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Intangible assets and the position of European countries in global value chains*

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Abstract

In this paper, we propose a conceptual and measurement framework to analyze the distribution of intangible assets within and across global value chains (GVCs) and provide novel empirical evidence for the European Union (EU). We shed light on the changing position of four main EU regional areas (Eastern, Southern, Western and Northern countries) in GVCs looking at the changes in the shares of the intangibles assets that their industries (high and low tech manufacturing, and high and low knowledge intensive sectors) account for. We then conduct a structural decomposition analysis to disentangle the trade-related and technology-related drivers responsible for these changes. Our findings reveal that while economic integration within Europe has deepened over the last decades, it has only partially mitigated pre-existing asymmetries in the distribution of intangible assets, with distinct patterns between manufacturing and service industries. Eastern Europe in particular has improved its GVC position in intangible terms although through its growing role as a GVC supplier of manufacturing inputs rather than through an increase in the intangible intensity of its industries. In contrast, Western Europe has consolidated its role as a knowledge supplier in GVCs, increasing the share of knowledge inputs provided by its knowledge intensive sectors.

Keywords: Global Value Chains, Intangibles, Specialisation, Asymmetries.
JEL Codes: O33, O34, F14.

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1 Introduction

Over the past three decades, different views have been proposed regarding the effects of the participation in Global Value Chains (GVCs) by firms, industries and countries, some putting forward an optimistic vision and others a more problematic perspective.

The first stream of contributions has argued that participation in GVCs could drive knowledge diffusion and provide firms with the opportunity to access global markets by specializing in GVC segments (Baldwin and Robert-Nicoud, 2014; Baldwin and Lopez-Gonzalez, 2015; Grossman and Rossi-Hansberg, 2008; Kowalski et al., 2015). This stream of literature has essentially translated the Heckscher-Ohlin-Samuelson (HOS) approach to trade from goods to tasks. According to this view, firms and countries can benefit from specializing in only some segments of the GVC, thus gaining access to global markets and foreign knowledge and then gradually move up the value chain through a continuous upgrading. The second body of contributions has highlighted a more nuanced view also with reference to the EU experience, and in relation to the way in which the process of economic integration has taken place over the last few decades. Evidence has shown that European countries have indeed experienced a significant integration of their productive structures through an expansion and deepening of GVCs, although this process has lost steam in the most recent years (Kowalski et al., 2015). It is, however, far less clear whether and the extent to which this has been accompanied by processes of economic and technological upgrading of more peripheral and less innovative EU regions (Milberg and Winkler, 2011; Bontadini et al., 2024b).

Contributions taking a geo-political approach have also highlighted that the deep changes that occurred over the last few decades in the economic structure of the EU has reinforced previous production and technological hierarchies and only marginally mitigated pre-existing asymmetries and structural gaps within the EU (Celi et al., 2018; Bontadini et al., 2024a). Germany has been identified as a "headquarter economy" in the EU, with Eastern European playing the role of "factory economies", providing low value-added intermediates and remaining at the periphery of production networks (Milberg and Winkler, 2011; Cirillo and Guarascio, 2015; Garbellini et al., 2014; Celi et al., 2018). The persistence of a polarized division of labour within the EU has been analysed also by taking into account the functional specialisation of countries and industries, that is looking at the relevance played by activities with very different knowledge and qualitative contents such as fabrication, managers, R&D and marketing activities (Timmer et al., 2019; Stöllinger, 2021; Bontadini et al., 2024b) and types of foreign direct investments (FDI) associated with these different "functions" (Coveri and Zanfei, 2022).

In parallel with this, the economic literature has devoted growing attention to patents, knowledge, and, more recently, intangible assets, that have been recognized as drivers of productivity and economic growth (Corrado et al., 2022) and as a new source of market power associated with the increasing concentration of the ownership and control of knowledge and data and a substantial reinforcement of the intellectual property regimes (Pagano, 2014; Rikap, 2021). Yet, the potential role of such intangible assets to widen or reduce technological and economic gaps and polarization remains an under-investigated topic. A large part of contributions on the nexus between technology and GVCs have mostly adopted a narrow production perspectives of such a nexus, focusing on the offshorability of labour intensive, low technology production stages and the opportunities offered by automation on the reshorability of some of these production stages, i.e. two cost-cutting and labour-saving strategies (Hijzen and Swaim, 2007; Ottaviano, 2015). However, technology is likely to play a more complex role on the structure and organization of GVCs and this applies in particular to the role played by intangible assets which are likely strengthening the path-dependent nature of knowledge accumulation, and Schumpeterian rents, allowing firms (and countries) to reinforce specific advantages within the value chains (Dosi et al., 1988, 2015). This also resonates with the growing, albeit still scant, literature on the idea of trade in intangibles (Fu and Ghauri, 2021) and "intellectual monopoly" in GVCs (Milberg and Winkler, 2011), finding that the rise of intangible assets within GVCs has led to new sources of market power. All told, the relationship between intangible assets endowments and the country-industries position in GVCs, remains an understudied topic, from a conceptual, methodological and empirical point of view.

Drawing on the OECD ICIO Tables (2023) and intangible asset stock data from EUKLEMS&INTAN-Prod (Bontadini et al., 2023) for the period 2000–2019, this paper contributes to filling this gap by proposing a conceptual and measurement framework to empirically examine the distribution of intangible assets within GVCs and the relative position of each country-industry in Europe.[1] We argue that a country-industry's position within a GVC can be understood as the share of intangible asset stocks it contributes to within that GVC. Its overall position across all GVCs is then measured as a weighted average of these shares, using value-added flows as weights. This approach captures the idea that a country-industry's position in GVCs depends not only on its own technological endowments and trade characteristics, but also on those of the GVCs in which it participates. A key contribution of the paper is the development and implementation of a structural decomposition analysis (SDA) that disentangles the role of the two most important drivers of a country-industry's technological position

[1] Although the measures reflect global production linkages based on the full input–output database, the empirical analysis is confined to European economies. Accordingly, and for ease of exposition, we use the term European GVCs in what follows.

within GVCs: (i) trade-related factors, linked to changes in their economic relevance within GVCs, and (ii) technology-related factors, associated with their endowment of intangible assets. This decomposition enables us to map and characterize the economic and technological positions and trajectories of the industries of the different European countries within GVCs.

Our analysis yields four main findings. First, asymmetries in the GVCs intangible positions of manufacturing industries of different European countries have been shrinking and this is driven by the relocation of manufacturing production activities towards Eastern EU countries, although the bulk of knowledge accumulation has remained in Western and Northern countries. Second, in services, in contrast to manufacturing, pre-existing asymmetries have increased, with an increasing concentration of knowledge assets in Western and Northern EU countries. Third, although intangible intensity has risen across sectors we find heterogeneity in terms of GVC intangible position. Our SDA reveals that, in manufacturing, increases in intangibles per unit of output have been outweighed by a negative trade effect in Western and Northern countries, whereas in services, trade and GVC reallocation have been the main drivers of the change in GVCINT position, with only a modest contribution from the changes in the levels of intangibles per unit of output. Taken together, these results suggest that manufacturing, especially in core European economies, has increased its stock of intangible assets while outsourcing productive activities. In contrast, knowledge-intensive business services have improved their GVC intangible position not only through knowledge accumulation but also by further integrating into GVCs.

While Dimas et al. (2026) and Dimas et al. (2024) have studied intangible assets within a GVC framework using intermediate consumption of intangible-producing services, and Bontadini et al. (2024b) has used intangible assets to qualify GVC participation from a technological point of view, the present contribution is, to the best of our knowledge, the first to propose a conceptual and measurement framework of GVC intangible position based on capitalized asset stocks and to decompose its changes into trade- and technology-related drivers through a structural decomposition analysis. They are also relevant in light of the current revival of national and EU industrial policies and the relocation of production activities as part of the EU's Open Strategic Autonomy, highlighting the importance of the location of knowledge accumulation and not just production.

The remainder of the paper is structured as follows. Section 2 presents the conceptual framework that underpins this methodological and empirical exercise presented in the following sections. Section 3 describes the data sources and indicators used in the analysis. Section 4 provides descriptive evidence based on these indicators. Section 5 outlines the structural decomposition methodology and discusses the main results. Finally, Section 6 offers concluding remarks and policy implications.

2 Theoretical framework and contribution

2.1 Intangible assets and GVC position.

The acknowledgement that innovation and knowledge-based assets are key drivers of economic growth is well established. Economic activities are becoming increasingly intangible, grounded in ideas rather than simply in machines or buildings (Haskel and Westlake, 2017). Based on the seminal work by Corrado et al. (2005, 2009) a framework has emerged to conceptualize and measure intangible assets, complementing what is currently being done within National Accounts – which capture R&D, Software and databases and other intellectual property products[2]–with measures of organizational capital, brand, design, training, and new financial products.[3] A broad literature has ensued from this, linking intangibles to productivity growth (Corrado et al., 2022; Crass and Peters, 2014; Crouzet and Eberly, 2021) and other complementary technologies, especially digital ones (Brynjolfsson et al., 2021), leading to productivity spillovers (Corrado et al., 2017).

Intangible assets have salient economic features that differentiate them from tangible ones. They require large initial sunk costs coupled with very little marginal costs, leading to significant economies of scale; their lack of a physical vessel also makes them partially tradable and difficult to diffuse (Crouzet et al., 2022). This contributes to a significant concentration of intangible assets in few large firms and industries (Bajgar et al., 2021). Some contributions in the literature have therefore linked the accumulation of intangible assets with the growing concentration of profits and the emergence of intellectual monopoly (Rikap, 2021; Durand and Milberg, 2020).

The idea that an uneven distribution of knowledge affects the distribution of value added is in line with what the GVC literature has often called the "smile curve" (Mudambi, 2007; Shin et al., 2012; Kaplinsky, 2015) and the broader notion of functional specialisation (Stöllinger, 2021; Coveri and Zanfei, 2022; Bontadini et al., 2024b; Timmer et al., 2019). The core idea here is that value added, technology and innovation capabilities are concentrated at the two ends of GVCs: in the upstream business functions and stages such as R&D and design, and downstream ones such as marketing and distribution; this functional division of knowledge-based activities within GVCs maps quite nicely into the assets identified in the intangible framework described above. These issues have been at the centre of a vast strand of literature, largely stemming from innovation and development studies, that have

[2] These are often computed as a residual in national accounts and include artistic originals and mineral explorations

[3] For a detailed discussion of what these assets entail and how stocks are compiled we refer the interested reader to Bontadini et al. (2023) and (Bontadini et al., 2024a).

conceptualised different forms of GVC governance, position, and upgrading (Gereffi et al., 2005; Giuliani et al., 2005; Morrison et al., 2008). This stream of works has looked at the accumulation of technological capabilities–and knowledge more broadly–as a key driver of countries, industries and firms' ability to upgrade by shifting position both along and across GVCs.[4]

Our work speaks to a growing, albeit still scant, strand of literature that has looked at the nexus between GVCs and technology. In fact, despite the relevance played by knowledge and technology assets within GVCs, the literature on this research area is still at an early stage. Specifically, only a handful of contributions, to the best of our knowledge, have explicitly studied intangible assets and GVCs. Marcolin et al. (2017) focus on a subset of intangible assets, organisational capital, and provide novel evidence on its positive relationship with GVC participation. Moving the analysis forward, Jona-Lasinio et al. (2019) link intangible assets and GVC participation, finding a positive link between knowledge-based capital and GVC participation and value added appropriation. Alsamawi et al. (2020) find that total intangible capital accounts for a relatively large share of income in manufacturing GVCs and that this share has increased between 2005 and 2015 in OECD countries. Jaax and Miroudot (2021), following Chen et al. (2017, 2018), compute intangible assets as an unmeasured residual and explore the importance of trade openness and intellectual property rights to harness higher returns on investment. Fu and Ghauri (2021) using an array of data on intellectual property and different modes of value added capture study how trade in intangibles within GVC significantly affects existing trade imbalances among countries. Doan et al. (2024) have studied the impact of participation in GVCs on innovation looking at the case of Vietnamese small and medium enterprises, finding a positive effect on the introduction of product innovation. Bontadini et al. (2024b) use intangible assets, along with patents intensity, to qualify country-industries' GVC participation from a technological point of view and to study its relationship with functional specialisation. Most recently, Dimas et al. (2026, 2024) have also investigated intangible assets within a GVC framework. They build on the framework of Corrado et al. (2005) and use data on the *intermediate consumption* of intangible-producing knowledge intensive services, rather than properly capitalised assets. Following on from this stream of literature the present contribution moves from the idea that looking at the distribution of intangible assets along GVCs can be informative of a country's position, in technological terms, within the GVCs in which it participates. We do so by developing a measure of GVC intangible position, which is the outcome of a country-industry's own intangible intensity and GVC integration, and of that of the other country-industries in

[4] This literature has put forward several definitions of upgrading, a review of which is well beyond the scope of this contribution, that includes both economic, technological and social aspects.

the same GVC. We discuss our conceptual and measurement framework in detail in Section 2.2.

