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EVIDENCE FROM EUROPEAN INDUSTRIES

Marco Sforza

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Dipartimento di Economia
Università degli Studi Roma Tre
Via Silvio D'Amico, 77 - 00145 Roma
Tel. 0039-06-57335655 fax 0039-06-57335771
workpapers@uniroma3.it
https://economia.uniroma3.it/

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Are digital technologies reshaping trade patterns? Evidence from European industries

Marco Sforza*

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Abstract

The paper explores the relationship between the industry-level diffusion of digital technologies and the regionalisation of trade in value added. Theoretical literature underlines two potential effects of these technologies. They may facilitate coordination, favouring higher fragmentation, but also redefine comparative advantages, pushing toward relocation. The aim of the paper is to provide empirical evidence on the relationship between digital technologies and trade regionalisation, for a panel of selected European countries and sectors over the period 2005-2018. I build a dataset combining data from TiVA-OECD, EU-KLEMS and Eurostat SBS. I define two regionalisation measures, comparing intra-EU against extra-EU trade flows, to capture the relative importance of the two regions for input sourcing and output destination. The econometric analyses show a differentiated effect on the two measures: digital capital reduces regionalisation of the input sourcing, while positively correlating with the regionalisation of the intermediate output. Finally, a differentiated effect is also found in magnitude between technologies, namely, physical ICT and software.

JEL Classification: O330, F100, F150

Keywords: Digital technologies; Global Value Chains; Trade regionalisation.

*Department of Economics, Roma Tre University. ✉ marco.sforza@uniroma3.it
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1 Introduction

In recent years, a debate on the potential effects of digitalisation on trade dynamics has emerged (Antràs 2020; Brun et al. 2019). The diffusion of new digital technologies directly affects firms' and industries' dynamics through three main drivers of change, namely digitalisation of processes, automation of labour and coordination through platforms (Eurofound 2018). The combination of the three phenomena results in an evolution of relationships between firms and sectors, which leads to disintermediation (through platforms), servitization, and flexible and distributed production (automation and digitalisation).

In this scenario, the implications for firms and sectors, and their trade linkages are twofold. On one side, the increasing efficiency gained with digital technologies, and the lower cost of coordination may enhance the opportunities for further fragmentation of the international production structure (World Trade Organization 2019).

On the other hand, in many advanced economies, there may be an incentive to relocate production closer to the end market, since new technologies are more capital-intensive, and require complementary investments in infrastructures and skilled labour (World Bank 2020).

These two opposite driving forces lead to a reconfiguration of the comparative advantages across countries. Minimising labour costs may no longer be one of the main drivers of the firms' offshoring decisions. From the advanced countries' perspective, these dynamics may lead to a reshaping of trade patterns between countries and regions, ultimately leading to a phenomenon of trade regionalisation, that is, a progressive concentration of trade in contiguous geographical areas.

The aim of the paper is to provide empirical evidence on the ongoing dynamics between sectoral digitalisation and trade linkages in value-added and with a focus on European sectors. The research question is whether the diffusion of digital technologies may have affected the regionalisation of trade in value-added in a set of EU countries, given their high economic, political, and institutional integration.

To explore the trade patterns, I build an original dataset for a set of European countries, and for selected industries (i.e., manufacturing and ICT-intensive sectors), combining data from multiple sources. To account for trade in intermediate goods, I use TiVA-OECD inter-country input-output tables, which allow building the regionalisation measures using established indicators of backward and forward participation (Koopman, Powers, et al. 2010). Since the focus of the paper is on trade regionalisation, I decompose the backward and forward measures to define the regionalisation indicator, following a regional-to-global perspective (Bontadini et al. 2022).

The diffusion of digital technologies is proxied by the digital capital stock, which is obtained from the EU-KLEMS/INTANProd database, as well as data on tangible and intangible capital stock. The latter source allows for a decomposition of digital capital into two components: ICT and software. As I review in the literature section, it is essential to distinguish different kinds of technologies, since the difference between them may exert a differentiated effect on the studied trade linkages. Moreover, given the growing importance of the complementarity between intangible capital and digital technologies (Crouzet et al. 2022; Gal et al. 2019), I also use data from INTANProd to complement the analysis with measures not included in the national accounts. Finally, a set of control variables on labour cost, cost competitiveness, and sectoral structure is obtained from Eurostat Structural Business Statistics.

A balanced panel is built for a time span going from 2005 to 2018. The countries included in the sample are Austria, Belgium, Czech Republic, Germany, France, Italy, and Slovakia, while the sectors are all the industries from the NACE "C" (manufacturing) and "J" (information and communication) divisions. The time span and the countries in the sample are selected to avoid missing information and to ensure the comparability between countries and years.

The dataset is used to analyse the contribution of digital technologies to trade regionalisation. The econometric analysis uses a fixed effect IV estimator, to account for the potential endogeneity. The results show differentiated effects of digital technologies on the regionalisation measures, as well as differences in intensity among technologies. The digital capital stock is negatively correlated with the regionalisation of trade linkages, pushing for further international production fragmentation on the input sourcing side (i.e., *backward* linkages). On the other hand, the regionalisation of the output destination emerges, with a positive association between the digital capital stock and the *forward* regional linkages. The results also show a differentiated effect between technologies, with software driving the effect on the "globalisation" of input sourcing, while ICT drives the one on output regionalisation. The results remain robust at changes in control variables and across sub-samples.

Two main findings arise from the analyses. I provide an empirical assessment of the role of digital technologies in shaping trade linkages. The first evidence is the lower degree of regionalisation associated with a larger use of digital technologies, for input sourcing. On the other side, the same technologies are correlated with a higher regionalisation of the (intermediate) output, which seems to be associated with a trend of sectoral upgrading.

The second finding relates to the difference in magnitude between digital technologies, within the same regionalisation measure, and within technological taxonomies. This result may clear the way for further analyses of the differentiated effect between distinct digital technologies, which are currently driving the change, i.e., the role of big data, software platforms, and algorithms.

The paper is organised as follows: Section 2 explores the motivations and the literature review, concluding with the introduction of the research question. Section 3 presents the dataset, the variables of interest and the descriptive analysis, while the econometric analysis is provided in Section 4, along with the results. Finally, Section 5 discusses the results and presents the concluding remarks.

2 Motivations and background literature

2.1 Recent trend in international trade

In the last decades, international trade flows were shaped by the research of an improved resiliency for value chains and production networks, the increasing concentration of trade flows in contiguous regions (i.e., regionalisation), and the diffusion of digital technologies, along with all the consequences of the latter, in terms of labour, markets' coordination, and changes in production techniques.

The trend toward a slowdown in the growth of globalisation - the so-called *slowbalization* - is an ongoing process since the Global Financial Crisis (2008), which led to a concentration in trade flows among developed economies[1] (World Trade Organization 2021). The increased number of regional trade agreements supported the regionalisation of trade, prompting – and supporting – the decisions of Global Value Chains (GVCs) to locate the stages of production in contiguous regions, reversing the trend of continuous global expansion experienced since the 1990s (Gereffi 2014).
Moreover, increasing costs in emerging economies and geopolitical reasons pushed lead firms in GVCs to strengthen their supply chains, by selecting a lower number of firms, but more capable (i.e., rationalisation), and expanding inventories to prevent the risk of supply disruption, that is, enhancing their resilience (Brun et al. 2019; Gereffi and Lee 2012).

In this framework, the spread of advanced digital technologies may have several impacts on all the cited phenomena. In fact, the new production techniques allowed by new digitised processes, as well as the impact on labour and markets' transaction coordination, are likely to affect production localisation decisions in Global Value Chains.
Digital technologies (DTs hereafter) may also extend disintermediation, through the use of digital platforms to coordinate both production and transactions (Eurofound 2018), as well as may increase servitization, leading to a relevant role in data creation and exploitation. Lastly, DTs may allow flexible and distributed production, with massive digitisation and automation

[1] On the contrary, despite the increasing number of regional trade agreements, emerging economies continued to push toward an increase in economic integration (World Trade Organization 2021).

of routine-intensive production tasks, with implications for both productivity and labour (Brun et al. 2019; Acemoglu et al. 2020; Acemoglu et al. 2019).

In line with "traditional ICT"[2], some advanced digital technologies continue to contribute (at a faster pace) to the decline of information and transaction costs thus ensuring easier coordination within, and among, firms.

On the other hand, some other advanced (digital) production technologies, mainly related to physical processes, are characterised by different needs, in terms of labour skills and infrastructures, and this may encourage locating specific stages of production in advanced countries.

The differentiated potential effects of the spread of digital technologies shall be discussed in the remainder of the section, but it is worth presenting here the rationale behind the research. As outlined before, some digital technologies may push toward a further fragmentation of production networks, while others may incentive to relocate production in advanced countries. These hypotheses are both likely to stand (Antràs 2020), and are largely dependent on technological opportunities of the industries - where digital technologies may, or may not, pervade production techniques - and countries. For all those reasons, the paper aims at shedding a light on the contribution of DTs in shaping the regionalisation trends in European industries in the last decade.

2.2 ICT, GVC trade and productivity

Since the 1990s, a new paradigm consisting of an internationally fragmented production structure has emerged, with the rise of the Global Value Chains/Global Production Networks (Gereffi and Lee 2012). The different stages of production and the final assembly began to be separated into physically and geographically distinct locations to obtain productivity gains through specialization and offshoring of specific tasks (Grossman et al. 2008), allowed by the decline of trade costs and increased openness in trade. The latter was the result of a new international political environment, that eventually also lead to China's entry into the international trade network in 2001. Moreover, the sustained decline of ICT costs contributed to reducing communication and coordination costs and to "globalisation's second unbundling" (Baldwin 2016).

The continuous dissemination of ICT throughout the economy, along with the decrease in the costs of connectivity, led to the emergence of the digital economy, at the end of the 2000s. But the increasing role of digital technologies had a double-faced impact on the economy. On

[2] By "traditional ICT" I refer to the bundle of technologies that have characterized the first wave of digitalisation, which have driven the "globalisation's second unbundling" (Baldwin 2016). Namely, these technologies are: PC, internet (and later broadband internet), and early versions of SCM and ERP software.

the one hand, it contributed to boost firms' productivity (Cette et al. 2021; Biagi 2013; Cardona et al. 2013), since these technologies allow firms to reduce costs, automate tasks, enable complementary innovations, enhance their resilience (Ralston et al. 2020; Bertschek et al. 2019; Niebel et al. 2019; Aboal et al. 2018). On the other hand, the ICT diffusion led to an increase in divergence between firms, and within sectors, since the penetration of digital technologies is uneven. The heterogeneous impacts, and the resulting divergence, shall be attributed, among other factors, to the lack of infrastructure, skills, and organizational capital (Nicoletti et al. 2020; Gal et al. 2019; Sorbe et al. 2019). Moreover, the productivity gains through the implementation of digital-related technologies are also emphasised where there is a larger proportion of tasks that can be automated (Sorbe et al. 2019), and where these technologies are used to implement data-intensive decision-making strategies (Brynjolfsson et al. 2017).

