corporate assets, including ICT, positively impacts firm

productivity. Furthermore, Bajgar et al. [39] verify that the accumulation of intangible assets, primarily innovative property, software and database, has a positive impact on the growth of large companies. These types of intangible assets allow multinational corporations to increase their market share. As a result, the growing concentration of large multinational corporations is stronger in globalised and digitally intensive industries.

Intangible assets have a significant impact on the creation of value added and on the participation of the country or the company in globally organised production within GVCs. Thus, ICT development is a crucial factor for the origin and development of GVCs in the global economy.

According to Corrado et al. [40], the accumulation of ICT assets increases productivity and participation in the GVC. However, as mentioned by Jona-Lasinio et al. [1], it needs to be supplemented by the accumulation of investment in intangible assets. Therefore, our research focus on the impact of the ICT asset accumulation on the participation and value creation among GVC. Therefore, our attention is concentrated primarily on the impact of intangible ICT assets, which are referred to as SoftDB.

The accumulation of intangible assets has an important role in the innovation performance of companies and countries. Therefore, we expect a positive impact of ICT assets on the country's total participation in the GVC. Our assumption is based on the findings of Adarov and Stehrer [41]. They confirm the positive impact of ICT assets on value-added growth in the EU, Japan, and the USA. Similarly, Gerefi et al. [42] confirm that intangible assets (information and knowledge transfer) are important for organising and coordinating a globally organised production within the GVC. ICT assets are primarily associated with backward participation, i.e., with production depending on imports of intermediate goods (foreign value added) Jona-Lasinio et al. [1], Adarov and Stehrer [43]. Accumulation of ICT assets is particularly important for countries with a high share of foreign value-added exports as discussed in Jona-Lasinio et al. [1].

We also expect ICT assets to have a higher impact on backward participation than forward participation. We use data gathered by Stehrer et al. [44]. Moreover, we expand our dataset by focusing our attention on the role of intangible ICT assets in the country's participation in the GVC. We assume that intangible ICT assets have a stronger positive impact on the country's participation in the GVC than tangible assets. We base this hypothesis on the findings of Thum-Thysen et al. [2], who confirm the stronger impact of intangible assets in terms of productivity, and Tsakanikas et al. [3], who confirm this relationship and suggest that this relationship is stronger in countries participating in the GVC. We extend our analysis by investigating the impact of asset accumulation separately in the industrial (manufacturing) sector (C) and in the service sector (TBS). We expect a strong impact of total ICT assets in the service sector and a stronger impact on intangible ICT assets in the case of the industrial sector. According to Adarov and Stehrer [43], intangible ICT assets are primarily associated with the participation of the industrial sector in the GVC. This impact is higher, mainly in the automotive sector. According to Adarov and Stehrer [41], tangible assets have a negative impact on value-added growth. Based on this, we assume that the tangible ICT assets will harm the country's participation in the GVC. Therefore, tangible ICT assets are associated with backward participation, i.e., countries with a lower volume of domestic value added in foreign export.

The corporate income tax rate (CIT) retrieved from the OECD database is used as a control variable. We assume that increasing CIT will have a negative impact on the country's participation in the GVC, as the high corporate taxes may negatively affect the potential arrival of foreign direct investments. This relationship is confirmed by Jona-Lasinio et al. [1], and the term is well discussed by Andrejovska [45] and Mihokova et al. [46].

Based on the aforementioned, the following hypotheses are formulated:

1. The investment in total ICT (tangible and intangibles) increases the participation in global value chains.

2. The effect of total ICT investments differs depending on the form of participation (Backward and Forward). Total ICT investments have a higher impact on backward than on forward participation.
3. The effect of intangible ICT (software) differs; it is higher than the effect of tangible ICT (hardware) on global value chains participation.
4. ICT assets in TBS have a stronger impact on participation in the GVC than in the manufacturing sector.
5. Intangibles ICT assets in the manufacturing sector have a stronger impact on participation in the GVC than in the TBS.

This paper is divided into three parts. The first part deals with the theoretical definition of intangible assets and ICT assets and their impact on the economy, value creation, and participation in the GVC. The second part explains the methodological procedure and data used in econometric analysis. The third part presents econometric results of random effects panel regression and a discussion of the findings.