2.2 Conceptual framework

We start from the premise, in line with the GVC literature discussed above, that a country-industry's position in a GVC can be captured by the share of knowledge and capabilities it controls within that GVC and that this in turn can be understood in terms of the intangible capital stocks accumulated. Country-industries participate in several GVCs, so their overall position within the international production network can be measured as the average share of intangibles that they account for across the GVCs in which they participate. This is what we will call *GVC intangible position* (or GVCINT), in the remaining part of the paper.

Let us now qualify the notion of GVCINT position in more detail. First, position is a *relative* concept that depends on other country-industries' intangible intensity in each GVC it participates in and the importance of that GVC for the country-industry. Keeping this in mind, we can think of four components of a country-industry GVC position, which we clarify taking the Italian textile industry as an example:

1. A country-industry's own intangible intensity – e.g. the stock of intangible capital that the Italian textile industry deploys per unit of output.

2. A country-industry's importance as a supplier within a given GVCs – e.g. the Italian textile industry will contribute to the French textile sector more than to the Polish automotive industry and it will therefore occupy a more prominent position as a supplier.

3. The intangible intensity of the GVC – e.g. the French textile industry will require more intangible assets per unit of final output than Spanish food and beverage but less than the German automotive industry. Given a level of a country-industry's intangible intensity, its position will be, all other things equal, more prominent in less intangible intensive GVCs. In our example, the Italian textile will therefore have a relatively more prominent position as intangible supplier of the Spanish food and beverage GVC, rather than the French textile.

4. A GVC's importance for the country-industry – e.g. the French textile sector is a more important buyer for the Italian textile than the Spanish food and beverage and will therefore be more important for the Italian textile's overall GVC position, i.e. *across* all GVCs to which it participates.

Translating these into dynamic terms, a country-industry can improve its GVC position through any of the four channels above:

1. By increasing its intangible intensity – i.e. by increasing the stock of intangibles it uses to produce its output.
2. By increasing its importance as a supplier– i.e. by becoming a larger supplier of value added within the GVC; this can be achieved by increasing the qualitative content of the inputs produced for the other GVC partners but also by becoming a more competitive supplier through cost reducing strategies.
3. Through a decrease in the intangible intensity of other suppliers in the GVCs in which it participates – e.g. if suppliers within the French textile GVC reduce their stock of intangibles (and therefore reduce the French textile GVC's overall intangible intensity), the relative position of the Italian Textile will improve.
4. By reallocating its GVC participation towards other GVCs in which it accounts for a larger share of intangibles – e.g. if the Italian textile industry shifts its participation from French textile to a less intangible intensive GVC, say the Spanish food and beverage, this will also improve its GVC position through this "reallocation mix" effect.

This framework allows us to isolate both *technology* (Terms 1 and 3) and *trade* components (Terms 2 and 4)[5], which the literature on GVC has identified as key drivers of GVC position (Fu and Ghauri, 2021; Durand and Milberg, 2020; Bontadini et al., 2024b; Delera and Foster-McGregor, 2023). Furthermore, we also identify both *own* (Terms 1 and 2) and *relative* components (Terms 3 and 4). Focusing on this distinction, it is important to consider the broader implications of the activation of the four different drivers of the GVC intangible position of country-industries in terms of technological upgrading and economic development. Terms 1 and 2 (country-industries' own components) above have in fact a rather univocal interpretation: if a country increases its own intangible intensity or its importance as GVC supplier this is beneficial for its GVC intangible position and prospects of economic and technological upgrading. In contrast, terms 3 and 4, which are the relative counterparts of 1 and 2, do not have a straightforward interpretation in terms of a country-industry upgrading. Our framework suggests that a decrease in the intangible intensity of the GVC a country participate in (Term 3) will, in relative terms, improve its position within that

[5] While we label these components as trade-related, they capture deeper dynamics related to the relocation of production and shifts in the sectoral specialisation of country–industries within GVCs.

GVC. Similarly, Term 4 implies that if a country reallocates its GVC participation towards less intangible intensive GVC, this will, in relative terms, also improve its intangible GVC position. It is not obvious, however, that either of these channels would be conducive to countries' economic and technological development. In fact, the literature on the relationship between a country-industry performance and its partner's technological intensity has yielded nuanced results (Fu and Gong, 2011; Delera and Foster-McGregor, 2023; Bontadini et al., 2024b; Marcolin et al., 2017). It is nonetheless important to identify the mechanisms underlying a country-industry's improvement in its GVC intangible position. This theoretical framework–which we formalise and quantify in Section 5–allows us to do just that, by mapping country-industries GVC position in terms of intangibles, its changes, and the underlying drivers thereof.

3 Data and indicators

We leverage data on the stocks of intangible assets and inter-country input-output (ICIO) tables. The focus on European economies is justified by a few reasons. First, the EU is one of the most regionally integrated economies (Bontadini et al., 2025) and Eastern Europe has seen an unprecedented access to the EU and the World economy. Second, the EU rests on the Single Market granting freedom of movement of goods, services and knowledge, while also pursuing cohesion policy objectives to manage differences in economic outcomes across the continent. Third, the EU industrial policies are facing a double challenge: strengthening its technological capabilities and providing a secure access to key goods and technology in light of the recently changed geopolitical scenario; continuing to persue its cohesion policy objectives. In the light of all this, it becomes crucial to understand where knowledge-based assets are accumulated within the European continent and where countries are positioned along GVCs in terms of knowledge production.

Databases The analysis merges different data sources. First, the inter-country input-output (ICIO) data from the OECD Release 2023 at the country-industry level. The dataset covers 77 countries and 45 industries from 1995–2020.

Second, data on intangible assets are retrieved from the EUKLEMS & INTANProd database (Bontadini et al., 2023), which covers 30 countries and 42 industries from 1995 to 2021 in the 2024 Release. It provides detailed information on intangible assets investment and stocks, including national accounts intangible assets (R&D, software and database, and other intellectual property products (OIPP)) as well as non-national accounts estimates

(Brand, Organizational Capital, Design, and New Financial Products (NFP))[6]. It is important to note that the EUKLEMS & INTANProd data only covers EU countries, the UK, the US and Japan. We therefore have to treat all other countries as if they did not produce any intangible assets. This is of course a limitation of our approach, but it is mitigated by our focus on European countries and by the fact that the majority of value added in European value chains is supplied from within the EU itself (Bontadini et al., 2025), or the other countries included in EUKLEMS & INTANProd data.

Some industries in the EUKLEMS&INTANProd database are reported at a more aggregated level than those in the ICIO 2023 classification. To ensure consistency, we aggregate the ICIO 2023 industries to align with the EUKLEMS&INTANProd industry structure[7]. As a result, our final dataset covers 33 industries across 23 countries.[8]

Finally, we opt to use stocks at current prices[9] instead of flows measures of intangible assets to capture intangible assets accumulated over time. This is consistent with our aim of building a measure that captures a country-sector's contribution to the knowledge content of final production from a GVC perspective.

Indicators We aim to capture the position, in terms of knowledge stocks, of country-industries with respect to all GVCs they participate, that is their contribution to the overall knowledge stock accumulated in the GVCs. In order to measure such contribution we start from the standard input-output framework[10]:

$$\hat{V}X = \hat{V}(I-A)^{-1}\hat{F} = \hat{V}B\hat{F} \tag{1}$$

where $\hat{V}$ is a diagonalized vector of value-added per unit of output, B is the Leontief inverse, accounting for all direct and indirect linkages connecting all countries and industries, and $\hat{F}$ is a diagonalized vector of final demand satisfied by each country-industry. The global income matrix identifies country-industries on the rows and GVCs on the column identified

[6] The data from the EUKLEMS & INTANProd database is in national currency at current prices, while the data coming from ICIO is in U.S. dollars at current prices. Therefore, we convert the former into U.S. dollars by taking the nominal exchange rate from the OECD.

[7] The industry cross-walk used for this harmonization is presented in Table A.1 in Appendix A.

[8] Although the EUKLEMS&INTANProd database includes the EU27 plus the UK, we exclude countries that do not report data on intangible assets. The final list of countries, along with their regional classification, is shown in Table A.2.

[9] Constant prices would arguably be a better option to perform inter-temporal comparisons. However, ICIO tables are currently available only at current prices, we therefore opt to preserve consistency and perform our analysis with all variables at current prices.

[10] Concerning notation, we refer to matrices with upper-case letters, and vectors with lower-case letters. Vectors are always column ones, when we refer to a row vector we use the transpose of the column vector, which we identify with $'$. Vectors that are diagonalized are reported as matrix with $\hat{}$.

by the country-industry *of completion*.[11]

In this standard setting, $\hat{V}B\hat{F}$ shows where value added is sourced and where it is activated by final demand (whose main components are household consumption, government consumption, and gross fixed capital formation).

If we replace the diagonalized vector of value added with one containing the stock of intangible assets per unit of output, we obtain the $\hat{I}B\hat{F}$ matrix:

$$\hat{I}B\hat{F} = \begin{pmatrix} i_a b_{aa} f_a & i_a b_{ab} f_b & i_a b_{ac} f_c \\ i_b b_{ba} f_a & i_b b_{bb} f_b & i_b c_{bc} f_c \\ i_c b_{ca} f_a & i_c b_{cb} f_b & i_c c_{cc} f_c \end{pmatrix} \tag{2}$$

$\hat{I}B\hat{F}$ is a matrix that combines a diagonalized vector of intangible stock per unit of output ($\hat{I}$), with the usual Leontief inverse and a diagonalized vector of final demand (B and $\hat{F}$, respectively). Each element of this matrix is a country-industry's contribution to each GVC, in intangible terms. For example, $i_b b_{ba} f_a$ represents the intangible stock in b that contributes to final production reaching completion in GVC a. It follows that each column of this matrix can be interpreted as the stock of intangible assets that contribute to the production of each GVC.[12]

In order to understand the importance (and therefore position) of each country-industry (on the rows) with respect to each GVC (on the columns), we can compute equation 2 in relative terms. To do this, we look at the share of total intangible stock that each country-industry accounts for in each GVC. This means dividing each cell of the IBF matrix by the column total:

$$\mathrm{IBF_{sh}} = \hat{I}B\hat{F} \cdot \mathrm{diag}\left(\frac{1}{\iota' \cdot \hat{I}B\hat{F}}\right)$$

Where ι' is a summation row vector of appropriate dimensions. $\mathrm{IBF_{sh}}$ is a square matrix providing information on how much each country-industry contributes in intangible terms to each GVC. For instance, taking the simplified example from Equation 2, the first element of the matrix would be:

[11] The column perspective of equation 1 identifies what Pasinetti (1973) refers to as vertically integrated subsystems, which we refer to as GVCs, in this work. To illustrate, a country-industry perspective would consider output of a the textile industry by including the production of both intermediate goods (say yarn) and final goods (say t-shirts). In contrast, the GVC perspective would only consider final goods, but also include all inputs provided by other industries, e.g. chemicals to dye the fabric, design services to develop the model of the t-shirt and so forth.