But the firms' and sectors' upgrading in the Global Value Chains are strictly related to technology diffusion, particularly to digital technologies. Being involved in GVCs requires compliance with standards along the chain, that push the firms to adopt homogeneous technologies and procedures.

Therefore, relations between firms operating in value chains become the channel through which knowledge flows across the firms' boundaries and contributes to build technological and innovative capabilities of firms and sectors (Delera et al. 2022; Lema et al. 2018; Morrison et al. 2007), eventually affecting market share dynamics and firms' performance (Laursen et al. 2010).

Lastly, I shall briefly outline how digital technologies and firms' behaviour in international markets may interact. Digitisation of firms allows the latter to experience greater autonomy concerning the lead firms, thanks to the disintermediation enabled by digital technologies (Oliveira et al. 2021), as well as to gain a broad comparative advantage at the country level (Y. Wang et al. 2017), and to have better firm-level export performance, through direct and indirect effects of ICT (Añón Higón et al. 2022).

Moreover, digital technologies are closely related to intangible goods, that is, knowledge-based capital, such as innovative activities, intellectual property rights on software and algorithms, training activities and organizational capital. The shift toward a higher relevance of the intangibles in the overall economy has been highlighted extensively (Crouzet et al. 2022; Corrado, Haskel, et al. 2022), and has been proven to be particularly relevant to enable technology adoption in manufacturing firms (Gómez et al. 2012), but what concerns to the present paper is their relevance for the value appropriation's mechanism in the digital economy. As found by Jona-Lasinio et al. (2019), intangible capital boosts the participation in GVCs, and complements the use of ICT (the latter relatively more important in services than in manufacturing), while the return on productivity differs looking at the sectors' digital intensity (Battiati et al. 2019). The latter evidence may suggest a technological dimension in the industry-level absorption of digital technologies and in their role in affecting the mode and the magnitude of value chains' participation.

2.3 Potential impacts of digital technologies

At the beginning of this review, the two main potential effects of digitalisation on the structure of international production have been outlined. Let me now delve into differences in the potential impact of digital technologies on international trade.

The sustained decline in ICT and connectivity prices (World Trade Organization 2021) may continue to support the diffusion of digital technologies. In the wake of the digital economy, the increasing digitization of processes allows some non-tangible technologies to emerge, such as more powerful software to coordinate processes or platforms and digital ecosystems (Eurofound 2018; Teece 2018). These technologies allow firms to gain in efficiency, lower costs through "pay-per-use" services, support coordination of processes and transactions and access remote markets, via the reduction of information, matching, and coordination costs (Brun et al. 2019; World Bank 2020; Sung 2018).

Firms operating in value chains may be particularly affected by these technologies, since in these production structures the codifiability and the modularity - of general procedures and production stages - are essential features (Butollo et al. 2022; Sturgeon 2021). But the expansion of digital services in manufacturing may also rise concerns about the emergence of new monopolies and lock-in effects for firms, due to the strong network effects and the growing reliance on data generation and collection of the new production processes, leading to consequences in terms of market power and structures (Coveri et al. 2022; Antràs 2020).
To sum up, the aim of digital technologies such as software, platforms and digital ecosystems is to enhance firms' upgrading through gains in productivity, as well as a reduction in information and transaction costs. As a matter of fact, there is a wide consensus on the potential incentive toward further fragmentation in international production (World Bank 2020; UNCTAD 2019). In addition, DTs stimulate progresses in logistics and networking (Butollo 2021; Sturgeon 2021), then the result may be a reduction in distances between markets, and facilitation of sourcing or destination of intermediate goods along the chain.

The other potential impact of digital technologies may be of the opposite effect and mainly involves manufacturing. Progresses in digital technologies encompassed an ongoing shift toward a new production model. The latter is characterised by the digitization of processes, higher automation and smart manufacturing, and an increased inter-firm connection, especially between traditional manufacturing and services (Müller et al. 2018).

In manufacturing, the shift toward the *Industry 4.0* paradigm induces the emergence of smart factories, through deep integration between digital technologies - such as Internet of Things, 5G connectivity, cloud computing and big data analytics - and physical stages of production, with advanced robotics and virtual reality devices (UNIDO 2019; Sung 2018; Schwab 2016).

Moreover, the diffusion of additive manufacturing improves firms' prototyping abilities and enables higher product customization, affects value creation and value appropriation mechanisms, and has a particular effect on firms integrated into international trade (Johns 2022; Magnani et al. 2022; Freund et al. 2022). This technology consists of a "layer by layer additive construction of three-dimensional objects" (Andreoni et al. 2019), and allows to customise products on-demand, then rapidly responding to buyers' needs, or make components near the manufacturers that may need them, also lowering physical distances.

The shift toward these new production technologies requires adequate capabilities for firms and sectors, that are unevenly distributed across countries and regions. From a firm-level perspective, the diffusion of digital technologies requires skilled workers, developed financial markets to support access to credit, and managerial capabilities (Stornelli et al. 2021; Stentoft et al. 2021; Nicoletti et al. 2020; Horváth et al. 2019), as well as innovative capabilities to expand firms' absorptive capacity (Muscio et al. 2020; Cohen et al. 1990), possibly supported by appropriate industrial policies (Landesmann et al. 2019).

Since these requirements are essentially met in developed economies, where there are developed markets, skilled workers, and high levels of R&D activities, there is a reconfiguration of the comparative advantages in the firms' location choices. The push toward a production technique with higher requirements in terms of capital and capabilities makes it more convenient to locate production in countries (and regions) where the needed complementary factors are relatively more abundant, such as in advanced economies.

This mechanism of a transition toward digital factories in manufacturing, and their growing integration with services, makes obsolete the principle of outsourcing/offshoring decisions based on simple cost-differentials (World Trade Organization 2019). However, even though advanced digital technologies are characterised by high pervasiveness (Martinelli et al. 2021), technological opportunities are heterogeneous across sectors, then the digital transition may leave room for a further polarization of the geography of production. A plausible scenario is the one depicted by Bárcia de Mattos et al. (2021), also supported by WTO (2019) and Bailey et al. (2018), which argue that basic and low-priced goods may continue to be imported, against complex and high-priced productions that may be nearshored.

2.4 Research Question

The aim of the paper is to assess whether the diffusion of digital technologies contributed to the existing trend of slowdown in globalization, namely, the regionalisation of trade flows in a sample of selected European countries. Since the literature has not provided sound empirical evidence on the potential impacts of digital technologies on production networks, the aim is to shed a light on an ongoing process and to highlight a possible pattern of structural change.

The focus of the analysis is on trade regionalisation, namely, the progressive reallocation and concentration of trade flows within a geographically or economically defined region. In the paper, I adopt a regional-to-global perspective, and I, therefore, define two regions. The first is the economic region of the European Union, characterized by a strong economic and political integration, on which the analysis is focused. On the other hand, all the flows coming or destined for countries outside the EU region are assigned to the extra-EU region (i.e., the rest of the world). The two measures of trade flows are combined into a ratio, following Bontadini et al. (2022), which allows measuring the relative importance of intra-EU value-added against the extra-EU flows (the ratio between intra-EU and extra-EU)[3].

To provide this evidence, and to account for the industry-country contribution to international production, the analysis will focus on trade in value-added (Foster-McGregor et al. 2013; Ahmad 2013). The use of trade in value-added allows focusing on the contribution of the single country-industry pair to the Global Value Chains, addressing the double counting issue that occurs when intermediate goods are employed in international production.

I distinguish the input-sourcing perspective from the output-destination perspective. The first refers to the origin of the intermediate goods used in the production of a country-industry pair, while the latter refers to the destination of the output as an intermediate good, that is, the value-added originating in the country-industry pair, contained in the export of the single region.

Moreover, also technology diffusion will be defined by making a distinction between ICT and software capital, to account for the heterogeneity among different types of technologies, which has been outlined before. The analysis will focus on a sample of European countries and sectors, producing tradable goods, and namely, manufacturing and ICT sectors. Manufacturing is conventionally considered a tradable sector, but I also include ICT (NACE "J" division) since some professional activities – such as IT consultancy and related activities – should be

[3] A detailed description of the procedure used to build the regionalisation measures is available in Section 3.1.2.

considered, at least partially, a tradable sector[4]. The countries are selected among the most involved in international trade and with a large manufacturing sector. The period considered ranges from 2005 to 2018, which is a large time span that seems to be sufficient to catch the regionalisation trend.

Therefore, the research question to be answered in the paper is the following:

Hypothesis 1 *Have Digital Technologies contributed to the regionalisation of value-added trade flows?*

I shall not present here an a priori hypothesis on the expected outcome, since, as extensively discussed before, the theory does not provide a definite direction. However, differentiated impacts are expected, both for technologies and on the sourcing/destination perspectives.

As already mentioned, some technologies, such as those aimed at reducing information and transaction costs, may facilitate the firms' participation in international markets, and then promote further fragmentation. On the other side, technologies related to physical production may push toward the location of certain stages of production in developed countries, strengthening the regional linkages. Therefore, the latter mechanism may positively influence the destination of production within the EU region.

In the next sections, the dataset and the main variables, as well as the descriptive and econometric analyses, are presented.

3 Data and measurements

The dataset combines different sources: I use the TiVA-OECD inter-country input-output tables for trade in value-added (release 2021); data for capital stock, both digital and traditional, are provided by the EU-KLEMS/INTANProd project; finally, I integrate a set of control variables, such as country-industry structure, size (in terms of value-added and employment), cost competitiveness, and labour cost from Eurostat Structural Business Statistics.

The countries are selected among those more involved in international trade and with a large share of manufacturing on total value added (World Trade Organization 2021). The selected countries are Austria, Belgium, Czech Republic, Germany, France, Italy, and Slovakia. From the analysis are excluded the countries with a modest share of manufacturing on total value-added, and countries with a highly unbalanced distribution of the regionalisation indicators, to avoid outliers and ensure the comparability of data.

[4] The list of the considered countries and sectors is available in Table 1

Table 1: Sample composition - Countries and sectors

Countries		NACE 2-digit sectors		
	N. obs.		N. obs.	Description
Austria	140	C10-C12	68	Food, beverages, and tobacco
Belgium	138	C13-C15	68	Textile, apparel, leather
Czech Rep.	140	C16-C18	68	Wood, paper, printing
Germany	140	C20	68	Chemical products
France	112	C22-C23	68	Rubber, plastic and non-metallic mineral products
Italy	140	C24-C25	68	Basic metals and fabricated metal products
Slovakia	140	C26	68	Computer and electronics
		C27	67	Electrical equipment
Total	950	C28	68	Machinery
		C29-C30	68	Automotive
		C31-C33	68	Furniture, oth. Manufact., repairing
		J58-J60	68	Publishing and broadcasting
		J61	67	Telecommunications
		J62-J63	68	Computer programming, consultancy and IT services

Note: NACE division "C" is manufacturing, division "J" is information and communication.