2. Materials and Methods

The impact of tangible and intangible ICT assets on the domestic and foreign value-added share of gross export is examined using panel data techniques. The specification of the model is described in the following Equation (1):

$$\ln GVC_{i,t} = \sum_{q \in Q} \beta_q \Delta \ln K_{q,i,t} + \alpha_1 \Delta \ln L_{i,t} + \alpha_2 \Delta \ln INTERMED_{i,t} + \alpha_3 CIT_{i,t} + \delta_i + \varepsilon_{i,t} \quad (1)$$

where $\ln GVC_{i,t}$ is the measure of various forms of participation in global value chains. The global value chain index is standardised by hours worked because it is heterogeneous across countries. $\Delta \ln K_{q,i,t}$ denotes the measure of capital inputs in the form of real capital stock. The capital assets are split into two basic categories: ICT and Non_ICT assets. Moreover, ICT assets are deeply investigated as intangible ICT represented by SoftDB indicator and tangible represented by HARDWARE indicator (Table 1). Non_ICT assets are defined in the EU-KLEMS database and in Stehrer et al. [44]. As we analyse the impact of the change in the accumulation of ICT assets on participation in the GVC, we express capital input variables in the form of indices, 2010 = 100. Moreover, GVC participation variables are standardised by the number of hours worked. There are big disparities in the expression of capital input variables in the form of absolute values; therefore, we use indexed variables.

Table 1. Definition of variables used in econometric analysis.

Name of the Variable	Definition	Source
	Dependent variable based on export	
DVAFEX_TH_ln	Domestic value added embodied in foreign exports/Total hours worked (natural logarithm)	OECD TIVA
FVADEX_TH_ln	Foreign value added embodied in domestic exports/Total hours worked (natural logarithm)	OECD TIVA
ΔICT_ln	Tangible and intangible ICT assets	EU_KLEMS
ΔNon_ICT_ln	Tangible and intangible non-ICT assets	EU_KLEMS
ΔSOFTDB_ln	Intangible ICT assets	EU_KLEMS
ΔHARDWARE_ln	Tangible ICT assets	EU_KLEMS
ΔIntermed_ln	Intermediates inputs	EU_KLEMS
ΔLAB_SERV_ln	Labour services	EU_KLEMS
CIT	Corporate income tax rate	OECD
	ROBUSTNESS check—variable based on final demand	
DVAFFD_TH_ln	Domestic value added embodied in foreign final demand/Total hours worked (natural logarithm)	OECD TIVA
FVAFFD_TH_ln	Foreign value added embodied in domestic final demand/Total hours worked (natural logarithm)	OECD TIVA

$\Delta lnL_{i,t}$ is the labour input. We use the labour services growth index for baseline estimation. Based on the definition of Stehrer et al. [44], the growth of labour services is quantified as a combination of the hours worked and the change in the labour composition. The Törnqvist volume index for labour services is broken down into a labour composition effect and change in hours worked effect. The change in labour input is defined as follows:

$$\Delta lnL_{i,t} = \Delta lnLC_{i,t} + \Delta lnH_{i,t} \tag{2}$$

Imported intermediates (INTERMED) serve as the control variable. According to O'Mahony and Timmer [47], GVCs represent a value-added trade involving cross-border trade with intermediates. The higher the volume of imported intermediate products, the higher the country's participation in the global organised production. Therefore, we assume that the intermediates positively affect the country's participation in the GVC. The next control variable, the corporate income tax rate (CIT), may have an impact on the multinational corporation's decision to locate a foreign affiliate. We assume that the higher the tax rate, the lower the probability of a foreign affiliate arriving in the country. Thus, tax increase causes a decrease in the country's participation in the GVC. The data for control variables are retrieved from the OECD database and OECD-TIVA. Finally, δ_i denotes the vector of country and industry random effect.

For econometric analysis, panel regression and random effect estimation techniques are used. A panel robust Hausman test confirmed the random effects panel regression (we accept the null hypothesis and use random effect estimation). We also applied the Augmented Dickey–Fuller test to verify the stationarity of the time series. As a result, we can confirm that time series are stationary (the null hypothesis—the series has a unit root; as *p* value (0.01) is statistically significant, we reject the null hypothesis, and we conclude that the time series are stationary). Moreover, the DF statistics have high negative values. We also test the model for heteroskedasticity, endogeneity, stationarity, correlation and multicolinearity.