[12] This approach is in line with measures of employment within GVCs as developed by the OECD itself that have become standard in the literature (Pahl et al., 2022; Fontagné et al., 2024). It shares with these contributions the proportionality assumption that a country-industry participates with the same intensity in intangible to all GVCs.

$$\frac{i_a \cdot b_{aa} \cdot f_a}{i_a \cdot b_{aa} \cdot f_a + i_b \cdot b_{ba} \cdot f_a + i_c \cdot b_{ca} \cdot f_a}$$

This is the intangible contribution of country a to, in this case, the production of GVCs reaching completion in country a itself, divided by the total amount of intangible that is involved in the GVC production.

This measure will therefore capture, in a bilateral way, how important each country-industry is with respect to each GVC it contributes to.

In order to understand a country-industry's overall position in terms of intangible assets (across all GVCs it contributes to), we move from bilateral (country-industry with respect to GVCs) to country-industry level measures that inform us on its average importance with respect to all the GVCs it contributes to. To do this, we take the average across the columns of the IBF_{sh} matrix –this is, across all the GVCs that the country-industry contributes to–, weighted by how much of the country-industry's value-added is absorbed by each GVC. In other words, we are giving more importance to GVCs that absorb a large share of country-industries' value added and are therefore, more important markets. We retrieve these weights from the global income matrix ($\hat{V}B\hat{F}$ as defined above) as shares of the row sum of the same matrix:

$$\text{VBF}_{\text{sh}} = \text{diag}\left(\frac{1}{\hat{V}B\hat{F} \cdot \iota}\right) \cdot \hat{V}B\hat{F}$$

Where ι is a summation column vector of appropriate dimensions. Using elements of VBF_{sh} as weights [13] to compute a row mean of IBF_{sh} will yield a country-industry measure of the importance, in intangible terms, that each country-industry has, on average, across all GVCs it contributes to.

Therefore, our final measure of the country-industry contribution to intangible stocks is given by the following equation:

$$GVCINT_{ci} = \text{IBF}_{\text{sh}} * \text{VBF}_{\text{sh}} \cdot \iota = \underbrace{\hat{I}B\hat{F} \cdot \text{diag}\left(\frac{1}{\iota' \cdot \hat{I}B\hat{F}}\right)}_{\text{Intangible GVC participation (col share)}} \odot \underbrace{\text{diag}\left(\frac{1}{\hat{V}B\hat{F} \cdot \iota}\right) \cdot \hat{V}B\hat{F}}_{\text{Income share (row share)}} \cdot \iota \tag{3}$$

Equation 3 computes the average share of intangible stocks of country-industry ci to value chains. Therefore, $GVCINT_{ci}$ is a column vector of $Nx1$, where N is the number of country-industries. We refer to this as the country-industry *GVC intangible position*, as it captures the average position, in terms of intangible share, that a country-industry occupies

[13] note that VBF_{sh} sums up to one along the rows

across all the GVCs to which it participates: the higher the value, the stronger its position in terms of intangible asset supply.

Naturally, these measures can be computed both with and without domestic linkages. Since our interest lies here primarily with a country-industry's GVC position we focus here only on foreign linkages. To give the intuition of what this measure captures, it is useful to make an example. Let's consider again Italy's textile sector; our measure would capture the share that our sector of interest accounts for of total intangible stocks engaged in production for each foreign value chain (e.g. Germany's automotive sector, France's textile, the UK's computer services etc.). This would be the first element of equation 3. It would then average this across all value chains weighting these by how much value added of Italy's textile is absorbed by each foreign GVC. So, for example if Italian textile industries contributes significantly to the French textile industry and rather little to the German automotive sector, this would be properly reflected in our weighting approach, through the second element of equation 3.

4 Intangible position in European GVCs

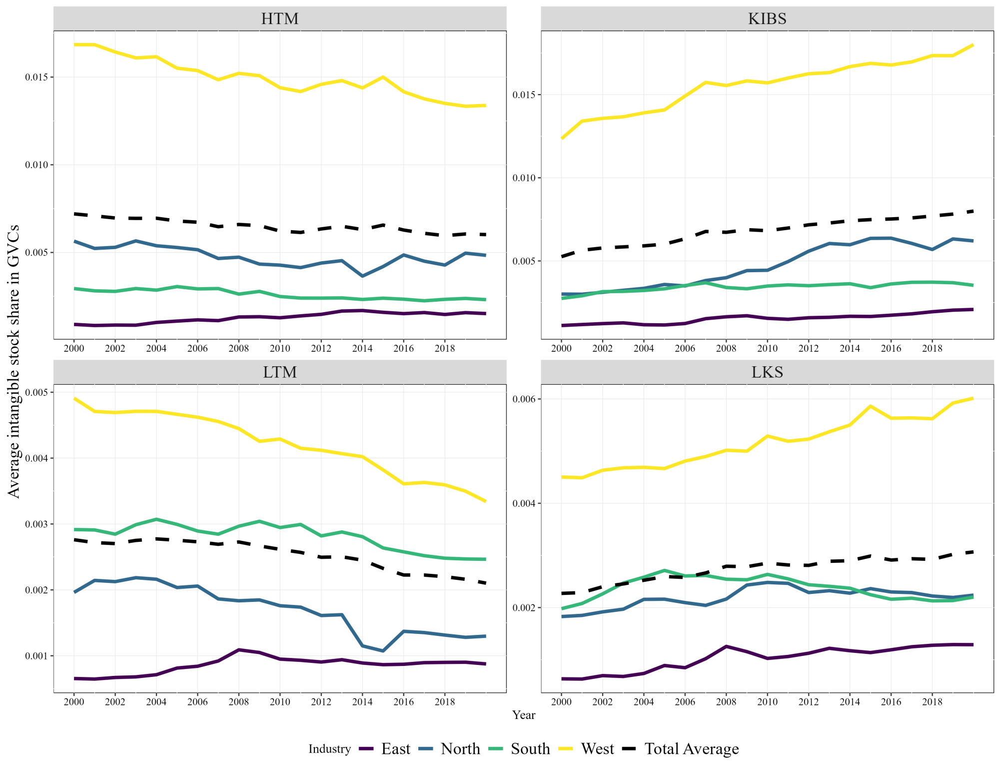
In this section, we present the results of our indicator. Figure 1 shows the trends in GVCINT by macro industries and regions in Europe.[14] Looking at the dynamics of the GVCINT indicator, Figure 1 shows rather different patterns both geographically and sector-wise.

First, high-tech manufacturing (HTM) and knowledge intensive business services (KIBS) account for the lion's share of intangibles in European GVCs.[15] Second, these two macro sectors are, however, following opposite trends. At the beginning of our period, HTM industries were the main producers of knowledge, but their share has been decreasing over time, while KIBS have been growing. This is true especially for the Western and Northern countries, as well as for the EU aggregate. This pattern along with reflecting the on-going process of tertiarization reveals that services have become a very relevant player in EU economies not only in terms of VA generation but also in terms of knowledge generation (also a result of a process of outsourcing of knowledge intensive activities from manufacturing to service suppliers).

[14] We consider the following macro-regions: West (Austria, Belgium, France, Germany, Luxembourg, the Netherlands, Ireland and the UK, North (Finland, Denmark and Sweden), South (Italy, Spain and Greece) and East (Romania, Hungary, Slovakia, Slovenia, Czechia, Latvia, Lithuania and Estonia). Concerning macro-sectors, we follow the OECD classification, see Galindo-Rueda and Verger (2016), of industries based on R&D intensity. For simplicity, we refer to high technology services as knowledge intensive business services (KIBS) and to low technology services as low knowledge services (LKS). Table A.3 shows the classification.

[15] Note that the graphs have different scales for the two top panels compared to the two bottom panels

Figure 1: Average total intangible stock share in GVCs (foreign, intangible stock at current prices)



Notes: The figure reports average shares of intangible stocks along GVCs, over the 2000–2019 period. We compute an unweighted average of GVCINT by macro-region and industry.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

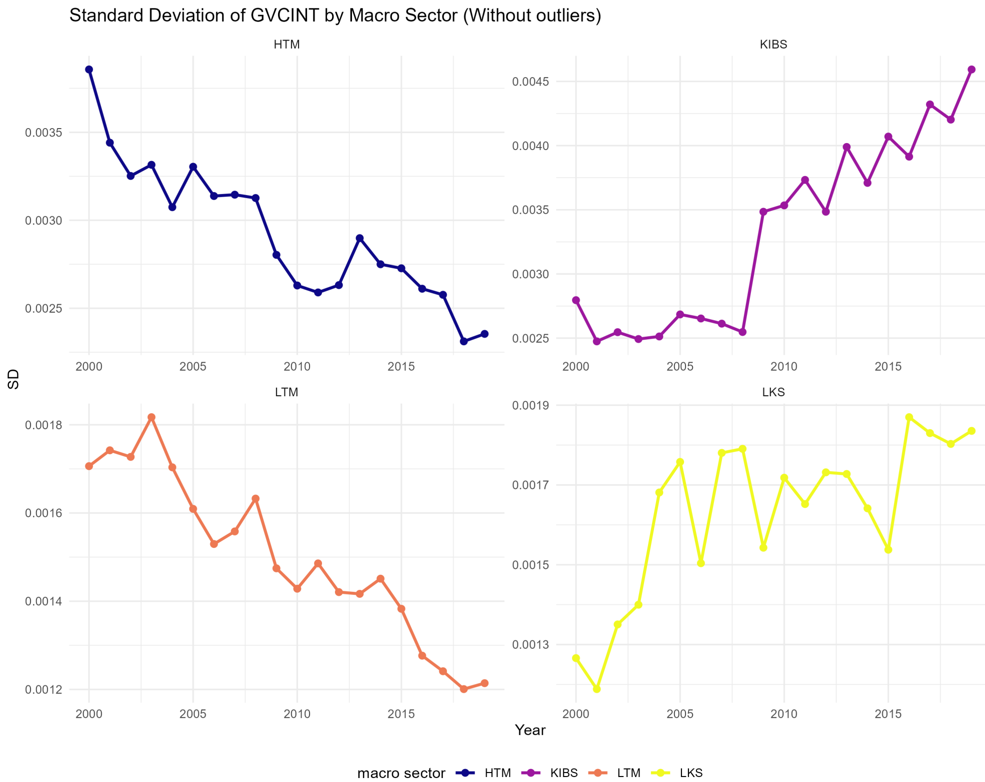
Figure 1 also highlights difference in patterns across EU regions. While it is true that Eastern countries account for very small shares of intangible assets, this is also the only region experiencing an increase in GVCINT across all macrosectors.[16] In contrast, the share

[16]A general feature that emerges from the Figure is that GVCINT takes rather small values, at least at the aggregate level. While this may seem counter-intuitive, it reflects a characteristic of the measure. First, GVCINT is a weighted average of each country-industry's intangible share (the first term in equation 3) across all GVCs, weighted on the share of value added absorbed by each GVCs (the second term in equation 3). A country–industry may play a significant role in providing intangible inputs to a particular value chain, while that same value chain may absorb a very small share of the country-industry's value added, receiving therefore a small weight when computing GVCINT. We find evidence of this, which we discuss in the Appendix. Overall, the two terms of equation 3 are only modestly correlated to one another (see Figure B.1) and when we find evidence of negative assortative matching at the ends of the distribution. To illustrate, Tables B.1 and B.2, look at the German pharmaceutical sector and the French computer and electronic sector respectively and find that the value chains that account for large shares of intangible absorb small shares of its value added. Vice versa, the German pharmaceutical industry accounts for small shares of total intangibles in the value chain that absorb the majority of its value added. This negative assortative matching means that small values of the first term of equation 3 receive large weights, explaining why GVCINT takes small values, even when country–industries exhibit substantial intangible intensity in specific segments of global value chains.We report only two illustrative examples that are sufficient to convey the empirical regularity of interest. All additional results confirm the same qualitative relationship and are therefore not included for the sake of space. However, they are available upon request.

of intangibles of HTM industries has remained stable in Northern Europe and decreased in Western and Southern Europe. This also applies to low-tech manufacturing sectors (LTM), suggesting that all EU regions, barring the East, have experienced a decline (or stagnation) in the intangible share of their manufacturing industries within European GVCs. This has led to a reduction of the asymmetries in the geographical distribution of GVC intangible shares. In contrast, in all regions there has been an increase in the shares of intangibles accounted for by services, although the gap between the "intangible contribution" provided by Western European service industries and the contribution of the tertiary sectors of the other regions has been widening. It is also worth pointing out that in less knowledge intensive services Eastern European countries have reduced their distance with respect to Southern European ones.