Regarding the industries, those selected are all the sectors from the NACE divisions "C" (manufacturing) and "J" (information and communication). These sectors are involved in digital transformation because of the use of digital technologies in production (NACE C, in general), the provision of digital-related services (NACE J), or the production of ICT devices (NACE C26-C27).

The design of participation and regionalisation measures, as well as the selection of DTs' variables, shall be explored in the next sub-sections. It is worth stressing now the main advantages of the selected data sources.

Regarding the dependent variables, the use of TiVA-OECD tables allows us to follow standard procedures of value-added decompositions. Consistently with all the literature on GVCs and international trade, using these data I shall build the participation measures, as well as define novel measures of trade regionalisation, differentiating the regional origin/destination of value-added content of trade. The process used to build indicators is presented in detail in the remainder of the section. The use of the EU-KLEMS/INTANProd database enables to account for the different natures of digital capital, distinguishing the ICT capital from the software component[5].

Moreover, also tangible capital stock (excluding ICT capital) and intangible capital stock (that excludes software and database) are included in the analysis. The latest release of the EU-KLEMS/INTANProd database (2021) provides measures of capital stock, including intangible capital, that are estimated in a fully consistent way with traditional national accounts' aggregates (EU-KLEMS 2021). These two latter aggregates allow controlling for the role of traditional capital and, particularly, for the role of intangibles, which may be relevant for the analysis, as before discussed.

3.1 GVCs participation

A preliminary analysis is carried on using established indicators of GVCs' participation (Koopman et al., 2010, 2012), computed following the procedures proposed by Belotti et al. (2021) and Borin and Mancini (2019).

I shall use the *backward* and the *forward* indicators. The former accounts for the input-sourcing perspective and corresponds to foreign inputs in domestic exports as a share of the total gross export (i.e., *Foreign Value Added in Domestic Exports*, $FVADEX$). The latter accounts for the output-destination perspective and corresponds to the domestic intermediate inputs used in a third country's export as a share of the total gross export (i.e., *Domestic Value*

[5] ICT capital stock accounts for tangible (hardware) information and communication devices. "Software and database" component represents the "non-tangible" element of the more general IT capital stock.

Added in Foreign Exports, $DVAFEX$).

Finally, the ratio between the forward participation and the backward participation shall define the relative positioning along the chain. Values greater than the unity denote a forward positioning relatively larger with respect to the *backward*. This should report that the domestic contribution (in value-added) in foreign exports is larger with respect to the foreign value-added used as input, hence signalling an upstream positioning in the chain.
By contrast, when the country-sector contribution in chains' value-added is lower, that is, uses a larger share of foreign VA with respect to the share that supplies, the ratio is smaller than unity, and the sector is located downstream.

$$Bwd^{Part}_{i,c,t} = \frac{FVADEX_{i,c,t}}{TotGrossExp_{i,c,t}} \tag{1}$$

$$Fwd^{Part}_{i,c,t} = \frac{DVAFEX_{i,c,t}}{TotGrossExp_{i,c,t}} \tag{2}$$

$$Upstreamness_{i,c,t} = \frac{Fwd^{Part}_{i,c,t}}{Bwd^{Part}_{i,c,t}} = \frac{DVAFEX_{i,c,t}}{FVADEX_{i,c,t}} \tag{3}$$

3.2 Measuring regionalisation

To analyse the regionalisation phenomenon, the *backward* and *forward* indicators defined in the previous paragraph are declined in a regional-to-global perspective, following Bontadini et al. (2022).

Since we are interested in the trend for European sectors, we define two regions, as mentioned earlier: the first is composed of the European Union countries (*intra-EU*), while the second by the rest of the world, that is, all the extra-European Union countries (*extra-EU*)[6].

Each value-added flow is decomposed into two elements, according to the origin or destination:

- for the *backward* indicator: foreign VA in country's export originated in EU-countries, against foreign VA in country's export originated in extra-EU countries;
- for the *forward* indicator: domestic VA in EU-countries exports, against domestic VA in extra-EU countries' exports.

[6] In evaluating the flows, the regions are considered as if they were a single country, that is, considering the regional block as a whole. For each measure, when considering the *IntraEU* perspective, the reporting country is not considered part of the region (e.g., analysing Italy, when assessing its *IntraEU* flow, its values are not considered in the sum of the flows, to avoid double counting).

For each indicator, the ratios between intra-EU flows and extra-EU flows are computed:

$$BwdRegio_{i,c,t} = \frac{FVADEX_{i,c,t}^{Intra-EU}}{FVADEX_{i,c,t}^{Extra-EU}} \tag{4}$$

$$FwdRegio_{i,c,t} = \frac{DVAFEX_{i,c,t}^{Intra-EU}}{DVAFEX_{i,c,t}^{Extra-EU}} \tag{5}$$

Each indicator represents a relative positioning, for the country-industry pair, at time t. For each pair, it reveals which region is relatively more important for the trade in value-added and, namely, for its input-sourcing (*backward*) or output-destination (*forward*) of the intermediate goods. Concerning their interpretation, an increase in the ratios suggests an increase in regionalisation and vice versa.

To account for the movements of the index's components, i.e., the dynamics of numerator and denominator, the latter are also evaluated in relation to the country-sector total gross export:

$$BwdIntra_{i,c,t} = \frac{FVADEX_{i,c,t}^{Intra-EU}}{TotGrossExport_{i,c,t}} \tag{6}$$

$$BwdExtra_{i,c,t} = \frac{FVADEX_{i,c,t}^{Extra-EU}}{TotGrossExport_{i,c,t}} \tag{7}$$

$$FwdIntra_{i,c,t} = \frac{DVAFEX_{i,c,t}^{Intra-EU}}{TotGrossExport_{i,c,t}} \tag{8}$$

$$FwdExtra_{i,c,t} = \frac{DVAFEX_{i,c,t}^{Extra-EU}}{TotGrossExport_{i,c,t}} \tag{9}$$

3.3 Digital technologies and intangibles

The diffusion of digital technologies is measured through the capital stock variables available in the EU-KLEMS/INTANProd database.

The main variables of interest are the capital stock in information technologies and communication technologies, and the capital stock in software and database. All the variables are expressed in natural logarithm (then, respectively, the variables *ln_kict* and *ln_ksw*).

The rationale for the use of these two aggregations is the following. Information technologies and communication technologies are combined into a single variable (i.e., ICT capital stock) since both represent physical devices. Using the System of National Accounts definition, the ICT capital stock includes "devices using electronic controls and also the electronic components forming part of these devices" (European Commission et al. 2008).

Since intangible goods are not included in national accounts, the corresponding measures included in the INTANProd module rely on the theoretical framework of Corrado et al. (2005). This framework allows estimating the intangible components of capital accumulation, such as digitized information (software and database), innovative capabilities (i.e., R&D, intellectual property, and innovative activities), and economic competencies, such as brand equity, firm-specific training, and organizational capital (EU-KLEMS 2021).
From this module, I integrate the dataset with the measure of the software and database capital stock.

Finally, also tangible (non-digital) capital and intangible capital stocks are included in the dataset, to be used as a control. For each of them, the ICT component (from the tangible stock), and the software and database component (from the intangible stock) are deduced.

4 Descriptive analysis

In this section, I shall explore some descriptive evidence from the sample, on the regionalisation trend and on the diffusion of digital technologies.

4.1 Regionalisation indexes

Concerning regionalisation, I shall look at the evolution of the intra-vs-extra ratios, that is, the regional-to-global evolution of input sourcing and output destination of intermediate goods. Looking at the extreme values of the time series (Figure 1), may be observed an increase in the forward ratio. All the countries and the industries in the sample show a value of the forward ratio greater in 2018 than in 2005. Instead, a different dynamic is found for the backward ratio: the values of the ratio are almost constant comparing the first and the last years of the time span, both from a country perspective and an industry perspective.

Looking at the components of the ratios (Figures 2 and 3), a limited variability across countries for input sourcing seems to emerge. Both the components - intra-EU flows and extra-EU flows - grew, with limited variability (Figure 2).
From the forward perspective (Figure 3), we shall observe at the end of the period (in 2018) the extra-EU component is larger than its initial values, for most of the countries of the sample.

In Figures 4 to 6 the evolutions over time of the ratios are presented. The evidence is mixed: from a country perspective (Figure 4), there is high variability across countries, and we shall observe differentiated dynamics between the two ratios, with an increase in the forward regionalisation that seems to arise for many countries. From a sectoral perspective (Figures 5 and 6) the picture is rather different: there is low variability both between and within sectors,