We lag variables for one year for robustness check and possible endogeneity issues. We conclude that the data is robust. Moreover, for this purpose, we use two variables from OECD TIVA—domestic value added in foreign demand and foreign value added in the final domestic demand.

The sector's data of selected EU countries for labour and capital inputs come from EU_KLEMS. The global value chains participation data are retrieved from OECD_TIVA (Trade in Value Added) databases. The resulting panel dataset covers 10 EU countries (selected upon data availability) over 2000–2015. The countries represented in the econometric analysis are as follows: Austria, Czech Republic, Denmark, Finland, France, Germany, Italy, Netherland, Slovak Republic and Sweden. The list of industries is based on the NACE Rev. 2 (ISIC Rev. 4) economic activity classification. The descriptive statistics see in Table 2.

Table 2. Descriptive statistics.

Variable	Mean	St. Error	Median	St. Dev.	Minimum	Maximum	Count
DVA_FEX_TH	0.0560	0.0023	0.0207	0.1355	0.0002	2.1890	3520
FVA_DEX	0.0437	0.0031	0.0063	0.181	0.0001	2.8561	3520
GVC	0.0997	0.0048	0.0273	0.2856	0.0003	3.7431	3520
FFD_DVA_TH	0.042	0.0017	0.0214	0.0984	0.0004	1.8056	3520
DFD_FVA_TH	0.0724	0.0035	0.0198	0.2059	0.0007	2.5851	3520
GVC_FD	0.1144	0.0046	0.0433	0.274	0.0013	3.5237	3520
ICT	98.94	0.88	98.82	52.29	1.24	1434.89	3520
Non_ICT	97.58	0.24	98.99	14.11	23.37	220.33	3520
SoftDB	104.76	1.77	97.24	104.87	0	2800.00	3520
HARDWARE	146.58	3.81	107.39	226.22	0.9	5300.00	3520
LAB_SERV	104.51	0.3	100.66	17.93	24.89	239.42	3520
Intermed	95.76	0.2	97.89	11.98	34.02	193.48	3520
CIT	0.269	0.001	0.258	0.056	0.16	0.420	3520

The total panel dataset contains 3520 observations. The value of participation in the GVC is standardised by hours worked. The average mean value of DVA_FEX (0.056) is higher than FVA_DEX (0.0437). That means that countries participate mainly in upstream activities of GVCs. The data for ICT and Non_ICT are based on EU-KLEMS classification and volume indices 2010 = 100. The mean and median values have minimal differences. However, the average value of the ICT index (98.94) is higher than the Non_ICT index (97.58). The hardware ICT index (146.58) is higher than the intangible ICT index (104.58). The standard deviation indicates the data are more spread out.

3. Results

The first series of results reported in Table 3, using three models, demonstrates the effect of asset accumulation on a country's participation in the GVC. The first model (column 1) monitors the impact of ICT and non-ICT assets (Non_ICT). The second model (column 2) distinguishes between tangible (HARDWARE) and intangible (SoftDB) assets. The third model (column 3) takes into account the control variable of imported intermediates. The remaining models adjust the lagged effect of the accumulation of all assets.