Figure 1 has already provided some hints on the dynamics of asymmetries among the different macro-regions regarding the contribution they provide to European GVCs in terms of intangibles. In order to explore further whether recent changes in GVC positions have affected the level of asymmetry in the control of intangible assets along European GVCs, Figure 2 plots the evolution of the standard deviation of our GVCINT indicator by macro-sector. The figures shows in the case of the manufacturing industries a significant reduction over time in the dispersion of the GVC shares, while the opposite occurs in the case of services. This reflects of course the differences in trends discussed previously. It is also worth noting that KIBS and HTM have much higher levels of dispersion suggesting that the distribution of intangible assets is particularly uneven in these sectors.

Figure 2: Standard deviation of GVCINT.



Notes: The figure reports standard deviation of the average shares of intangible stocks along GVCs, over the 2000–2019 period. Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

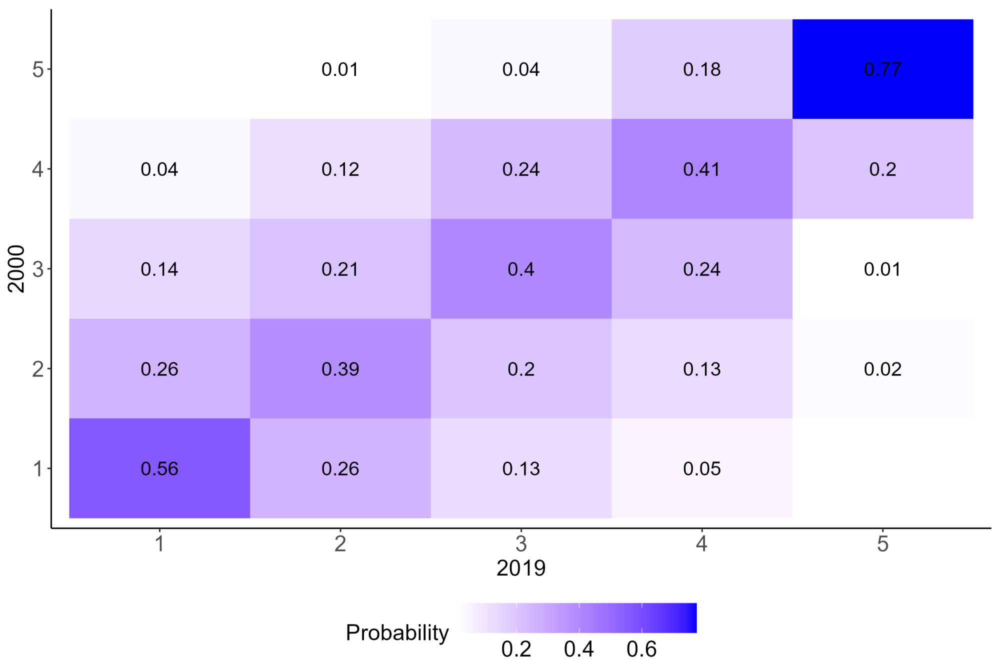
Further insights on the changes occurred in the distribution of intangible assets within the EU value chains can be obtained by looking in Figure 3 (considering the whole economy) and 4 (distinguishing among the four macrosectors) at the extent to which country-industries have moved – between 2000 and 2019 - with respect to our GVCINT indicator, across the different quantiles of the distribution.[17] The transition matrix in Figure 3 shows that the top of the distribution is quite stable, while some reshuffling takes place at the bottom and, especially, in the middle. For example 20% of country-industries that were in the second quintile in 2000 have moved up by 2019. At the top of the distribution 77% of country-industries have retained their position, while at the bottom only 56% have remained in the last quantile by 2019.

These patterns reflect some similarities but also differences between manufacturing and

[17] To analyze mobility over time, we construct a Markov transition matrix based on our GVCINT measure. For each year, we classify country-industries into quintiles according to their GVCINT values. We then compute the probability of transitioning from one quintile to another by calculating the share of country-industries that moved from a given quintile in 2000 to each quintiles in 2019. Specifically, for each initial quintile in 2000, we compute the proportion of country-industries that transitioned to each destination quintile in 2019. This results in a transition matrix where rows represent the starting quintile in 2011, columns represent the destination quintile in 2019, and the row probabilities sum to one.

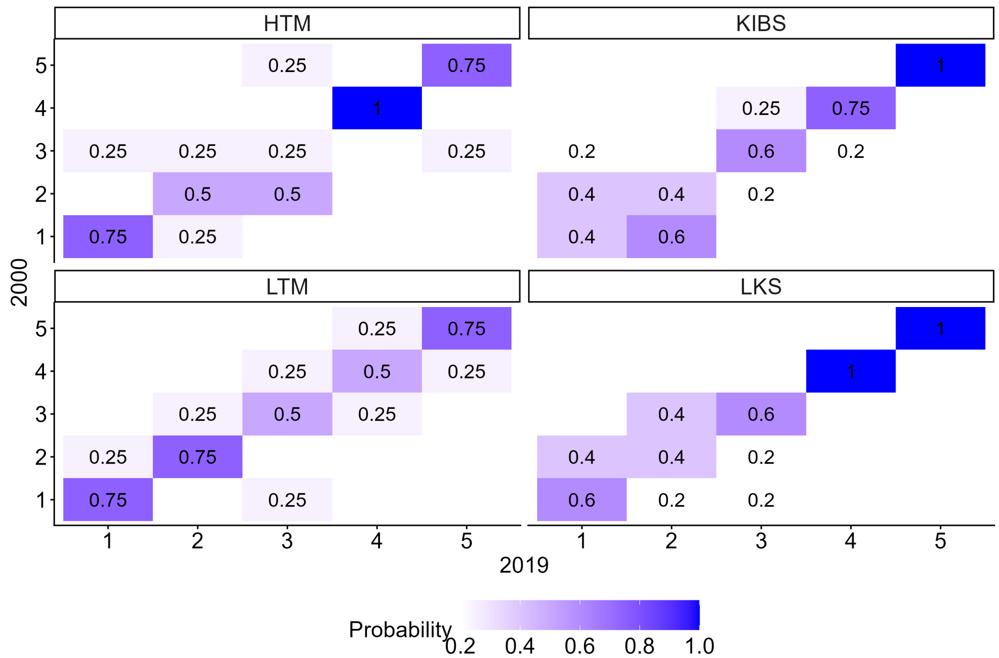
service industries (see Figure 4). While in all macrosectors some changes are observable in the middle of the distribution, in services there is no change in ranking at the top of the distribution. Leaders in terms of GVC intangible shares have not lost any position over the observed time period. In contrast, at the bottom of the distribution we observe less persistence in services than in manufacturing, indicating some shifting from the first to second quartile. Combined with the evidence from Figure 2, this suggests that, while some reshuffling is indeed taking place at the lower end of the distribution, the growing polarisation in GVC intangible position in services is driven by country-industries at the top of the distribution further consolidating their dominant position.

Figure 3: Transition matrix between quintile of GVCINT.



Notes: The figure reports the probability of transition from quintile x in t_0 to quintile y t_1 conditional the initial quintile category. The period of analysis refers to 2000–2019.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

Figure 4: Transition matrix between quintile of GVCINT by macro sector.



Notes: The figure reports the probability of transition from quintile x in t_0 to quintile y t_1 conditional the initial quintile category. The period of analysis refers to 2000–2019.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

All in all, the evidence discussed thus far paints a rather nuanced picture. High-tech manufacturing is confirmed to be a significant supplier of intangible capital in European GVCs, but it has been overtaken by KIBS. At the same time, the technological contribution provided by the two macro-sectors also exhibit different regional patterns and dynamics: the share of intangibles accounted for by Eastern European HTM industries increased at the expenses of the contribution provided by HTM industries of more technologically advanced areas (Western and Northern area) and this has contributed to a reduction of the level of knowledge asymmetry across country-industries as shown by the evidence contained in Figures 2. Services, especially KIBS, have consolidated their importance as knowledge suppliers in GVCs; however, this structural shift has been accompanied by an increasing role played by KIBS of Western and Northern countries that has contributed to reinforcing pre-existing asymmetries, as shown in Figure 2 and in the high stability at the top of the distribution in the transition matrices Figures 3 and 4, respectively. Understanding what is driving these heterogenous patterns is not trivial. As discussed in section 2, the GVC intangible position measured by our GVCINT indicator is inherently relative: it is driven not only by a country-industry's own characteristics but also by how it compares to others within each GVC, both in terms of intangible intensity and trade linkages. It therefore appears relevant to further explore the movements of each of the four components of our measure, discussed in section 2.2, to disentangle their role in driving changes in GVC intangible shares. To this we now turn in the following section.