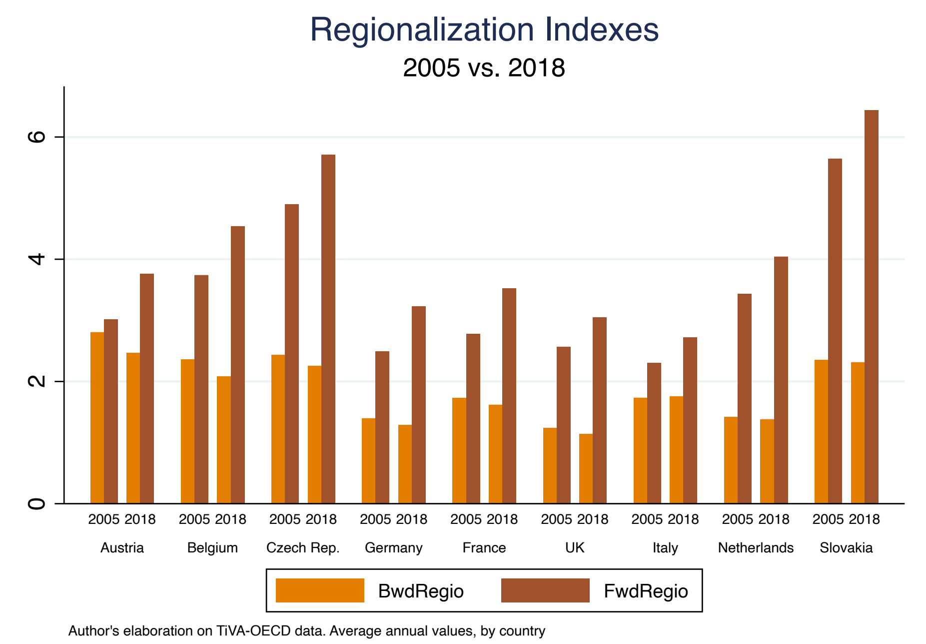

Figure 1: Regionalisation indexes by country

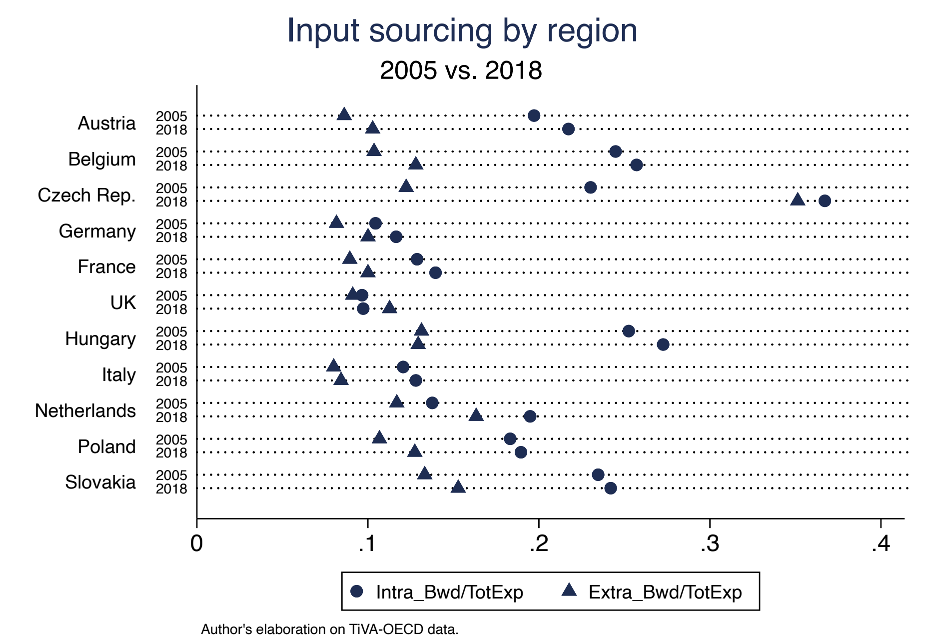

Figure 2: Input sourcing by country

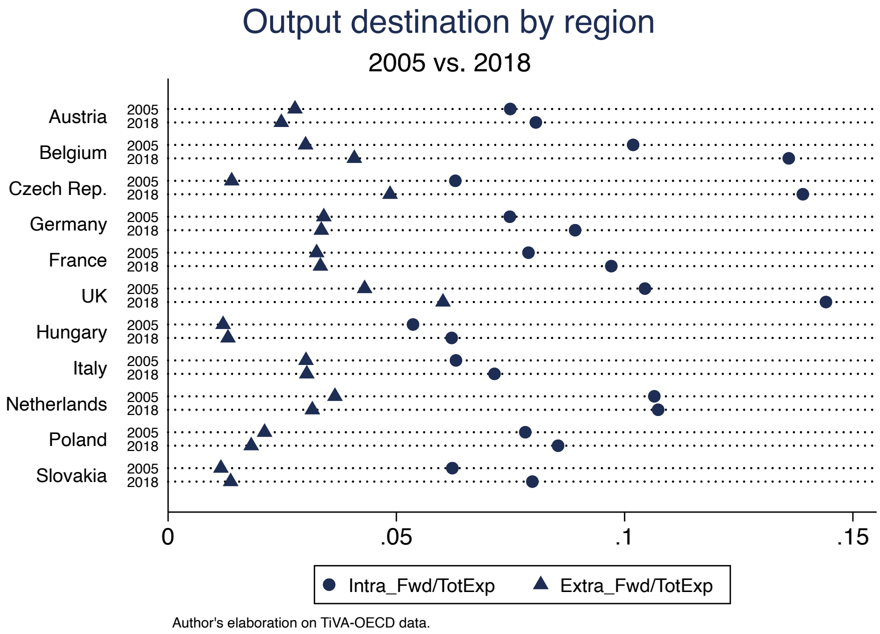

Figure 3: Output destination by country

except for non-manufacturing industries (NACE "J"). Moreover, the trend between backward and forward is homogeneous, once again, only for manufacturing sectors. This evidence seems to suggest that the dynamics of trade regionalisation, both for the backward and forward ratios, are driven by a country component, rather than the industries' technological specificity.
To partially account for the latter, in Figures 7 and 8 the trend is displayed according to two technological taxonomies. In Figure 7 the OECD Taxonomy of Digital Intensive Sector is used (Calvino et al. 2018): the increase in the forward ratio occurred for both classes, with some differences. For the medium-high and high digital sectors, the growth rate has been steady over time, while for low and medium-low sectors the increase in the forward began around 2015, with the concurrent decline of the backward ratio. The other technological taxonomy used is the Revised Pavitt Taxonomy (Bogliacino et al. 2016), in Figure 8: here, variations were smaller, except for the science-based sectors.

However, the figures do not account for the countries' degrees of specialization and only show average values. With the econometric analysis carried on in the remainder of the paper, I shall provide a more granular picture.

4.2 Digital technologies

Let us analyse the dynamics of digital capital stock. In Figures 9 and 10 the initial and final values for ICT and software are shown, according to country and sectoral breakdowns. The