Table 3. Random effect panel regression results of the impact of ICT assets on total global value chains participation. The level of statistical significance is indicated as follows with symbols * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Total GVC Participation	DVAFEX_TH+ FFVADEX_TH	DVAFEX_TH+ FVADEX_TH	DVAFEX_TH+ FVADEX_TH	DVAFEX_TH+ FVADEX_TH	DVAFEX_TH+ FVADEX_TH	DVAFEX_TH+ FVADEX_TH
	(1)	(2)	(3)	(5)	(6)	(7)
ΔICT_ln	0.336 *** (0.022)	0.188 *** (0.019)	0.071 *** (0.017)			
ΔNon_ICT_ln	0.639 *** (0.057)	0.922 *** (0.044)	0.784 *** (0.039)			
ΔSoftDB_ln		0.117 *** (0.013)	0.076 ***			
ΔHARDWARE_ln		−0.057 *** (0.012)	−0.012 −0.046 *** (0.01)			
ΔICT ln_{t-1}				0.211 *** (0.018)	0.187 *** (0.019)	0.071 *** (0.018)
ΔNon_ICT ln_{t-1}				0.851 *** (0.047)	0.816 *** (0.046)	0.707 *** (0.041)
ΔSoftDB ln_{t-1}					0.105 *** (0.013)	0.075 *** (0.011)
ΔHARDWARE ln_{t-1}					−0.059 ** (0.012)	−0.045 ** (0.01)
ΔINTERMED_ln			1.374 *** (0.045)			1.347 *** (0.047)
ΔLAB_SERV_ln	−0.981 *** (0.062)	−1.016 *** (0.049)	−0.672 *** (0.045)	−1.017 *** (0.05)	−0.975 *** (0.05)	−0.620 *** (0.046)
CIT	−1.583 *** (0.037)	−1.478 *** (0.038)	−1.066 *** (0.041)	−1.540 *** (0.041)	−1.432 *** (0.042)	−1.010 *** (0.04)
Balanced	YES	YES	YES	YES	YES	YES
Random	YES	YES	YES	YES	YES	YES
Observation	3520	3520	3520	3300	3300	3300
R2	0.542	0.556	0.651	0.503	0.518	0.619
F_stat	***	***	***	***	***	***
Hausman	0.2795	0.1371	0.4793	0.2574	0.1778	0.4369

Tables 4 and 5 show the results of a regression panel analysis of the asset accumulation separately for backward and forward participation in the GVC.

Table 4. Random effect panel regression results of the impact of ICT assets on forward linkages global value chains participation. The level of statistical significance is indicated as follows with symbols * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

FL	DVAFEX/TH	DVAFEX/TH	DVAFEX/TH	DVAFEX/TH	DVAFEX/TH	DVAFEX/TH
	(1)	(2)	(3)	(5)	(6)	(7)
ΔICT_ln	0.208 *** (0.016)	0.184 *** (0.047)	0.090 *** (0.017)			
ΔNon_ICT_ln	0.882 *** (0.042)	0.842 *** (0.042)	0.730 *** (0.039)			
ΔSoftDB_ln		0.111 *** (0.012)	0.078 *** (0.011)			
ΔHARDWARE_ln		−0.063 *** (0.011)	−0.053 *** (0.010)			
ΔICT ln $_{t-1}$				0.202 *** (0.017)	0.180 **** (0.019)	0.088 ** (0.018)
ΔNon_ICT ln $_{t-1}$				0.777 *** (0.045)	0.745 *** (0.044)	0.658 *** (0.041)
ΔSoftDB ln $_{t-1}$					0.099 *** (0.012)	0.074 *** (0.011)
ΔHARDWARE ln $_{t-1}$					−0.057 *** (0.011)	−0.046 *** (0.010)
ΔINTERMED_ln			1.107 *** (0.045)			1.071 *** (0.046)
ΔLAB_SERV_ln	−0.967 *** (0.047)	−0.922 *** (0.047)	−0.644 *** (0.044)	−0.916 *** (0.048)	−0.875 *** (0.048)	−0.592 *** (0.046)
CIT	−1.459 *** (0.035)	−1.356 *** (0.036)	−1.024 *** (0.036)	−1.408 *** (0.039)	−1.305 *** (0.040)	−0.971 *** (0.040)
Balanced	YES	YES	YES	YES	YES	YES
Random	YES	YES	YES	YES	YES	YES
Observation	3520	3520	3520	3300	3300	3300
R2	0.527	0.542	0.613	0.484	0.599	0.572
F_stat	***	***	***	***	***	***
Hausman	0.1173	0.0746	0.2257	0.0511	0.06878	0.1379

Table 5. Random effect panel regression results of the impact of ICT assets on backward linkages global value chains participation. The level of statistical significance is indicated as follows with symbols * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