5 Drivers of GVC intangible position: Structural decomposition

5.1 Structural decomposition of GVC intangible position

In order to decompose our measure of GVC intangible share, we start again from equation 3, omitting the symbol ˆ for simplicity:

$$GVCINT_{ci} = \underbrace{IBF \cdot \text{diag}\left(\frac{1}{\iota' \cdot IBF}\right)}_{\text{Intangible GVC participation (col share)}} * \underbrace{\text{diag}\left(\frac{1}{VBF \cdot \iota}\right) \cdot VBF}_{\text{Income share (row share)}} \cdot \iota = \text{IBF}_{\text{sh}} * \text{VBF}_{\text{sh}} \cdot \iota \tag{4}$$

Bearing in mind that both I and F are diagonalized vectors that only have one value for each column (and zero everywhere else), the first term can be rewritten as:

$$IBF \cdot \text{diag}\left(\frac{1}{\iota' \cdot IBF}\right) = IB \cdot F\,\text{diag}\left(\frac{1}{\iota' \cdot IBF}\right) = IB \cdot \text{diag}\left(\frac{1}{\iota' \cdot IB}\right) \tag{5}$$

Note the second term in Equation 5 – $F \cdot \text{diag}\left(\frac{1}{\iota' \cdot IBF}\right) = \text{diag}\left(\frac{1}{\iota' \cdot IB}\right)$ – can be interpreted as the GVC's total final output divided by the GVC's total intangibles, i.e. the inverse of the GVC's intangible intensity. This means that we are comparing a country industry's own intangible intensity in a given GVC, IB – which depends on: (i) the country-industry's own intangible stock per unit of output I (ii) its importance in the GVC, captured by B – with the GVC's total intensity in intangibles, $\text{diag}\left(\frac{1}{\iota' \cdot IB}\right)$. So, in line with our discussion in section 2.2, our measure GVCINT is the product of four elements:

$$\begin{aligned} GVCINT &= \underbrace{I'}_{\text{Intang. stock}} * \underbrace{B}_{\text{GVC linkages}} * \underbrace{\text{diag}\left(\frac{1}{\iota' IB}\right)}_{\text{GVC intang. intensity}} * \underbrace{VBF_{sh}}_{\text{GVC reallocation}} \\ &= I * B * Ish * Vsh \end{aligned} \tag{6}$$

Equation 6 allows to identify the four channels through which country-industry's GVC intangible position can improve and provides a more concise writing of each term. Changes over time, between $t0$ and $t1$ in GVCINT can therefore be decomposed in terms of changes of each of its component. The key intuition is that to measure the contribution to change of each term we look at the change occurring in that term keeping all other terms fixed. Naturally, whether we use $t1$ or $t0$ as reference period will affect the decomposition results. To deal with this, the literature on input-output analysis has traditionally resorted to taking the geometric average of the two polar opposite decompositions (Miller and Blair, 2022; Dietzenbacher and Los, 1998), which in our case yields:

$$\begin{aligned}
\Delta GVCINT = GVCINT^{t1} - GVCINT^{t0} = \\
= \underbrace{0.5\big(\Delta I\, B^{t0} Ish^{t0} Vsh^{t0} + \Delta I\, B^{t1} Ish^{t1} Vsh^{t1}\big)}_{\text{Intang. stock}} \\
+\underbrace{0.5\big(I^{t1}\, \Delta B\, Ish^{t0} Vsh^{t0} + I^{t0}\, \Delta B\, Ish^{t1} Vsh^{t1}\big)}_{\text{GVC linkages}} \\
+\underbrace{0.5\big(I^{t1} B^{t1}\, \Delta Ish\, Vsh^{t0} + I^{t0} B^{t0}\, \Delta Ish\, Vsh^{t1}\big)}_{\text{GVC intang. intensity}} \\
+\underbrace{0.5\big(I^{t1} B^{t1} Ish^{t1}\, \Delta Vsh + I^{t0} B^{t0} Ish^{t0}\, \Delta Vsh\big)}_{\text{GVC reallocation}}
\end{aligned} \tag{7}$$

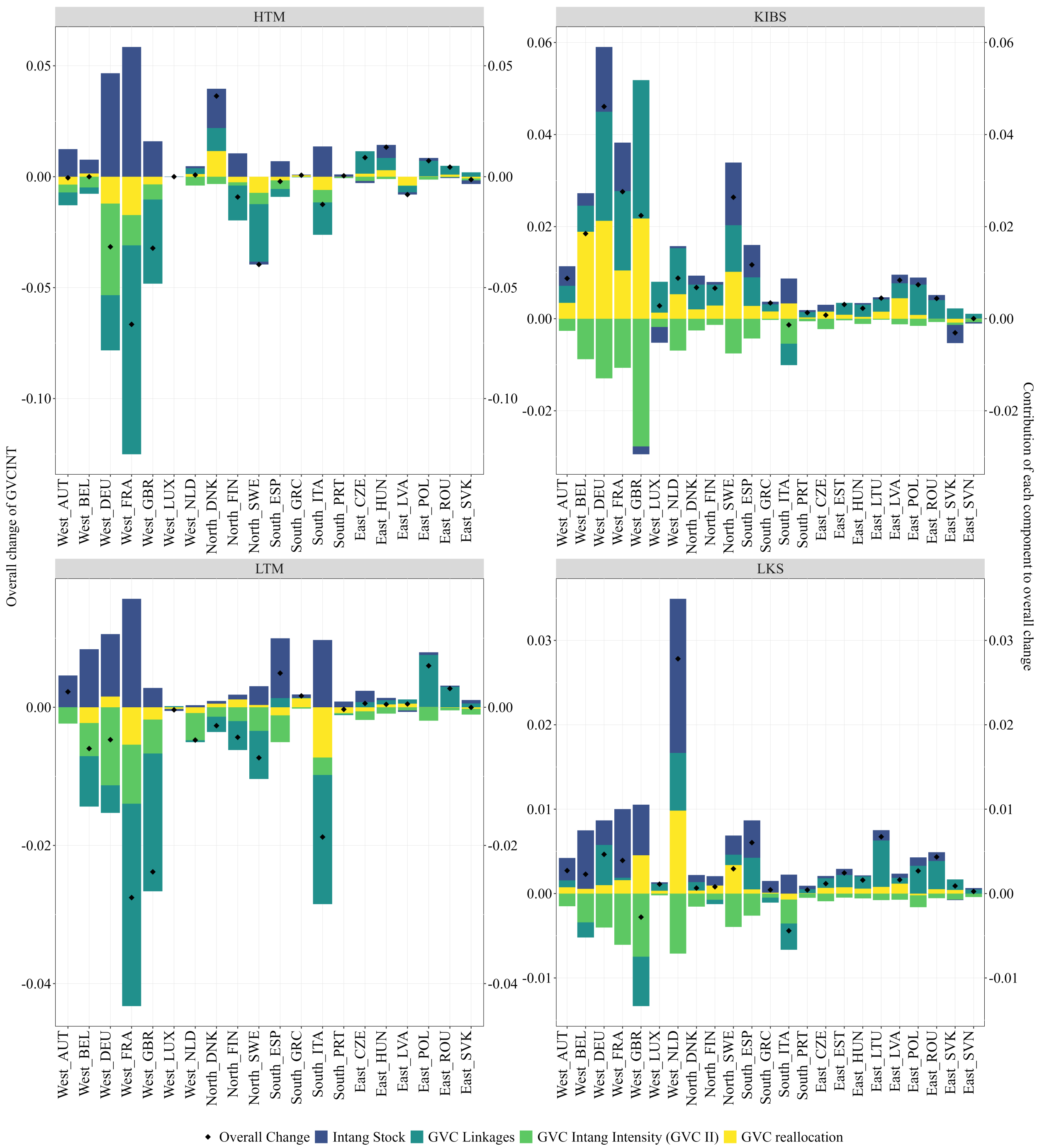
Terms 1 and 2 (*Intangible stock* and *GVC linkages*, respectively) are the first two channels that refer to country-industries' own intangible intensity and GVC linkage position, respectively. Terms 3 and 4, (*GVC intangible intensity* and *GVC reallocation*, respectively) reflect the two relative components discussed in our theoretical section, i.e. the intangible intensity and importance in value added terms of the GVCs to which a country-industry participates.

In what follows, we will analyze the drivers of the change in our GVCINT measure across macro sectors and regions.

5.2 Drivers of GVC intangible position in European GVCs

This section presents the decomposition results for the period 2000–2019. Figure 5 illustrates the contributions of each component to the overall change in GVCINT by macro-sector and country.

Figure 5: Decomposition results by macro sector and country



Notes: Dots refer to overall changes in the GVCINT measure and the columns the contribution of each driver. The results are expressed in absolute terms (i.e. weighted by the divisa index). Aggregations across countries and industries have been performed using as weights the relative importance within GVCINT changes.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

In line with what is shown in Figure 1, we observe a significant contrast between manufacturing and services. The left hand side panels of Figure 5 decompose changes in GVCINT for manufacturing industries and shows that Western and Southern countries have seen their GVC intangible position – the overall change is identified by the dot – reduce in the period 2000–2019. This has been mainly driven by a negative contribution of the GVC linkages component. In other words, manufacturing industries in Western and Southern Europe have lost relevance as suppliers of value added in European GVCs which has decreased the share of intangibles they account for. This has only been partially offset by an increase in the intangible intensity component, meaning that despite their reduced importance as suppliers Western and Southern manufacturing industries have consolidated their role as intangible producers. In contrast, Eastern European countries have improved their GVC intangible position mainly through an increase of the share of value added they supply to GVCs. These opposite patterns explain the convergence we observed in previous evidence (see Figure 1 and 2).

Turning to services, Figure 5 shows that trade linkages have contributed to the growth of GVCINT, in particular for knowledge intensive services, across most of the countries as a result of an overall process of tertiarization, as reflected by the growing share of value added supplied by services across GVCs, confirming what Lopez Gonzalez et al. (2019) have labeled as "globalization's third unbundling", which involves services. Furthermore, increases in intangible intensity have positively contributed to the change of the GVCINT indicator, especially in Northern and Western countries contributing to strengthening the dominant position of their service industries in GVCs, especially with reference to the role of KIBS.

As we have argued in Section 2.2, intangible position is a relative concept meaning it depends on the level of intangible investments of other countries participating in the same GVC, as captured by the third term of our decomposition in equation 7. If a GVC's intangible intensity increases while a country-industry's own intangible intensity does not, its GVC intangible position will deteriorate. We know that, overall, intangible intensity has grown across the board. All things being equal, this produces a negative effect on countries' GVC intangible position. This is reflected in the overall negative contribution of GVC intangible intensity in Figure 5.

The fourth term of our decomposition, captures reallocation across GVCs, i.e. whether a country-industry has shifted its GVC participation towards GVCs in which it accounts for a larger (smaller) share of intangibles, which improves (deteriorates) its GVC position in intangible terms. Here again we find a divergent pattern between manufacturing and service industries. The former has seen a mostly negative contribution of the GVC reallocation component as a result of their increasing integration with GVCs in which they supply a smaller share of total intangibles. The opposite is true for services instead, where the GVC reallocation component is mostly positive, especially for Western KIBS industries. These two trends are coherent with the emerging role of services in GVCs. Manufacturing industries have linked into intangible intensive GVCs with prominent KIBS suppliers, which has decreased, in relative terms, their GVC intangible position. For KIBS, the opposite has occurred: as a growing share of their value added has fed into less intangible intensive manufacturing GVCs their GVC intangible position has improved in relative terms.

All in all Figure 5 delivers the following key messages regarding the effects of the increasing EU integration (via GVCs) on the distribution and control of intangibles. First, manufacturing activities have relocated from the West to the East as we can see in the positive contribution of GVC linkages for Eastern countries, which is instead negative for the rest of the EU. This relocation of production activities has determined some redistribution also of knowledge assets. Second, knowledge stock accumulation has remained concentrated in Western and Northern countries. Third, there has been a substantial shift of knowledge asset accumulation within GVCs, from high-tech manufacturing to service industries with the KIBS sectors overtaking the high-tech manufacturing industries as knowledge suppliers of GVCs. Fourth, intangible stock and GVC linkages have emerged as the main components explaining the overall change in GVCINT over the period covered by our analysis.[18] In particular the *trade* component has been a key driver of changes in the distribution of intangible assets in GVCs with distinct dynamics across manufacturing and services. In the manufacturing sector, the growth of the intangible intensity of industries located in Northern and Western countries has only partially compensated the relocation of production activities from Western, Southern, and Northern Europe towards Eastern countries. In contrast, in KIBS both intangible intensity and GVC linkages have strengthened the predominant position of Western and Northern countries.