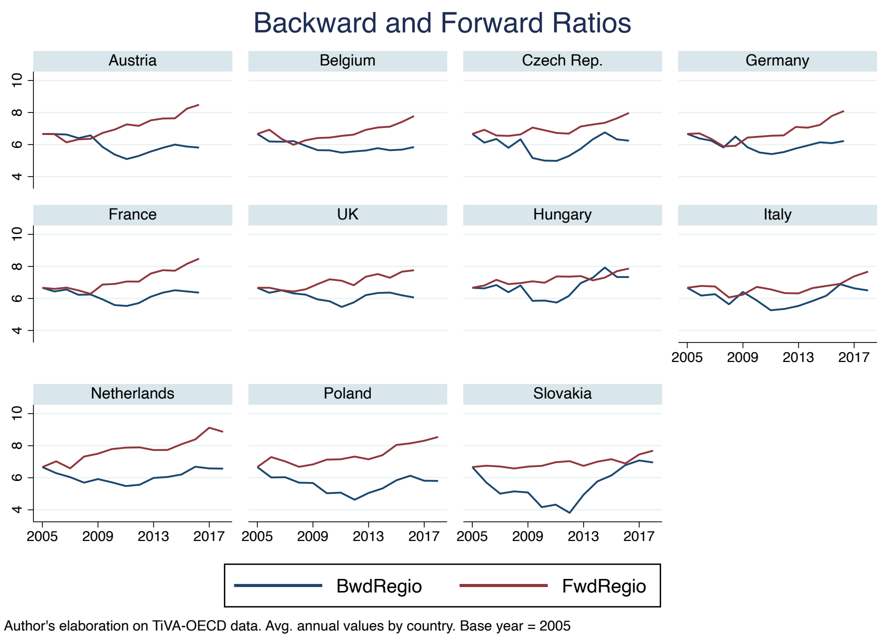

Figure 4: Evolution over time, by country

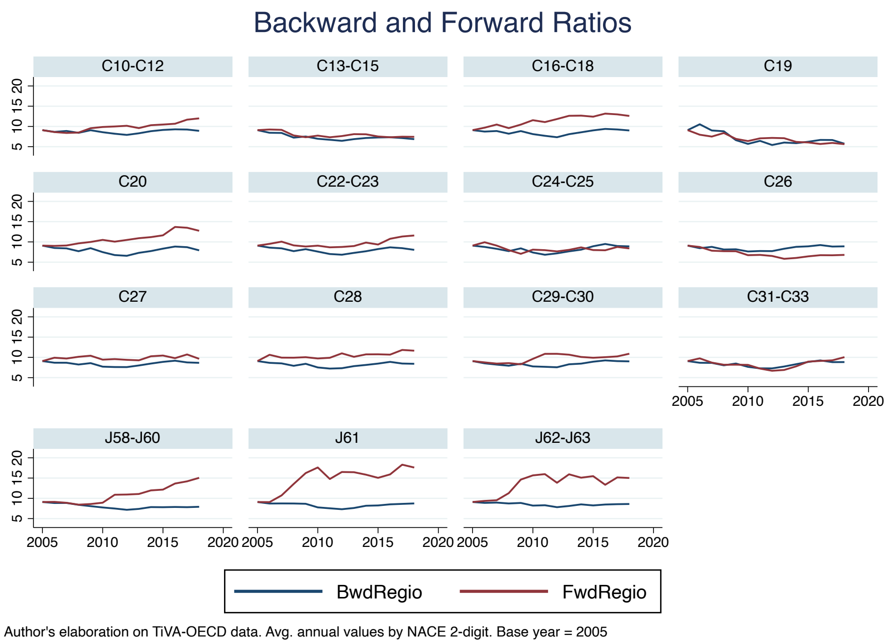

Figure 5: Evolution over time, by NACE 2-digit sector

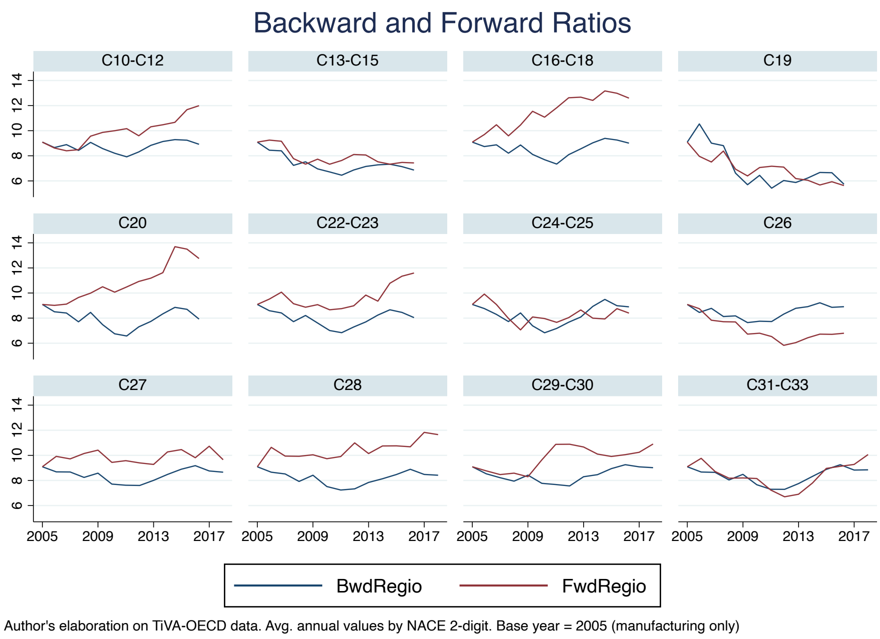

Figure 6: Evolution over time, manufacturing sub-sample

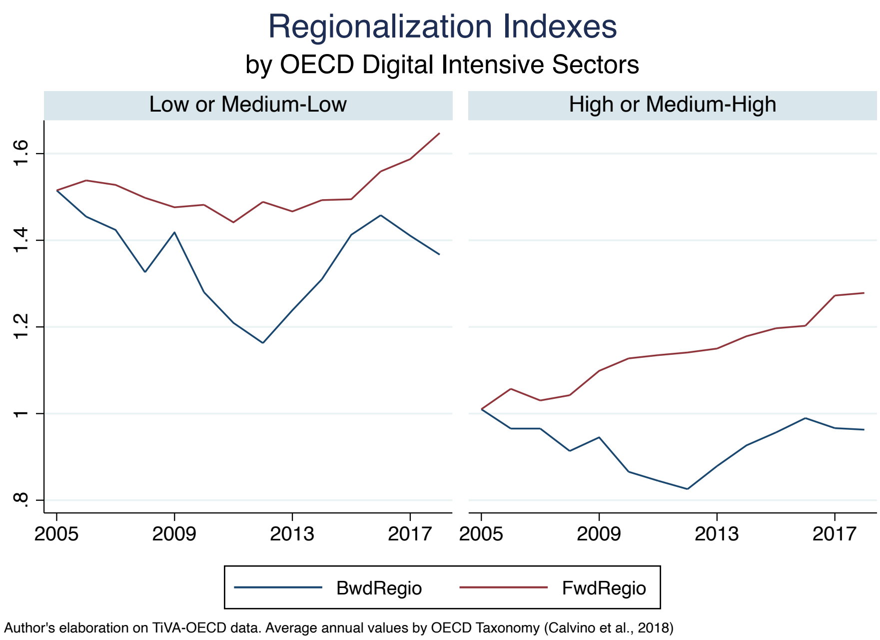

Figure 7: Evolution over time, by OECD Digital Intensity

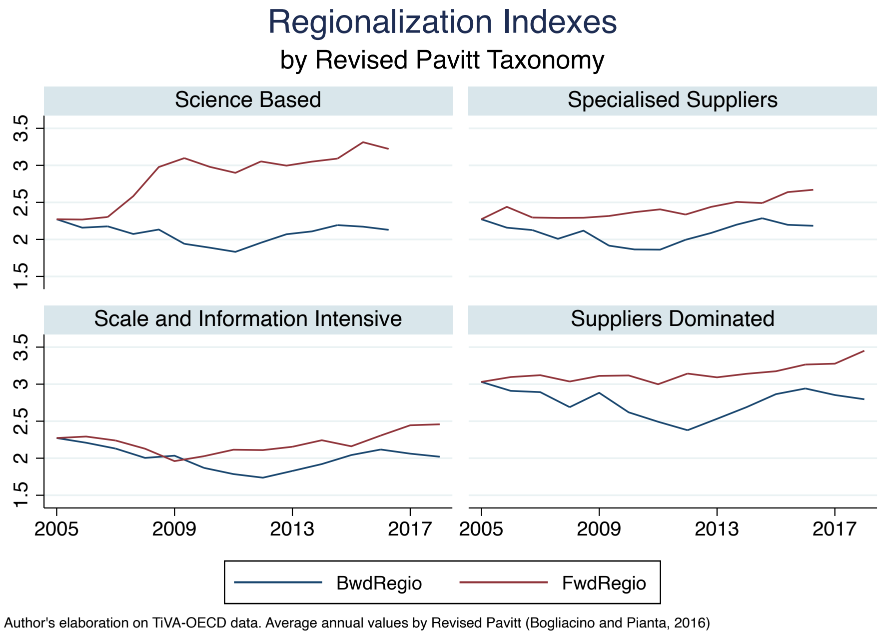

Figure 8: Evolution over time, by Revised Pavitt Taxonomy

values of the capital stock are in proportion to the total capital stock[7].

Looking at the differences between the first and the last year of the series, there is limited growth of the ICT capital stock across sectors and countries, while is relevant the growth of the software component.

Focusing on manufacturing (Figure 10), this is especially true for sectors classified as Specialised Suppliers[8] and Scale and Information Intensive[9]. These industries show generally higher levels of ICT and Software capital stock, but also a specific, and significant, increase in the share of software capital stock. Sectors with a lower technological intensity, such as the Supplier Dominated (from NACE C10 to NACE C18), show a smaller share of digital capital, but nevertheless a relevant increase in the share of software capital stock. Delving into the sectors' digital intensity, in Figure 11 we shall look at the breakdown according to the OECD Taxonomy. As may be expected, the relevance of digital capital is higher in industries classified with high or medium-high digital intensity. Nevertheless, is relevant to notice the significant increase, once again, for the software component, across all classes.

Finally, it is worth noting the evolution and the relevance of tangible and intangible capital stock across the OECD Taxonomy. In Figure 12 I shall compare the stock of digital capital (in share) in the first and last year of the series, according to the Taxonomy of Digital Intensive

[7] Net capital stock in volume (*Gross Fixed Capital Formation*), 2015 reference prices, all assets.
[8] Manufacture of: electrical equipment (C27); furniture (C31-C33); machinery (C28); automotive (C29-C30)
[9] Manufacture of: basic metals (C24-C25); coke and refined petroleum products (C19); rubber and plastic (C22-C23)

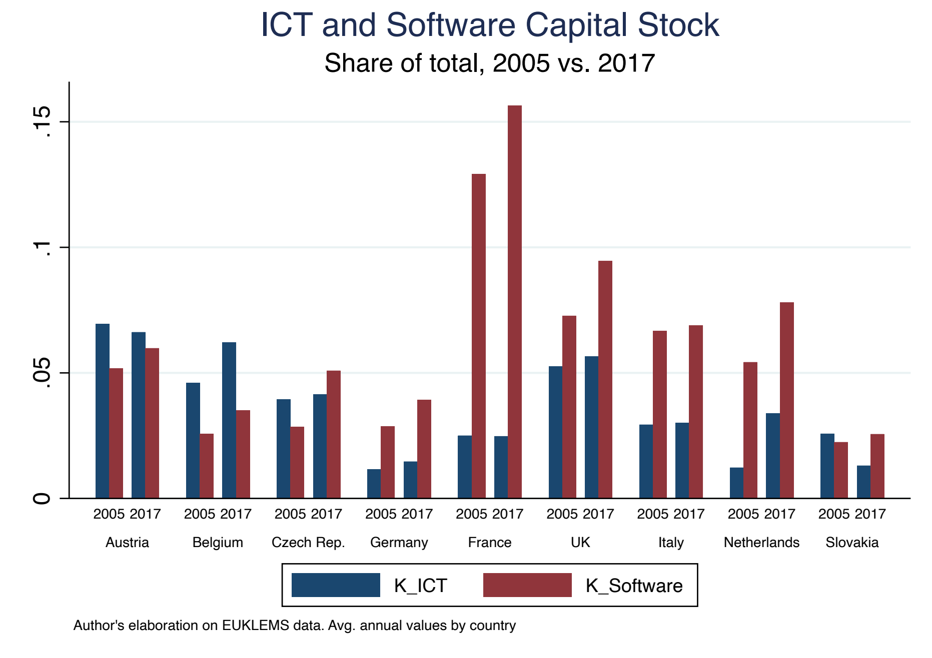

Figure 9: Digital capital stock, by country

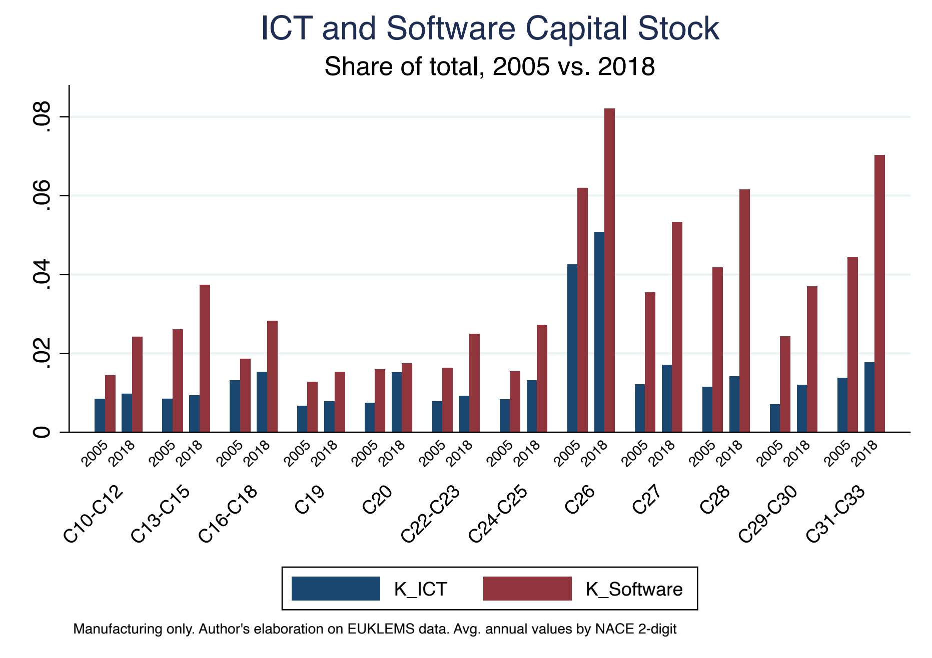

Figure 10: Digital capital stock, by NACE 2-digit sector

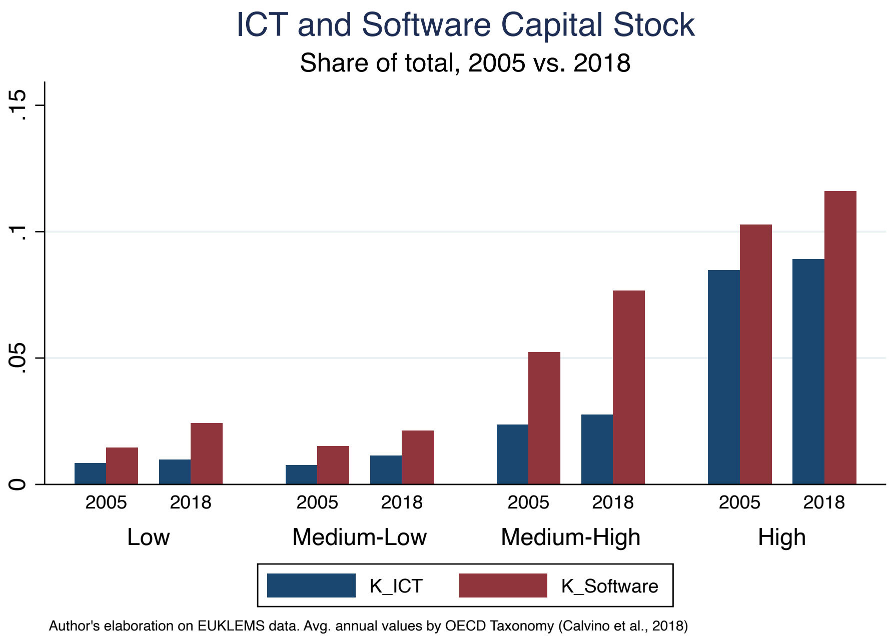

Figure 11: Digital capital stock, by OECD Digital Intensity

Sectors. There is a clear association between the increase in digital intensity and the growing relevance of intangible capital (without the software component). This evidence points out the relevance of the intangibles – such as innovative capabilities and organizational capital – to enhance the sectors' absorptive capacity.