BL	FVADEX/TH	FVADEX/TH	FVADEX/TH	FVADEX/TH	FVADEX/TH	FVADEX/TH
	(1)	(2)	(3)	(5)	(6)	(7)
ΔICT_ln	0.345 ** (0.022)	0.295 ** (0.024)	0.164 ** (0.022)			
ΔNon_ICT_ln	0.642 ** (0.056)	0.684 ** (0.056)	0.448 ** (0.051)			
ΔSoftDB_ln		0.120 ** (0.016)	0.074 ** (0.015)			
ΔHARDWARE_ln		−0.017 (0.015)	−0.004 * (0.014)			
ΔICT ln$_{t-1}$				0.323 ** (0.023)	0.285 ** (0.065)	0.152 ** (0.024)
ΔNon_ICT ln$_{t-1}$				0.488 ** (0.060)	0.454 ** (0.060)	0.329 ** (0.055)
ΔSoftDB ln$_{t-1}$					0.111 ** (0.017)	0.075 ** (0.015)
ΔHARDWARE ln$_{t-1}$					−0.034 ** (0.015)	−0.018 * (0.014)
ΔINTERMED_ln			1.550 ** (0.059)			1.544 ** (0.062)

Table 5. *Cont.*

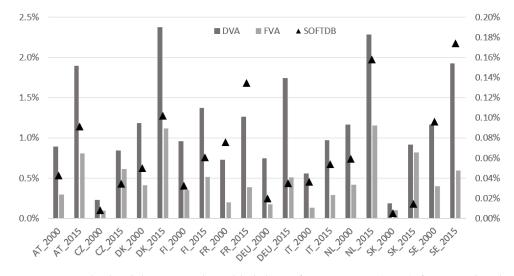| BL	FVADEX/TH	FVADEX/TH	FVADEX/TH	FVADEX/TH	FVADEX/TH	FVADEX/TH
	(1)	(2)	(3)	(5)	(6)	(7)
ΔLAB_SERV_ln	−1.002 **	−0.989 **	−0.600 **	−0.964 **	−0.939 **	−0.533 **
	(0.061)	(0.062)	(0.058)	(0.065)	(0.065)	(0.062)
CIT	−1.921 **	−1.826 **	−1.361 **	−1.941 **	−1.837 **	−1.353 **
	(0.047)	(0.048)	(0.047)	(0.053)	(0.054)	(0.053)
Balanced	YES	YES	YES	YES	YES	YES
Random	YES	YES	YES	YES	YES	YES
Observation	3520	3520	3520	3300	3300	3300
R2	0.485	0.493	0.579	0.441	0.450	0.540
F_stat	**	**	**	**	**	**
Hausman	0.2148	0.0746	0.396	0.2344	0.1038	0.4141

Table 6 presents a comparative analysis of the impact of the selected asset on the total GVC participation for the industrial (C) and the services sector (TBS).

Table 6. Random effect panel regression results of the impact of ICT assets on participation in the GVC in the manufacturing sector (C) and total business sectors (TBS). The level of statistical significance is indicated as follows with symbols * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$.

Total GVC Participation	DVAFEX_TH+FVADEX_TH	DVAFEX_TH+FVADEX_TH	DVAFEX_TH+FVADEX_TH
	(1)	(2)	(3)
ΔICT $\ln_{t-1}$ C	0.063 **	0.017	−0.034
	(0.022)	(0.025)	(0.021)
ΔICT $\ln_{t-1}$ TBS	0.265 ***	0.249 ***	0.167 ***
	(0.031)	(0.034)	(0.034)
ΔNon_ICT $\ln_{t-1}$ C	1.014 ***	0.977 ***	0.892 ***
	(0.054)	(0.053)	(0.045)
ΔNon_ICT $\ln_{t-1}$ TBS	0.108	0.080*	−0.129
	(0.088)	(0.088)	(0.086)
ΔSoftDB $\ln_{t-1}$ C		0.157 ***	0.124 ***
		(0.019)	(0.016)
ΔSoftDB $\ln_{t-1}$ TBS		0.070 ***	0.040 *
		(0.023)	(0.022)
ΔHARDWARE $\ln_{t-1}$ C		−0.051 **	−0.052 **
		(0.014)	(0.012)
ΔHARDWARE $\ln_{t-1}$ TBS		−0.059 ***	−0.035 *
		(0.022)	(0.021)
ΔINTERMED_ln C			1.296 ***
			(0.050)
ΔINTERMED_ln TBS			1.123 ***
			(0.107)
ΔLAB_SERV_ln C	−1.228 ***	−1.163 ***	−0.664 ***
	(0.060)	(0.060)	(0.055)
ΔLAB_SERV_ln TBS	0.740 ***	0.721 ***	0.598 ***
	(0.118)	(0.118)	(0.113)
CIT_C	−1.460 ***	−1.322 ***	−0.977 ***
	(0.053)	(0.054)	(0.048)
CIT_TBS	−1.083 ***	−1.007 ***	−0.818 ***
	(0.063)	(0.066)	(0.065)
Balanced	YES	YES	YES
Random	YES	YES	YES
Observation_C	1800	1800	1800
Observation_TBS	1065	1065	1065
R2 C	0.563	0.584	0.697
R2 TBS	0.503	0.511	0.557
F_stat	***	***	***
Hausman_C	0.4943	0.6908	0.0736
Hausman_TBS	0.2548	0.3273	0.1172