In light of the predominance of GVC linkages and intangible stock components in explaining changes in GVCINT, we perform an ANOVA with Tukey's Honestly Significant Difference (HSD) post-hoc test to examine whether the observed differences across regions and macro-sectors are statistically significant (see Appendix C).[19]

The results of the tests are shown in Figures 6 and 7. For intangible stock, Figure 6 shows significant differences mainly between Western and Eastern countries, particularly in high- and low-tech manufacturing, and low knowledge intensive sectors, with Western economies generally displaying higher values (which means that the mean changes in this

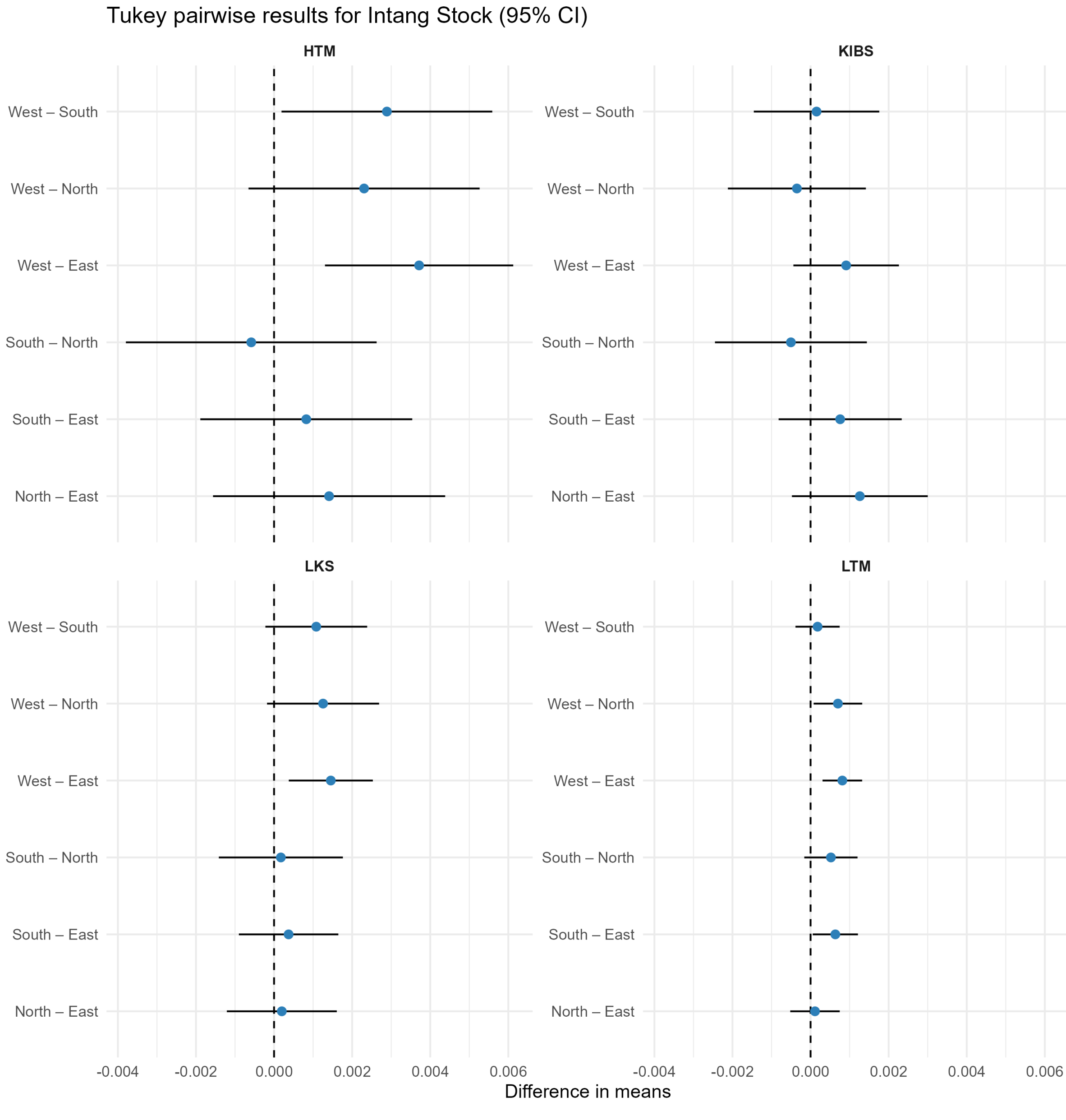
[18]This is confirmed in Tables B.4 and B.5, which report the distribution of the decomposition shares. Both the mean and median of GVC linkages (38.58 and 36.15, respectively) and intangible stock (23.24 and 21.19) are consistently the highest among the four components, whereas GVC intangible intensity and GVC reallocation account for much smaller contributions.

[19]The Tukey HSD test is particularly suitable in this context, as it allows pairwise comparisons between group means while correcting for multiple testing, reducing the risk of finding false positives when comparing multiple groups.

component are larger for Western countries than for the Eastern ones). In all these sectors, the West–East divide is strongly significant, confirming a persistent gap in the accumulation of intangible assets. Interestingly, there are no significant pairwise regional differences in the average change of the intangible stock component, across all macro-sectors, for KIBS.

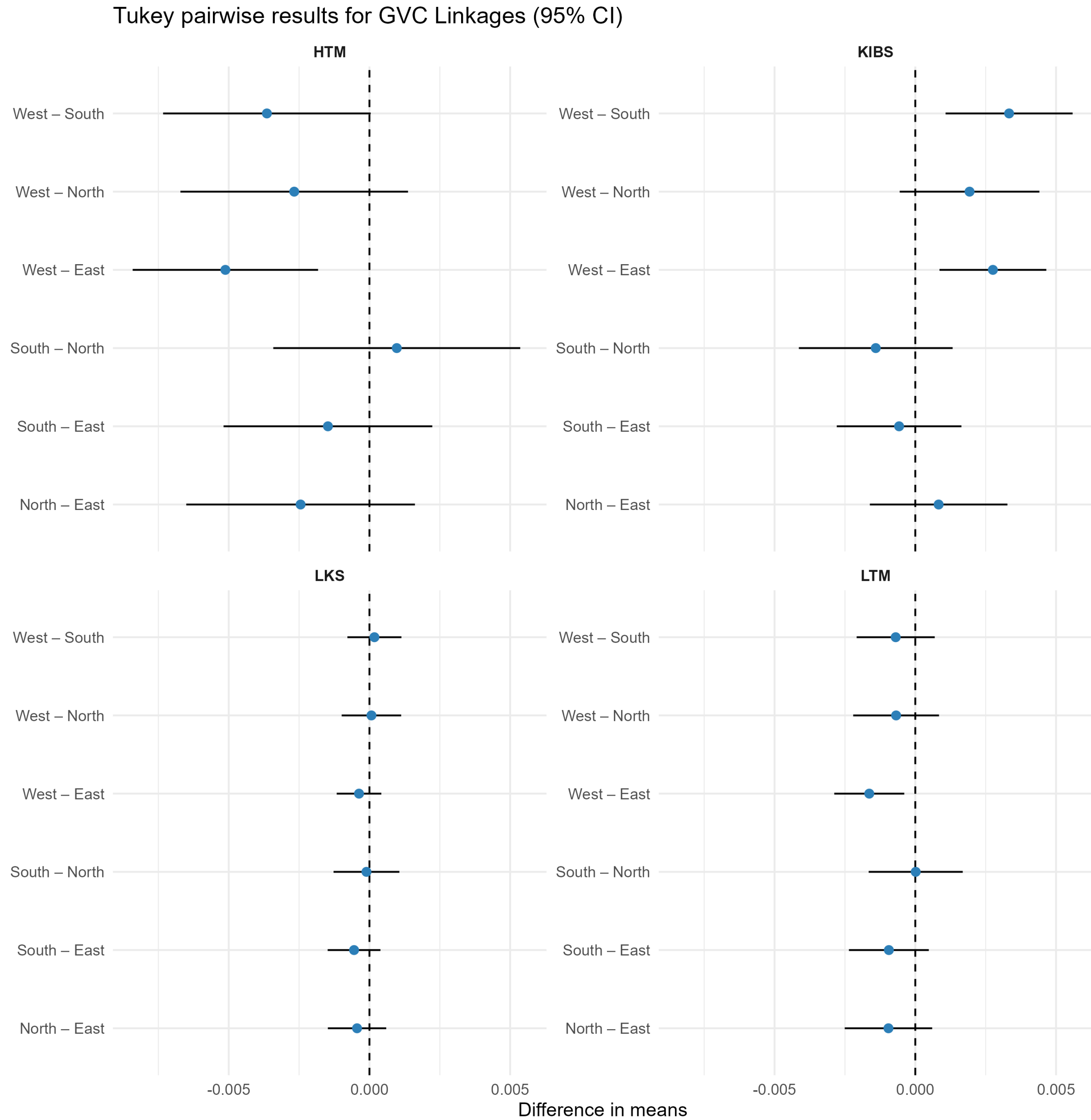
Figure 7 reports the results of the Tukey HSD test on pairwise differences between macro regions in the average change of the GVC linkages component (i.e. the trade component). The largest and most statistically significant differences are observed between Western and Eastern Europe in both high- and low-tech manufacturing, as well as in KIBS, with Eastern economies showing mean changes in the trade component that are larger than Western countries in manufacturing but smaller in KIBS. No significant differences emerge for low knowledge-intensive sectors and for all other pairwise combinations.

Figure 6: Results from the ANOVA – Tukey HSD Test on Intangible Stock (Term 1)



Notes: This figure displays the Tukey-adjusted pairwise mean differences in the intangible stock component (Term 1) between European regions, separately by macro sector. Each dot represents the estimated difference in means, with horizontal lines indicating the 95% confidence interval. The vertical dashed line marks zero, corresponding to no difference between regional means. Estimates are rescaled $\times 10^6$ *for readability. A difference is statistically significant if its confidence interval does not overlap zero.*
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

Figure 7: Results from the ANOVA – Tukey HSD Test on GVC linkages (Term 2)



Notes: This figure displays the Tukey-adjusted pairwise mean differences in the GVC linkages (Term 2) between European regions, separately by macro sector. Each dot represents the estimated difference in means, with horizontal lines indicating the 95% confidence interval. The vertical dashed line marks zero, corresponding to no difference between regional means. Estimates are rescaled $\times 10^6$ for readability. A difference is statistically significant if its confidence interval does not overlap zero.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

6 Conclusion

In this paper we have proposed a new conceptual and measurement framework to empirically examine the distribution of intangible assets in the European industry adopting a GVC perspective. To achieve this, we have developed a new indicator, GVCINT, designed to quantify the share of intangible assets that EU country-industries accounts for in GVCs. We have then decomposed this measure through a structural decomposition analysis to capture the underlying drivers of the changes in the indicator across sectors and regions.

The methodological framework proposed has proved to be effective with respect to the main analytical objectives of this contribution. It also shows some potentialities (to be explored in future research) in the direction of adopting a more granular examination of the role played by the different types of knowledge assets within GVCs and of extending the geo-economic coverage of the study. The SDA allowed us to disentangle the main drivers fuelling the redistribution of knowledge assets within European GVCs and in particular between the main EU geo-economic areas.

The empirical evidence has shown a rather composite picture regarding the levels and dynamics of the asymmetries in knowledge assets across the EU countries and industries as a result of the increasing integration of the EU production system. A first important finding consists of the divergent trajectories shown by manufacturing and service industries. In the case of the manufacturing industries a partial reduction of the asymmetries in the GVCINT position has taken place, in particular between Eastern and Western-Northern EU industries; the SDA has clearly shown that this process of convergence has mainly been driven by a process of relocation (offshoring) of production capacities from the Northern and Western to the Eastern EU geoeconomic areas. On the contrary, in the case of services, such a process of redistribution of intangible position has not taken place. In fact, service sectors have increased their relevance as input providers and generators of intangible assets in all GVCs. This role has been played in particular by the Knowledge-Intensive Business Services that have become the macro-sector accounting for the largest share of intangible assets in the EU value chains (overtaking the high tech manufacturing sectors). At the same time, KIBS have also emerged as a new key source of technological asymmetries within GVCs and across the EU being increasingly concentrated in the most technologically advanced EU areas. In fact, over the last two decades Northern and Western EU countries have further strengthened their dominant position as producers and diffusers of knowledge-based inputs. Vice versa, Eastern Europe's GVC upgrading has been primarily driven by its increased role as a supplier of manufacturing inputs for the other EU industries, and only to a limited extent by an increase of the intangible intensity of their production activities. This evidence confirms previous contributions (Celi et al., 2018; Bontadini et al., 2024b) indicating that the rapid integration of Eastern EU industries into European GVCs has occurred mainly through the supply of medium and low-cost manufacturing inputs, rather than through a real process of technological and "functional" upgrading.