5 Econometric analysis

As a result of the descriptive analysis, a pattern of regionalisation in forward linkages seems to emerge, while the growth of the backward regionalisation ratio seems to be limited. To evaluate the role of digital technologies in affecting these dynamics, an econometric analysis is going to be performed.

In the next paragraphs, I shall present the econometric analysis. The regionalisation indexes represent the dependent variables, while digital capital stock measures are the explanatory variables. A set of control variables is also used to account for other factors that may potentially influence sourcing/destination decisions. A description and the summary statistics for the variable used in the regressions are shown in Table 2.

5.1 Model specification

To explore the potential impact of digital technologies on regionalisation measures, I estimate a panel regression. The baseline equation is the following:

Table 2: Variables description and summary statistics

Variable	Source	Description	N	Mean	SD	Median	Min	Max
BwdRegio	TiVA-OECD	Backward ratio: intra-EU/extra-EU	950	1.95	0.64	1.86	0.48	3.94
bwd_ir	TiVA-OECD	Ratio: Bwd_Intra/TotGrossExport	950	0.19	0.088	0.18	0.027	0.492
bwd_er	TiVA-OECD	Ratio: Bwd_Extra/TotGrossExport	950	0.10	0.04	0.09	0.02	0.32
FwdRegio	TiVA-OECD	Forward ratio: intra-EU/extra-EU	950	4.02	2.21	3.45	0.71	12.06
fwd_ir	TiVA-OECD	Ratio: Fwd_Intra/TotGrossExp	950	0.09	0.06	0.08	0.02	0.63
fwd_er	TiVA-OECD	Ratio: Fwd_Extra/TotGrossExp	950	0.03	0.04	0.02	0.01	0.38
ln_kict	EU-KLEMS	(ln) ICT capital stock, volume (2015 prices)	935	5.56	2.01	5.55	-1.61	10.81
ln_ksw	EU-KLEMS	(ln) Software and Database capital stock, volume (2015 prices)	936	6.13	1.77	6.3	1.59	11.02
ln_ktang	EU-KLEMS	(ln) Tangible capital stock, excluding ICT, volume (2015 prices)	936	9.47	1.5	9.39	5.7	13.04
ln_kintang	EU-KLEMS	(ln) Intangible capital stock, excluding software, volume (2015 prices)	936	7.95	1.73	8.14	3.57	11.75
ln_ulc_sbs	SBS	(ln) ULC: wages/production value	948	-2.01	0.45	-1.99	-3.55	-0.93
size_ent	SBS	No. firms / Avg. No. Firms in NACE division	947	1.97	3.07	0.82	0	20.15
size_emp	SBS	Employees / Total country's employees	950	0.07	0.05	0.06	0.01	0.24
ln_ulc_2	SBS	(ln) Compensation per employee/gross VA per empl.	644	-0.06	1.16	-0.46	-1.59	3.15
ln_costcomp	SBS	(ln) Gross VA per empl. / Avg. personnel cost	653	0.5	0.28	0.42	-0.07	1.52
ln_krd	EU-KLEMS	(ln) R&D capital stock, volume (2015 prices)	936	7.08	2.29	7.45	-1.61	11.65
ln_kip	EU-KLEMS	(ln) Intellectual Property capital stock, volume (2015 prices)	950	8.72	1.77	9.09	5.05	12.12
pavitt		Revised Pavitt Taxonomy, 4 classes						
digint4		OECD Taxonomy of Digital Intensive sectors, 4 classes						
cou_iso3		Country, 3-digit ISO code						
nace		Industry, 2-digit NACE rev. 2 code						

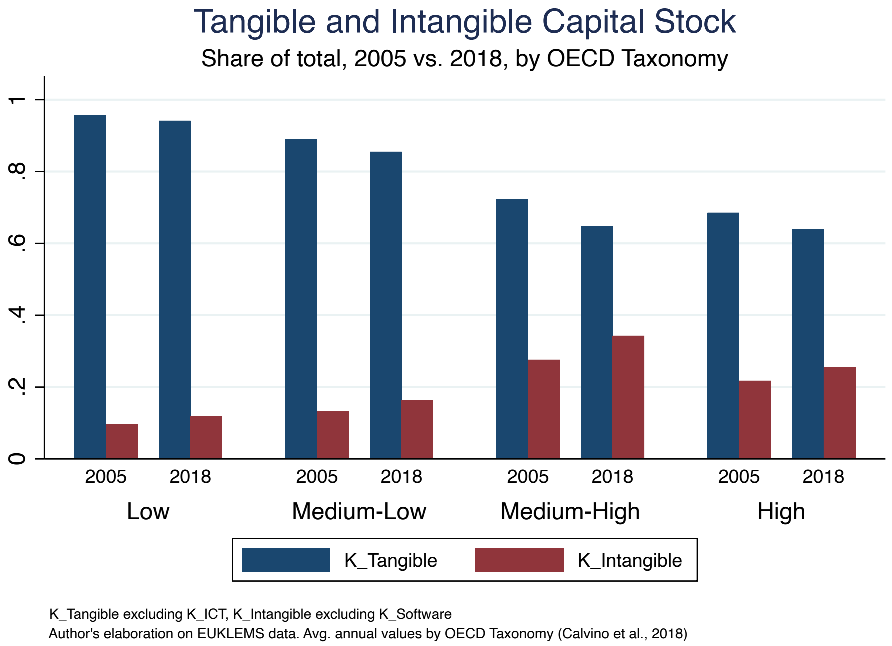

Figure 12: Tangible and Intangible capital stock, by OECD Digital Intensity

$$Regio^k_{i,c,t} = \beta_1 ICT_{i,c,t-1} + \beta_2 Software_{i,c,t-1} + \gamma_1 K^{Tang}_{i,c,t-1} + \gamma_2 K^{Intang}_{i,c,t-1} + \gamma_3 ULC_{i,c,t-1} + \\ + \gamma_4 Size^{Firms}_{i,c,t-1} + \gamma_5 Size^{Empl}_{i,c,t-1} + \tau_t + \sigma_i + \lambda_c + \varepsilon_{i,c,t} \quad (10)$$

The dependent variables are, in turn, the backward ratio ($BwdRegio$) and the forward ratio ($FwdRegio$), denoted by the superscript k for the variable $Regio$. The subscripts i and c identify, respectively, the industry and the country, and t the time unit.

An endogeneity concern may arise, due to the potential reverse causality between regionalisation measures and some explanatory variables (i.e., digital capital diffusion and capital accumulation, both tangible and intangible). In fact, the aim of the paper is to assess the role of those variables in affecting the regionalisation trends, but also the opposite may hold. The prior choice to offshore certain stages of production, or to locate other stages inside the European region, may also affect capital accumulation (European countries are advanced economies where the importance of intangible goods and digital technologies is greater), or determine the labour cost. To account for this potential relationship, all the explanatory variables are lagged by one temporal unit, to avoid simultaneity. Moreover, in the second step of the analysis, all the key explanatory variables are instrumented with an additional time lag, using a Two-Stage Least Square estimator. All the specifications are estimated with the fixed effects (within) estimator, following Wooldridge (2010).

The key explanatory variables are the (log of) ICT capital stock ($ICT_{i,c,t-1}$), and the (log of) software capital stock ($Software_{i,c,t-1}$). As discussed before, the adoption of digital technologies may have a twofold effect on the geography of production. On one side, DTs may help centrifugal forces favouring the connection between different markets (Autio et al. 2021), but on the other side, they may help the reconfiguration of comparative advantages toward a relocation in advanced economies (World Trade Organization 2019). Therefore, a differentiated effect is expected, both between technologies and on dependent variables.

Since intangible capital may have a role in the absorptive capacity of digital technologies, the (log of) capital stock in intangible – excluding the software component – is used (K^{Intang}), along with the measure (in log) of the tangible capital stock, to account for the industry's capital intensity (K^{Tang}).

The labour cost may also play a role in determining the firms' decision regarding the geographical allocation of production. It may also affect decisions in opposite ways: for labour and routine-intensive tasks, the decision to offshore may be driven by the aim of minimising the labour cost, then negatively affecting the regionalisation ratio. On the other hand, the labour cost may also be a proxy for the human capital employed in production. Then, for knowledge-intensive activities, it may be positively correlated with regionalisation, being sectors located upstream in the chains, so the expectations are differentiated on the two dependent variables. Then, to control for the labour factor, we also include the (log of) unit labour cost, computed as the ratio between wages and the industry's total production value ($ULC_{i,c,t-1}$).

To account for the structural aspects, I control for the employment share on the total country's employment ($Size^{Empl}$), and for the number of firms in the industry ($Size^{Firms}$)[10]. Finally, I also include a set of industry, country and time fixed effects.

5.2 Results

Table 3 reports the baseline results of the econometric analysis performed on the full sample, which includes all sectors from from NACE "C" and "J" divisions. The first two columns report the results on the regionalisation indexes - i.e., the $IntraEU/ExtraEU$ ratios - while columns from 3 to 5 use as dependent variables the overall participation and the upstreamness. All estimations are performed with a panel fixed-effects (within) estimator.

The backward ratio shows a negative correlation with digital technologies, both for ICT and software. The magnitude is different: the software impact is three times larger than the ICT effect, both being negative (-0.107 for ICT, and -0.259 for software). The negative association

[10] The variable reports the ratio between the number of firms in the sector and the average number of firms in the same NACE 2-digit division.

Table 3: Fixed-effects panel regression

	BwdRegio	FwdRegio	Participation Backward	Forward	Upstreamness
	(1)	(2)	(3)	(4)	(5)
ICT_{t-1}	-0.107***	0.176***	-0.004	-0.003	0.017*
	[0.023]	[0.05]	[0.003]	[0.003]	[0.01]
$Software_{t-1}$	-0.259***	-0.173**	-0.015***	0.004	0.046***
	[0.04]	[0.085]	[0.005]	[0.005]	[0.018]
K^{Tang}_{t-1}	0.619***	-0.232	0.022**	0.021**	0.022
	[0.072]	[0.154]	[0.009]	[0.008]	[0.032]
K^{Intang}_{t-1}	0.140**	0.131	-0.009	-0.019***	-0.041
	[0.06]	[0.128]	[0.008]	[0.007]	[0.027]
ULC_{t-1}	-0.145	-0.026	-0.022*	0.034***	0.035
	[0.091]	[0.195]	[0.012]	[0.01]	[0.04]
$Size^{Firms}_{t-1}$	0.002	0.026	0.003	0	-0.002
	[0.014]	[0.03]	[0.002]	[0.002]	[0.006]
$Size^{Empl}_{t-1}$	-8.106***	-2.253	0.376**	-0.163	-1.295**
	[1.355]	[2.898]	[0.171]	[0.154]	[0.6]
_cons	-2.509***	4.880***	0.142	0.135*	0.414
	[0.705]	[1.508]	[0.089]	[0.08]	[0.312]
N	950	950	950	950	950

Full sample. Fixed effects within estimator. Year FE included.
$*p < 0.1$, $**p < 0.05$, $***p < 0.01$. SE in parentheses.

between digital technologies and input-sourcing regionalisation means that an increase in digital capital stock is associated with lower inputs provided by European countries-sectors, and a relatively larger contribution of value added coming from outside the region. Digital capital then seems to exert a role in connecting markets, lowering transaction and information costs, and therefore shortening distances for input sourcing. Regarding the forward ratio, there is a positive effect for ICT on output regionalisation, while software exerts a negative effect of approximately the same magnitude, but has opposite signs, thus making the results difficult to interpret.