Figure 1 observes the standardised domestic and foreign value-added values in exports and the standardised value of intangible ICT assets (SoftDB). We can see that a high domestic value added accompanies a high share of intangible ICT assets in exports. At the same time, we can monitor the growing trend of production fragmentation and the expansion of global value chains via the volume of foreign value added in exports that is rising in all countries.

Figure 1. Standardised domestic value-added share of gross exports (DVA), foreign value share of gross export (FVA), and standardised (ratio to total hours worked) intangible ICT assets (SoftDB).

Generally, our results in Tables 3–5 indicate the positive impact of the ICT asset accumulation on the country's total GVC participation. We also confirm this positive impact separately on backward and forward participation. However, a more significant impact is observed for backward participation. That may be explained by the idea that countries dependent on importing foreign value added in the form of intermediates good require quality ICT infrastructure. For foreign affiliates to produce in time and to be able to communicate with their supply chain and headquarters is essential.

Non_ICT assets are positively associated with total participation in the GVC. The total participation index on GVC is expressed as the sum of forward (FL) and backward (BL) participation index. The coefficient of Non_ICT has a value of 0.639 (Table 3 column 1). The Non_ICT coefficient is positively associated with backward and forward participation. We observe this positive impact in both analysed sectors: manufacturing and TBS. Surprisingly, the tangible ICT assets (HARDWARE) coefficient is negative. This negative impact is significant in the case of forward and backward participation. That is particularly surprising for backward participation because we expected that production in countries with higher backward participation in GVC depends on the accumulation of tangible assets.

Our first and second hypothesis is supported by results shown in Tables 3–5. As we expect, the ICT assets positively impact GVC (Table 3 columns 1 and 5 (one year lagged)). The estimated coefficient for ICT is 0.336, indicating that a 10% rise of ICT assets is ceteris paribus correlated with the 3.36% rise of participation in the GVC. The estimated coefficient for Non_ICT is 0.639, indicating that a 10% rise of Non_ICT assets is ceteris paribus correlated with the 6.39% rise of participation in the GVC. The lagged effect is no stronger for ICT (0.211) and Non_ICT assets (0.851). The accumulation of ICT assets is positively correlated with the country's participation in the GVC. Corrado et al. [48] have shown that tangible, intangible, and ICT assets are positively associated with participation in the GVC, pointing to the complementary role of tangible and intangible assets and ICT assets. Adarov and Stehrer [43] and Jona-Lasinio et al. [1] confirm the significant impact of intangible ICT on the country's total GVC participation. They have observed a positive

relationship between the backward participation index and a significant negative effect for the forward participation index.

Our second and third hypothesis is supported by results shown in Tables 3–5. As expected, the intangible ICT assets positively impact GVC, backward and forward participation (Tables 4 and 5 columns 2 and 6). The estimated coefficient for intangible ICT is 0.117, and intangible ICT assets' lagged effect on total GVC participation is 0.105.