All in all, our empirical findings raise serious concerns regarding the long-term outcomes of the ongoing process of integration of the EU production space and in particular challenges the assumption that GVC participation per se, and in the case of all EU regions, automatically leads to upgrading toward knowledge-intensive activities. The evidence presented in this contribution shows on the contrary that EU industries that entered GVCs at the beginning of the new millennium with low level of knowledge stocks (per unit of output) have –-after a couple of decades– largely remained in a subordinated position, while knowledge leaders have maintained or strengthened their dominance through the control of the most critical and strategic knowledge assets. Thus, despite deeper integration of Eastern European economies into European value chains in HTM, core European countries have reinforced their position as key producers of intangible assets, driven by the positive contribution of knowledge accumulation to their GVCINT.

This evidence has several important implications for industrial (and science and technological) policies especially the ones designed at an EU level targeting green and digital transitions as well as the ones aiming at increasing European strategic autonomy and technological sovereignty (Edler et al., 2023; Caravella et al., 2024). All these policies rely heavily on raising the level and quality of the EU production and technological capabilities and on an acceleration in the accumulation of intangible assets. While there are no doubts concerning the necessity of increasing the level of intangible assets accumulated in the EU as a whole, a key aspect which should be taken into due consideration has to do with the distribution of such assets, a distribution affected both by market and profit driven forces related to the GVCs expansion and deepening and by the effects of national and EU policies. This in turn raises a potential and critical policy trade-off-dilemma, and namely between the objective of strengthening areas (country-industries) of excellence especially in the emerging technological fields – likely leading to an increase in the level of technological asymmetry and polarization – and the objective of achieving a more even distribution of knowledge assets and technological capabilities within and across the EU value chains (Monastiriotis and Gamtitsulashvili, 2025). Addressing such a dilemma is beyond the scope of this paper. However, whatever choice will be made it should be based on sound evidence on the level and dynamics of technological asymmetries fueled by the expansion and deepening of GVCs. The methodological framework proposed in this contribution might represent a useful tool for such a scope.

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Appendices

A Data

Table A.1 shows the industries disaggregation in the EUKLEMS&INTAN-Prod and the ICIO Tables from the OECD.

Table A.1: Comparison of Industry Classifications between EUKLEMS&INTANProd 2023 and ICIO Release 2023

Group	EUKLEMS&INTANProd 2023		ICIO Release 2023	
	Code	**Industry name**	**Code**	**Industry name**
A	A	Agriculture, forestry and fishing	A01_02	Agriculture, hunting, forestry
			A03	Fishing and aquaculture
B	B	Mining and quarrying	B05_06	Mining and quarrying, energy producing products
			B07_08	Mining and quarrying, non-energy producing products
			B09	Mining support service activities
C10-C12	C10-C12	Manufacture of food products; beverages and tobacco products	C10T12	Food products, beverages and tobacco
C13-C15	C13-C15	Manufacture of textiles, wearing apparel, leather and related products	C13T15	Textiles, textile products, leather and footwear
C16-C18	C16-C18	Manufacture of wood, paper, printing and reproduction	C16	Wood and products of wood and cork
			C17_18	Paper products and printing
C19	C19	Manufacture of coke and refined petroleum products	C19	Coke and refined petroleum products

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Group	**EUKLEMS&INTANProd 2023**		**ICIO Release 2023**	
	Code	**Industry name**	**Code**	**Industry name**
C20	C20	Manufacture of chemicals and chemical products	C20	Chemical and chemical products
C21	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	C21	Pharmaceuticals, medicinal chemical and botanical products
C22-C23	C22-C23	Manufacture of rubber and plastic products and other non-metallic mineral products	C22	Rubber and plastics products
			C23	Other non-metallic mineral products
C24-C25	C24-C25	Manufacture of basic metals and fabricated metal products, except machinery and equipment	C24	Basic metals
			C25	Fabricated metal products
C26	C26	Manufacture of computer, electronic and optical products	C26	Computer, electronic and optical equipment
C27	C27	Manufacture of electrical equipment	C27	Electrical equipment
C28	C28	Manufacture of machinery and equipment n.e.c.	C28	Machinery and equipment, nec
C29-C30	C29-C30	Manufacture of motor vehicles, trailers, semi-trailers and other transport equipment	C29	Motor vehicles, trailers and semi-trailers
			C30	Other transport equipment

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Group	**EUKLEMS&INTANProd 2023**		**ICIO Release 2023**	
	Code	**Industry name**	**Code**	**Industry name**
C31-C33	C31-C33	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	C31T33	Manufacturing nec; repair and installation of machinery and equipment
D	D	Electricity, gas, steam and air conditioning supply	D	Electricity, gas, steam and air conditioning supply
E	E	Water supply; sewerage, waste management and remediation activities	E	Water supply; sewerage, waste management and remediation activities
F	F	Construction	F	Construction
G	G	Wholesale and retail trade; repair of motor vehicles and motorcycles	G	Wholesale and retail trade; repair of motor vehicles
H	H	Transportation and storage	H	Transportation and storage
I	I	Accommodation and food service activities	I	Accommodation and food service activities
J58-J60	J58-J60	Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	J58T60	Publishing, audiovisual and broadcasting activities
J61	J61	Telecommunications	J61	Telecommunications
J62-J63	J62-J63	Computer programming, consultancy, and information service activities	J62_63	IT and other information services
K	K	Financial and insurance activities	K	Financial and insurance activities

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Group	EUKLEMS&INTANProd 2023		ICIO Release 2023	
	Code	**Industry name**	**Code**	**Industry name**
L	L	Real estate activities	L	Real estate activities
M	M	Professional, scientific and technical activities	M	Professional, scientific and technical activities
N	N	Administrative and support service activities	N	Administrative and support services
O	O	Public administration and defence; compulsory social security	O	Public administration and defence; compulsory social security
P	P	Education	P	Education
Q	Q	Human health and social work activities	Q	Human health and social work activities
R	R	Arts, entertainment and recreation	R	Arts, entertainment and recreation
S	S	Other service activities	S	Other service activities
T	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use

Table A.2 shows the countries that are included in the analysis together with their geographical classification (i.e. to which macro region they belong: East, North, South or West Europe). By contrast, Table A.3 shows the sectors that are included in the analysis together with their classification into macro sectors following the OECD classification of industries based on R&D intensity (Galindo-Rueda and Verger, 2016).

Table A.2: Classification of countries in macro regions

ISO code	Country	Macro Region
CZE	Czech Republic	East
EST	Estonia	East
HUN	Hungary	East
LTU	Lithuania	East
LVA	Latvia	East
POL	Poland	East
ROU	Romania	East
SVK	Slovakia	East
SVN	Slovenia	East
DNK	Denmark	North
FIN	Finland	North
SWE	Sweden	North
ESP	Spain	South
GRC	Greece	South
ITA	Italy	South
PRT	Portugal	South
AUT	Austria	West
BEL	Belgium	West
DEU	Germany	West
FRA	France	West
GBR	United Kingdom	West
LUX	Luxembourg	West
NLD	Netherlands	West

Table A.3: Classification of industries in macro sectors

ISIC Rev 4 Code	Industry name	Macro Sector
C20	Manufacture of chemicals and chemical products	HTM
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	HTM
C26	Manufacture of computer, electronic and optical products	HTM
C27	Manufacture of electrical equipment	HTM
C28	Manufacture of machinery and equipment n.e.c.	HTM
C29-C30	Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	HTM
J58-J60	Publishing, motion picture, video, television programme production; sound recording, programming and broadcasting activities	KIBS
J62-J63	Computer programming, consultancy, and information service activities	KIBS
K	Financial and insurance activities	KIBS
M	Professional, scientific and technical activities	KIBS
D	Electricity, gas, steam and air conditioning supply	LKS
E	Water supply; sewerage, waste management and remediation activities	LKS
F	Construction	LKS
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	LKS
H	Transportation services	LKS
I	Accommodation and food service activities	LKS
J61	Telecommunications	LKS
L	Real estate activities	LKS
N	Administrative and support service activities	LKS
O	Public administration and defence; compulsory social security	LKS
P	Education	LKS
Q	Human health and social work activities	LKS
R	Arts, entertainment and recreation	LKS
S	Other service activities	LKS
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	LKS
C10-C12	Manufacture of food products; beverages and tobacco products	LTM
C13-C15	Manufacture of textiles, wearing apparel, leather and related products	LTM
C16-C18	Manufacture of wood, paper, printing and reproduction	LTM
C19	Manufacture of coke and refined petroleum products	LTM
C22-C23	Manufacture of rubber and plastic products and other non-metallic mineral products	LTM
C24-C25	Manufacture of basic metals and fabricated metal products, except machinery and equipment	LTM
C31-C33	Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment	LTM
A	Agriculture, forestry and fishing	NTR
B	Mining and quarrying	NTR

A.1 Data imputation

There are some countries and industries for which we do not have data on our variable intangible stock in the EU-KLEMS&INTANT-Prod. Therefore, we have conducted some imputations in order to recover some data. We have implemented a procedure that varies by country, so in what follows we will describe how we have conducted the imputation by country.

Romania: For Romania, capital stock on national accounts intangibles (K_NatAcc) data is unavailable for manufacturing and its disaggregated industries. However, we have complete data for investment in national accounts (I_NatAcc). Therefore, we used the observed shares of I_NatAcc across industries to impute missings in K_NatAcc values at the industry level. The same procedure was also applied to recover missing values for K_RD and K_innovprop. Additionally, we recovered data for sectors J and G following the same approach. Finally, we have smoothed the resulting coefficients to avoid abrupt changes.

Hungary: A similar imputation approach was adopted for Hungary. Apart from recovering manufacturing, for this country we have also imputed J. Again, we used observed shares and smoothed the coefficients.

Poland: For Poland, we estimated shares using the average industry distributions from the Czech Republic (CZ) and Slovakia (SK), excluding Romania due to its previously imputed nature. For this country, we have also subtracted the asset new financial products (K_NFP) from non-national accounts (K_NonNatAcc) capital stock due to a jump in the data.

Sweden: For this country, data for industries C20 and C21 (and their combined aggregate C20-C21) were missing. To impute these values, we first verified that the total for sector C exceeded the sum of all disaggregated subsectors. The difference between total C and the sum of reported industries was assumed to represent the combined value for C20 and C21. We then split this total using the average shares for C20 and C21 observed in Finland and Denmark. For the years 2014 and 2015, we filled missing values by interpolating between 2013 and 2016 using average shares. For all other years, we distributed the difference directly using FI and DK shares.