The results on both the backward and forward ratios should be read in conjunction with the results on the overall participation and sectoral positioning (columns 3 to 5). Software capital shows a negative impact on backward participation: higher values reduce foreign value-added in domestic exports. On the other hand, no significant effects are detected for ICT and for forward participation. With regard to the sectoral positioning, the estimates show a positive impact for both ICT and software on the relative upstreamness of the industry. To understand the dynamics, we shall look at the results for the Revised Pavitt sub-samples (Table 4). The software capital stock has a positive effect on sectoral upgrading through the impact on sectors with high technological opportunities (such as science-based and specialized suppliers, both aimed at introducing innovations for other sectors. Finally, the output of these sectors is used

Table 4: Upstreamness by Revised Pavitt Taxonomy

	SB	SS	SII	SD
	(1)	(2)	(3)	(4)
ICT_{t-1}	0.04	0.027**	-0.007	0.007
	[0.028]	[0.013]	[0.023]	[0.006]
$Software_{t-1}$	0.115**	0.035*	0.027	0.031***
	[0.053]	[0.019]	[0.033]	[0.011]
K_{t-1}^{Tang}	0.202***	-0.134***	-0.104	-0.084***
	[0.073]	[0.038]	[0.086]	[0.029]
K_{t-1}^{Intang}	-0.155**	-0.122***	0.173***	-0.042
	[0.075]	[0.026]	[0.048]	[0.034]
ULC_{t-1}	0.054	0.232***	-0.028	0.025
	[0.104]	[0.053]	[0.069]	[0.035]
$Size_{t-1}^{Firms}$	-0.047	-0.009	-0.038	0.002
	[0.035]	[0.012]	[0.042]	[0.002]
$Size_{t-1}^{Empl}$	-1.519	0.897	-1.429	0.045
	[1.579]	[0.695]	[1.404]	[0.424]
_cons	-0.732	2.772***	-0.039	1.378***
	[0.684]	[0.355]	[1.004]	[0.368]
N	271	271	204	204

Dependent variable: $Upstreamness = Fwd^{part}/Bwd^{part}$
Sample split according to the Revised Pavitt Taxonomy:
SB = Science Based, SS = Specialised Suppliers,
SII = Scale and Inf. Intensive, SD = Supplier Dominated.
Fixed effects within estimator; Year FE always included.
$^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$. SE in parentheses.

as input in supplier-dominated industries, and this may enhance their upstreamness (column 4).

To tackle the issue of endogeneity, a second set of regressions is performed with an IV approach using a Two Stage Least Square estimator. Here, an additional lag is used to instrument all the explanatory variables of the analysis.

Table 5 presents the results of the IV regressions. The first two columns report the results on the regionalisation measures, while columns 3 to 5 the results on the overall participation and upstreamness.

The results remain partially robust to the instrumental variable procedure, confirming the sign and the significance of the effects of digital capital, but with different effects between technologies. On the backward ratio ($BwdRegio$, column 1), the coefficient of the software capital stock remains large and negative (with a value of -0.386), and no significance is detected on ICT. The opposite holds for the forward ratio ($FwdRegio$, column 2): ICT positively affects the forward linkages (with a coefficient of 0.233), while the effect is not significant for software.

Regarding the overall participation, ICT capital negatively affects the overall backward participation, leading to an increase in the upstreamness (0.042), while the effect is not significant for the forward linkages.

Table 5: Fixed effects IV regression (full sample)

			Participation		
	BwdRegio	FwdRegio	Backward	Forward	Upstreamness
	(1)	(2)	(3)	(4)	(5)
ICT	-0.06	0.233***	-0.013***	-0.002	0.042***
	[0.038]	[0.075]	[0.005]	[0.004]	[0.015]
$Software$	-0.386***	-0.056	-0.007	0.004	0.008
	[0.065]	[0.128]	[0.008]	[0.007]	[0.026]
K^{Tang}	0.844***	-0.091	0.048***	0.043***	0.043
	[0.099]	[0.197]	[0.012]	[0.010]	[0.040]
K^{Intang}	0.198**	-0.04	-0.028**	-0.021**	-0.086**
	[0.098]	[0.194]	[0.012]	[0.010]	[0.040]
ULC	-0.936***	0.155	-0.017	0.034	-0.065
	[0.216]	[0.427]	[0.026]	[0.022]	[0.087]
$Size^{Firms}$	0.041	0.111	0.018**	0.002	-0.023
	[0.067]	[0.132]	[0.008]	[0.007]	[0.027]
$Size^{Empl}$	-11.271***	-9.926**	0.946***	0.029	-0.878
	[2.412]	[4.771]	[0.288]	[0.247]	[0.975]
_cons	-6.154***	4.790**	0.028	-0.079	0.46
	[1.046]	[2.069]	[0.125]	[0.107]	[0.423]
N	852	852	852	852	852

All the variables have been lagged by one unit and instrumented with an additional lag. $*p < 0.1$, $**p < 0.05$, $***p < 0.01$. SE in parentheses.

5.3 Robustness and sensitivity analyses

As a robustness check, other sets of regressions are performed. Firstly, the IV fixed effect model is chosen as a baseline model for comparison. Then, the analysis is performed in the manufacturing sub-sample (that only includes NACE "C" industries), and therefore by excluding the NACE "J" division. Thus, I analyse the movements of the ratios' components, which are, respectively, the intra-EU backward (forward) and the extra-EU backward (forward). This analysis provides evidence on which aggregate influences the regionalisation trend. Lastly, to assess the sensitivity of the baseline regression, I change the definitions of some control variables, namely, of: i) the labour factor, and ii) the intangible capital.

Looking at the manufacturing sub-sample (Table 6), the results gain in magnitude and significance on the backward ratio, while confirming the effects on the forward ratio. Digital technologies negatively impact the regionalisation of the backward linkages, with a differentiated effect in magnitude. The software displays a larger impact in reducing the regionalisation of the input sourcing, which is roughly three times the effect of ICT (-0.289 for software, vis à vis -0.091 for ICT). Looking at the overall participation, the results remain robust compared to the full sample results, with a negative correlation between backward and ICT, while no significant effects are detected for the forward linkages and the upstreamness, either for ICT or software.

Regarding the second robustness check, the regionalisation ratio is split into its components,

Table 6: Fixed effects IV regression (manufacturing sub-sample)

			Participation		
	BwdRegio	FwdRegio	Backward	Forward	Upstreamness
	(1)	(2)	(3)	(4)	(5)
ICT	-0.091**	0.229***	-0.019***	-0.006	0.015
	[0.044]	[0.084]	[0.005]	[0.005]	[0.010]
$Software$	-0.289***	0.03	0,000	0.008	0.019
	[0.074]	[0.140]	[0.009]	[0.008]	[0.016]
K^{Tang}	1.036***	-0.055	0.040***	0.032**	-0.026
	[0.118]	[0.224]	[0.014]	[0.013]	[0.026]
K^{Intang}	0.202	0.097	-0.013	-0.006	-0.036
	[0.136]	[0.257]	[0.016]	[0.014]	[0.029]
ULC	-1.000***	0.689	-0.026	0.074**	0.263***
	[0.283]	[0.536]	[0.034]	[0.030]	[0.061]
$Size^{Firms}$	0.066	0.093	0.017*	0.003	-0.01
	[0.086]	[0.163]	[0.010]	[0.009]	[0.019]
$Size^{Empl}$	-9.064***	-9.082	0.919**	-0.402	-0.848
	[3.334]	[6.314]	[0.398]	[0.355]	[0.723]
_cons	-9.070***	4.160*	-0.029	0.03	1.389***
	[1.334]	[2.527]	[0.159]	[0.142]	[0.289]
N	670	670	670	670	670

All the variables have been lagged by one unit and instrumented with an additional lag. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$. SE in parentheses. Year fixed effects always included.

which became, in turn, the dependent variable. This test is to account for the source from which the regionalisation trend arises: is it due to an expansion (reduction) of the intra-EU flows, or to a reduction (expansion) of the extra-EU flows?

Having as a benchmark model the IV regression reported in columns 1 and 4, Table 7 reports the results for the ratios' components. The reduction of the backward regionalisation is due to a shrinking in the numerator, that is, the intra-regional flow, and a simultaneous expansion of the denominator, that is, the extra-EU value added, both driven by the software effect. On the other hand, there is not a clear pattern for the forward components' analyses since both the ICT and software coefficients are small and not significant.

As a sensitivity check, the set of control variables is changed, according to a different definition of them. The results for the backward and forward ratios are shown in Tables 8 and 9[11], where the first column always presents the estimation for the benchmark model.

Concerning the labour factor, which may play a role in determining the choice of geographical allocation of the production, it shall be substituted by a different definition of the unit labour cost and a measure of the sectoral cost competitiveness.

The second measure of the unit labour cost (*clup* in the tables) is defined as the ratio between

[11] Tables with further dependent variables (overall backward and forward linkages, and upstreamness) are available upon request.