In the case of backward participation, the coefficient of intangible ICT assets (SoftDB) is significant and positive (0.120) and is higher than in forwarding participation, where the coefficient of SoftDB is 0.111. We also confirm this effect for lagged capital variables. Therefore, intangible ICT assets have a positive impact on GVC participation. Countries with high backward participation use foreign value added (intermediate products) in their production; therefore, they must have a quality ICT infrastructure and connection.

Our expectation of the negative impact of the variable ΔLAB_SERV productivity (value added per worker) have been met. According to Adarov and Stehrer [43], the growth of labour services is associated with a decrease in labour productivity. The sluggish productivity growth is a major challenge for many advanced countries. As we expected, the control variable corporate income tax rate (CIT) has a significant negative coefficient. This effect is stronger in the case of backward participation.

Services play an irreplaceable role in globally organised production as discussed in Thangavelu et al. [49]. That means that services are increasingly involved in creating value added in production activities, especially in the manufacturing sectors. Table 6 shows the sectoral results for the effects of the ICT asset accumulation. The impact of ICT is positively and significantly associated with the country's participation in the GVC. It is stronger in the services (TBS) than in the manufacturing sector, confirming our fourth hypothesis. Jona-Lasinio, Manzocchi and Meliciani [1] also demonstrated that intangible ICT assets are positively associated with the service sector.

Intangible ICT assets (SOftDB) significantly positively impact GVC participation in both sectors. However, the impact is stronger in the manufacturing sector (0.157) than in the services (0.070). Our fifth hypothesis is verified. Tangible ICT (HARDWARE) assets are negatively associated with the country's participation in the GVC. This negative impact is similar for both sectors.

Our results are in line with the findings of Corrado et al. [40], Jona-Lasinio et al. [1], Adarov and Stehrer [50]. They confirmed the important role of intangible assets in the country's GVC participation. Moreover, Brynjolfsson et al. [51] and Corrado et al. [52] have shown the importance of complementary investments in intangible assets for ICT investments to have wide-ranging productivity effects through a change in business models, acting as a general-purpose technology and that ICT capital is more productive when complemented by intangible investment.

4. Conclusions

Due to the productivity growth slowdown in OECD countries, the empirical literature primarily focuses on the impact of intangible asset accumulation on productivity growth. This article examined the impact of the particular ICT asset accumulation on a country's GVC participation. We focused primarily on examining the role of intangible ICT assets in creating domestic and foreign value added in export. We used a sample of 10 EU countries for 2000–2015 (selected upon data availability). The driving force of production fragmentation is the process of European integration. As a result, the participation of EU countries in the GVC is higher than in other advanced economies, both in trade with intermediates and final production.

Descriptive statistics of variables show that the volume of domestic value added in foreign exports is growing, and so is the volume of foreign value added in domestic exports, showing the increase of the EU production fragmentation. Therefore, the determinants of the GVC in the EU need to be examined more closely.

Our panel regression results with random effects confirmed the positive and significant impact of the ICT asset accumulation on participation in the GVC. Examination of specific ICT assets has shown that intangible assets are significantly positively associated with the ability to create value added in the GVC and support total participation in the GVC. In addition, intangible ICT assets have positively impacted both backward and forward participation. However, intangible assets are more strongly associated with backward participation.

Extending the analysis to the sectoral level has shown that total ICT assets are positively associated with GVC participation and have a more significant impact on the service sector. On the other hand, intangible ICT assets are positively associated with the manufacturing sector. Moreover, the results showed that tangible ICT assets have a negative impact on GVC participation.

The discussion of intangible assets is important in order to provide reliable and evidence-based political support. Competition policy should be designed to support investment in intangible assets, according to Thum-Thysen et al. [2]. Investing in intangible assets and building a strong innovation science base has a crucial role in stimulating knowledge-based economy creation. That applies not only to ICT intensive sectors but to the whole economy. Integrating into GVC and upgrading their position are the policy priorities for countries. The main goal is to specialise in higher value-added activities by accumulating intangible assets.

The main research limitation is the availability of data. Our sample consists of 10 EU countries. Data for other EU countries were not available at the time of analysis. Our research is based on EU country data. It will be interesting to expand the analysis globally to arrive at more general conclusions. Although we have sufficiently long time series within our dataset, we do not examine the two-way relationship between the accumulation of ICT assets and value creation within GVC. Therefore, further research is required.

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