Table 7: Fixed-effects IV regression - Ratios' components (full sample)

	Backward			Forward		
	BwdRegio	Intra-EU	Extra-EU	FwdRegio	Intra-EU	Extra-EU
	(1)	(2)	(3)	(4)	(5)	(6)
ICT	-0.06	-0.012***	-0.001	0.233***	-0.002	0.000
	[0.038]	[0.003]	[0.002]	[0.075]	[0.003]	[0.002]
$Software$	-0.386***	-0.023***	0.016***	-0.056	0.008*	-0.004
	[0.065]	[0.006]	[0.004]	[0.128]	[0.004]	[0.003]
K^{Tang}	0.844***	0.076***	-0.028***	-0.091	0.016**	0.027***
	[0.099]	[0.009]	[0.006]	[0.197]	[0.007]	[0.004]
K^{Intang}	0.198**	0.000	-0.028***	-0.040	-0.021***	0.000
	[0.098]	[0.009]	[0.006]	[0.194]	[0.007]	[0.004]
ULC	-0.936***	-0.042**	0.025*	0.155	0.023	0.012
	[0.216]	[0.020]	[0.013]	[0.427]	[0.015]	[0.009]
$Size^{Firms}$	0.041	0.011*	0.006	0.111	0.002	0.000
	[0.067]	[0.006]	[0.004]	[0.132]	[0.005]	[0.003]
$Size^{Empl}$	-11.271***	-0.082	1.029***	-9.926**	0.027	0.002
	[2.412]	[0.221]	[0.149]	[4.771]	[0.167]	[0.097]
_cons	-6.154***	-0.438***	0.466***	4.790**	0.099	-0.178***
	[1.046]	[0.096]	[0.065]	[2.069]	[0.072]	[0.042]
N	852	852	852	852	852	852

All the variables have been lagged by one unit and instrumented with an additional lag.
Columns 1 and 4 show the regionalisation ratios (Intra-EU/Extra-EU).
Year fixed effects always included. SE in parentheses. $*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

the compensation for employee and the gross value added per employee. The source of the data is the EU-KLEMS database for the first component, and Eurostat SBS for the second. The results are shown in the second column of Tables 8 and 9.

The cost competitiveness variable is defined as the ratio between the gross value added per employee and the average personnel cost, both obtained from Eurostat SBS. The results are those in the third columns of Tables 8 and 9.

The intangible capital is going to be split into different measures. The first measure considers only the R&D capital stock (fourth columns), while the last definition is made of the sum of all the intellectual property-related variables. The latter are the intangible variables not included in the national accounts, drawn from EU-KLEMS/INTANProd's intangibles module: industrial design, innovative property, brand, organisational capital, training, and economic competencies. The results are shown in the fifth columns.

Overall, the results remain robust to change in the definition of the control variables, being the effect consistent across specifications, on magnitude sign, and significance.

Table 8: Backward regionalisation - Sensitivity analysis

	(1)	(2)	(3)	(4)	(5)
ICT	-0,06	0,04	0,012	-0,049	-0.064*
	[0.038]	[0.058]	[0.057]	[0.037]	[0.037]
$Software$	-0.386***	-0.334***	-0.385***	-0.283***	-0.374***
	[0.065]	[0.103]	[0.098]	[0.064]	[0.063]
K^{Tang}	0.844***	0.411***	0.291*	1.143***	0.796***
	[0.099]	[0.154]	[0.160]	[0.100]	[0.096]
K^{Intang}	0.198**	0,147	0.275*		
	[0.098]	[0.155]	[0.147]		
ULC	-0.936***			-1.152***	-0.910***
	[0.216]			[0.217]	[0.212]
$clup$		-1.119***			
		[0.328]			
$CostComp$			1.140***		
			[0.372]		
$R\&D$				-0.273***	
				[0.048]	
IP					0.417***
					[0.101]
$Size^{Firms}$	0,041	0.152*	0.148*	-0,024	0,018
	[0.067]	[0.078]	[0.076]	[0.066]	[0.067]
$Size^{Empl}$	-11.271***	-8.859**	-9.600**	-8.316***	-12.777***
	[2.412]	[4.067]	[4.002]	[2.114]	[2.346]
_cons	-6.154***	-1,081	-0,905	-6.725***	-7.618***
	[1.046]	[1.486]	[1.477]	[0.988]	[1.115]
N	852	624	632	852	852

Dependent variable: $BwdRegio = FVADEX\_Intra/FVADEX\_Extra$
Full sample. Year fixed effects always included.
SE in parentheses. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

Table 9: Forward regionalisation - Sensitivity analysis

	(1)	(2)	(3)	(4)	(5)
ICT	0.233***	0.303***	0.261**	0.241***	0.223***
	[0.075]	[0.103]	[0.104]	[0.074]	[0.074]
$Software$	-0.056	-0.258	-0.220	0.039	-0.075
	[0.128]	[0.184]	[0.178]	[0.130]	[0.127]
K^{Tang}	-0.091	-0.611**	-0.517*	0.197	-0.243
	[0.197]	[0.275]	[0.290]	[0.201]	[0.193]
K^{Intang}	-0.040	0.235	0.223		
	[0.194]	[0.278]	[0.267]		
ULC	0.155			-0.071	0.236
	[0.427]			[0.437]	[0.426]
$clup$		0.368			
		[0.586]			
$CostComp$			-0.190		
			[0.672]		
$R\&D$				-0.345***	
				[0.096]	
IP					0.531***
					[0.203]
$Size^{Firms}$	0.111	0.189	0.178	0.042	0.094
	[0.132]	[0.139]	[0.138]	[0.132]	[0.134]
$Size^{Empl}$	-9.926**	-16.616**	-15.903**	-8.932**	-14.600***
	[4.771]	[7.263]	[7.238]	[4.249]	[4.721]
_cons	4.790**	8.466***	7.723***	3.166	2.017
	[2.069]	[2.654]	[2.670]	[1.986]	[2.244]
N	852	624	632	852	852

Dependent variable: $FwdRegio = DVAFEX\_Intra/DVAFEX\_Extra$
Full sample. Year fixed effects always included.
SE in parentheses. $*p < 0.1$, $**p < 0.05$, $***p < 0.01$.

6 Discussion and concluding remarks

In the paper, I try to shed some light on the relationship between the diffusion of digital technologies - here proxied by the capital accumulation in ICT and software - and the European sectoral regionalisation of trade in value-added.

I investigate the industries' input sourcing and their output destination in value added to understand to what extent digital technologies might have affected the trade regionalisation, defined as the relative importance of the intra-EU value-added flows against those originating (destined) from (to) extra-EU countries.

The econometric analysis is carried out on a sample of European countries, those most involved in manufacturing and in international trade. The industries selected are all the sectors from the NACE manufacturing and ICT divisions.

The descriptive analysis highlights an increase over time of the forward regionalisation, while the variability of the backward regionalisation appeared to be more contained. Moreover, the high variability - both between and within indicators - seems to be due to country specificity, rather than to the sector. Nevertheless, the robustness is verified with regard to sectoral, and not country-level, heterogeneity. On the technological side, may be observed a strong increase over time for the software capital accumulation throughout the sectors, while the growth of the ICT stock is smaller. To delve into the dynamics of the ratios and their components, as well as to distinguish the impacts from different factors, an econometric analysis has been carried out.

The econometric analysis, through the use of the fixed effects (within) estimator, allows controlling for several factors affecting the dynamics of the ratios. The analysis is performed on the regionalisation indexes, as well as their components, the overall GVCs' participation, and relative sectoral positioning indicators.

6.1 Main results

After controlling for the role of non-digital tangible and intangible capital, as well as labour cost and industry structure, digital technologies in the form of ICT and software capital stock show a differentiated effect, both within technologies and between indicators, as partially expected.

In the literature review, has been highlighted (Butollo et al. 2022; Antràs 2020) a potential effect in reducing costs and lowering distances of digital technologies. Concerning the input sourcing regionalisation (i.e., the backward ratio), a negative correlation emerges with both ICT and software. Looking at manufacturing, the use of digital capital increases the input sourcing from outside the European region, by reducing the intra-EU flows ($BwdIntra$), and expanding

the extra-EU foreign value-added flows ($BwdExtra$).
The impact is also differentiated in magnitude between technologies: the software reduces input regionalisation with a coefficient three times larger than ICT.

The results are different in sign, magnitude, and significance for the forward participation indicator. The ICT capital is positively associated with the regionalisation of the output of the European sectors, while no significative effect is detected for software. Then, higher use of ICT capital in European sectors leads to a greater proportion of domestic value added in European export, rather than in extra-EU economies.
This result may be explained with a process of sectoral upgrading for European industries, that should allow sectors to source inputs from outside the region and to focus their production on phases with higher value-added, where the use of digital technologies (i.e., ICT) may be relatively more important.
The process of upgrading is also resulting from the estimation for the upstreamness variable, namely, the sectoral positioning. Digital capital is positively correlated with the latter, although only with the ICT capital, being the software coefficient non-significant. Hence, the use of ICT enables sectoral upgrading through the provision of higher value added to the production chain. Moreover, using the sample split according to the Revised Pavitt taxonomy, I detect a positive effect of both technologies on upstreamness for specialized suppliers, a positive effect of ICT for science-based sectors, and a positive effect of software for supplier-dominated sectors.

6.2 Contribution to the literature

From the analyses, three main results arise, consistent with the trend outlined in the literature review and the hypothesis put forward.

The first and main result is the differentiated effect of technology on the two indicators. Digital technologies affect in a different way the trade linkages. From the input sourcing perspective, ICT and software seem to lower transaction costs, easing the coordination across distances, and then potentially contributing to boost the fragmentation of the production. On the other hand, ICT capital is positively correlated with a higher regionalisation of the output destination, the forward linkages. This result seems to outline the upgrading in the specialization of European sectors toward more technological productions, and this is due to sectoral dynamics and specialization. The European industries lower costs by sourcing inputs from outside the region and using them in production. Their output is then reprocessed within the region, adding value, and then exported again, as an intermediate or final good.

Digital capital positively affects the sectors' upstreamness also according to the Revised

Pavitt taxonomy: the coefficients are positive wherever they are significative. Moreover, the impacts on the upstreamness are larger in the sectors with higher technological opportunities, i.e., science-based and specialised suppliers' sectors, aimed at providing innovations to other sectors.

The second result is the differentiated effect between technologies on the same dependent variable. When we look at manufacturing, the software shows a very strong impact on the regionalisation ratio, higher with respect to the ICT component of digital capital. This may be due to the perspective we are considering: the input sourcing, namely the supply of intermediate input.

It seems plausible that software, such as platforms, cloud computing, and digital ecosystems, enables lower coordination and matching costs more than hardware devices, that are included in the ICT capital. Therefore, it is consistent to observe a higher effect of software against physical ICT capital on the input sourcing.

On the other hand, the effect is somewhat different when considering the output destination. Here, following the hypothesis of sectoral upgrading, is the digital (physical) capital that does exert a regionalisation effect for productions that may have a higher capital intensity.

A third result that may be worth mentioning is the differentiated effect between digital and non-digital capital, the latter being both tangible and intangible.

What the results show on the input-sourcing (i.e., the *backward* linkages), is an opposite impact of digital capital - exerting a negative effect on the regionalisation - and the traditional capital, both tangible and intangible, being positively correlated with the increase in the input regionalisation measure. On the other hand, the same non-digital capital variables have a negative sign on the output destination, although the coefficients are not significant. This evidence seems also to be consistent and complementary with those reported by Bontadini et al. (2022) on "nearshoring" and "farsharing" dynamics[12], both related to traditional capital.

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[12] By the term "nearshoring" they refer to the increase in regionalisation of the input, while "farsharing" refers to the globalisation of the output.

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