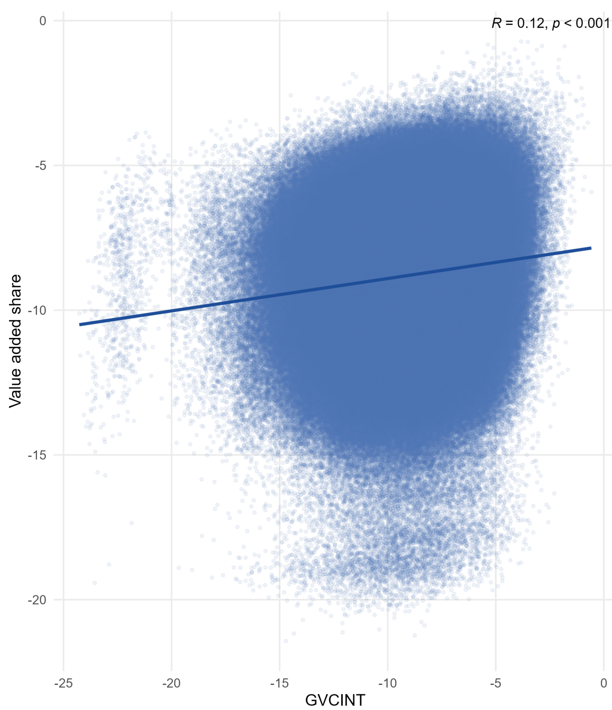
Spain: Spain lacked disaggregated data for sectors C26 and C27 and C20 and C21, although aggregate values for C20-C21 and C26-C27 were available. We used average industry shares from Italy to split these aggregates into C20 and C21, and into C26 and C27 respectively.

Portugal: For Portugal, industry-level data for K_NatAcc was missing entirely. Due to the lumpy nature of investment in intangibles, we used average shares from Spain and Italy to impute values across Portuguese industries.

Once all gaps were filled, we computed total intangible capital (K_Intang) as the sum of national accounts-based intangibles (K_NatAcc) and non-national accounts-based intangibles (K_NonNatAcc).

B Methodology and further descriptives

Figure B.1: Correlation between GVCINT and value added share (at bilateral level)



Notes: The figure illustrates the relationship between GVCINT and the value-added share at the bilateral level, for 2000 and 2019.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

Table B.1: Germany pharmaceutical (C21): Top 5 value chains by intangible contribution and value added absorption

Partner	IBFsh	VBFsh	GVCINT
Value chains with the highest intangible contributions			
USA_C21	0.19	0.12	0.02
EST_Q	0.14	0.00	0.00
SVK_Q	0.12	0.00	0.00
ROU_Q	0.11	0.01	0.00
EST_C21	0.11	0.00	0.00
Value chains absorbing the largest shares of value added			
USA_C21	0.19	0.12	0.02
USA_Q	0.06	0.11	0.01
JPN_Q	0.07	0.08	0.01
GBR_Q	0.04	0.04	0.00
ITA_Q	0.07	0.04	0.00

Notes: Panel A lists the value chains to which Germany's pharmaceutical (C21) industry contributes the largest shares of intangible assets, measured by the GVC intangible contribution share (i.e. GVCINT). Panel B lists the value chains that absorb the largest shares of value added generated by the German pharmaceutical industry. For each value chain, the table reports both the corresponding GVCINT and value added shares, highlighting the misalignment between intangible contributions and value added absorption across GVCs.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data

Table B.2: France computer and electronics (C26): Top 5 value chains by intangible contribution and value added absorption

Partner	IBFsh	VBFsh	GVCINT
Value chains with the highest intangible contributions			
MLT_C26	0.26	0.00	0.00
MLT_J61	0.11	0.00	0.00
BEL_C26	0.08	0.01	0.00
MLT_J62_63	0.08	0.00	0.00
PRT_C26	0.07	0.00	0
Value chains absorbing the largest shares of value added			
GBR_Q	0.02	0.04	0.00
USA_O	0.01	0.04	0.00
GBR_O	0.02	0.03	0.00
DEU_C29_30	0.01	0.03	0.00
USA_C29_30	0.01	0.03	0.00

Notes: Panel A lists the value chains to which France's computer and electronics (C26) industry contributes the largest shares of intangible assets, measured by the GVC intangible contribution share (i.e. GVCINT). Panel B lists the value chains that absorb the largest shares of value added generated by the France's computer and electronics (C26) industry. For each value chain, the table reports both the corresponding GVCINT and value added shares, highlighting the misalignment between intangible contributions and value added absorption across GVCs.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data

B.1 Structural Decomposition Analysis

Table B.3: Change in GVCINT by individual components

		2000–2019				
Macro-sector	Region	Intang. Stock	GVC Linkages	GVC Int. Intensity	GVC Realloc.	Overall
HTM	East	0.00	0.03	-0.01	0.00	0.02
	North	0.03	-0.03	-0.01	0.00	-0.01
	South	0.02	-0.02	-0.01	-0.01	-0.01
	West	0.14	-0.16	-0.07	-0.03	-0.13
KIBS	East	0.00	0.03	-0.01	0.01	0.03
	North	0.02	0.02	-0.01	0.02	0.04
	South	0.01	0.00	-0.01	0.01	0.02
	West	0.03	0.10	-0.07	0.08	0.13
LKS	East	0.01	0.02	-0.01	0.00	0.02
	North	0.00	0.00	-0.01	0.00	0.00
	South	0.01	0.00	-0.01	0.00	0.00
	West	0.05	0.01	-0.03	0.02	0.04
LTM	East	0.00	0.01	-0.01	0.00	0.01
	North	0.00	-0.01	-0.01	0.00	-0.01
	South	0.02	-0.02	-0.01	-0.01	-0.01
	West	0.04	-0.06	-0.04	-0.01	-0.06

Notes: The table shows the results of the SDA decomposition by macro-region and macro-sector for the period 2000–2019.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data

Table B.4: Contribution to the overall change in GVCINT

Country	**Macro Sector**	**Intang. Stock**	**GVC Linkages**	**GVC Int. Intensity**	**GVC Realloc.**
West_AUT	HTM	49.03	23.02	14.06	13.90
West_BEL	HTM	40.48	18.48	31.53	9.50
West_DEU	HTM	37.36	19.88	33.07	9.69
West_FRA	HTM	31.88	51.29	7.41	9.43
West_GBR	HTM	24.89	59.04	10.68	5.39
West_LUX	HTM	38.29	54.43	6.96	0.32
West_NLD	HTM	11.10	29.29	45.53	14.08
North_DNK	HTM	41.17	24.25	7.70	26.88
North_FIN	HTM	34.89	51.83	5.09	8.20
North_SWE	HTM	3.25	65.41	12.89	18.45
South_ESP	HTM	43.36	22.21	24.34	10.10
South_GRC	HTM	23.71	4.16	16.31	55.82

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Country	Macro Sector	Intang. Stock	GVC Linkages	GVC Int. Intensity	GVC Realloc.
South_ITA	HTM	34.33	36.55	14.10	15.02
South_PRT	HTM	63.03	1.81	27.62	7.53
East_CZE	HTM	6.80	70.16	13.20	9.84
East_HUN	HTM	38.43	35.94	6.60	19.03
East_LVA	HTM	13.21	35.74	2.07	48.99
East_POL	HTM	13.26	72.20	13.23	1.32
East_ROU	HTM	5.28	72.43	5.50	16.79
East_SVK	HTM	31.53	37.98	15.43	15.06
West_AUT	KIBS	30.30	26.29	18.81	24.60
West_BEL	KIBS	7.47	15.81	24.37	52.36
West_DEU	KIBS	19.56	32.90	18.00	29.54
West_FRA	KIBS	21.52	35.24	21.81	21.44
West_GBR	KIBS	2.08	37.00	34.14	26.79
West_LUX	KIBS	25.83	50.51	13.60	10.06
West_NLD	KIBS	1.89	44.13	30.59	23.39
North_DNK	KIBS	16.39	45.11	21.56	16.95
North_FIN	KIBS	6.35	48.28	14.57	30.80
North_SWE	KIBS	32.80	24.44	18.19	24.57
South_ESP	KIBS	34.59	30.54	21.21	13.67
South_GRC	KIBS	14.50	38.89	6.73	39.89
South_ITA	KIBS	28.79	24.79	28.77	17.64
South_PRT	KIBS	18.12	47.52	22.83	11.54
East_CZE	KIBS	26.31	2.30	42.64	28.75
East_EST	KIBS	0.23	67.93	9.10	22.74
East_HUN	KIBS	7.33	58.68	25.10	8.89
East_LTU	KIBS	9.91	54.45	4.16	31.49
East_LVA	KIBS	17.53	30.19	11.24	41.04
East_POL	KIBS	14.55	62.70	14.78	7.97
East_ROU	KIBS	19.13	68.28	11.99	0.59
East_SVK	KIBS	52.31	29.81	6.82	11.06
East_SVN	KIBS	12.85	50.89	31.01	5.25
West_AUT	LKS	46.43	14.31	26.32	12.94
West_BEL	LKS	54.66	14.12	26.86	4.36
West_DEU	LKS	22.86	37.62	31.73	7.79
West_FRA	LKS	50.45	1.91	37.80	9.83
West_GBR	LKS	25.15	24.55	31.30	19.00
West_LUX	LKS	11.46	53.39	13.76	21.39
West_NLD	LKS	43.45	16.27	16.91	23.36

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Country	Macro Sector	Intang. Stock	GVC Linkages	GVC Int. Intensity	GVC Realloc.
North_DNK	LKS	22.66	26.50	41.35	9.49
North_FIN	LKS	33.82	16.03	21.92	28.23
North_SWE	LKS	21.04	11.30	36.45	31.21
South_ESP	LKS	39.09	33.23	23.27	4.41
South_GRC	LKS	54.19	22.27	19.16	4.37
South_ITA	LKS	25.22	34.98	31.88	7.92
South_PRT	LKS	28.39	33.76	35.34	2.51
East_CZE	LKS	8.82	38.61	30.38	22.19
East_EST	LKS	21.16	43.13	14.08	21.63
East_HUN	LKS	4.23	53.17	20.84	21.76
East_LTU	LKS	14.80	66.20	9.48	9.52
East_LVA	LKS	16.23	22.15	23.66	37.96
East_POL	LKS	16.95	55.75	23.81	3.48
East_ROU	LKS	19.08	61.33	10.27	9.33
East_SVK	LKS	2.43	50.93	29.12	17.52
East_SVN	LKS	17.94	43.78	37.77	0.51
West_AUT	LTM	65.97	0.12	33.87	0.03
West_BEL	LTM	36.87	31.97	21.18	9.98
West_DEU	LTM	34.98	15.46	43.60	5.96
West_FRA	LTM	26.64	49.69	14.52	9.16
West_GBR	LTM	9.52	67.76	16.64	6.08
West_LUX	LTM	39.56	22.17	4.69	33.59
West_NLD	LTM	5.83	5.18	73.22	15.77
North_DNK	LTM	8.51	49.44	30.33	11.73
North_FIN	LTM	8.72	52.12	24.95	14.21
North_SWE	LTM	20.37	51.87	25.35	2.41
South_ESP	LTM	57.53	8.88	25.77	7.81
South_GRC	LTM	22.86	4.04	9.63	63.47
South_ITA	LTM	25.44	48.92	6.61	19.03
South_PRT	LTM	42.36	6.30	9.31	42.03
East_CZE	LTM	38.78	17.83	29.49	13.90
East_HUN	LTM	14.02	27.71	40.69	17.58
East_LVA	LTM	11.81	33.42	24.96	29.82
East_POL	LTM	3.91	76.12	19.63	0.33
East_ROU	LTM	5.26	82.60	10.77	1.37
East_SVK	LTM	23.70	25.80	39.76	10.74

Notes: This table reports the contribution of each component of the decomposition to the overall change in GVCINT over the period 2000–2019. The shares are computed as the absolute value of each component divided by the sum of the absolute values of all components, i.e. $\text{Share}_i = |\text{term}_i| / \sum_{j=1}^{4} |\text{term}_j|$. Therefore, each row sums to 100%. *Source*: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

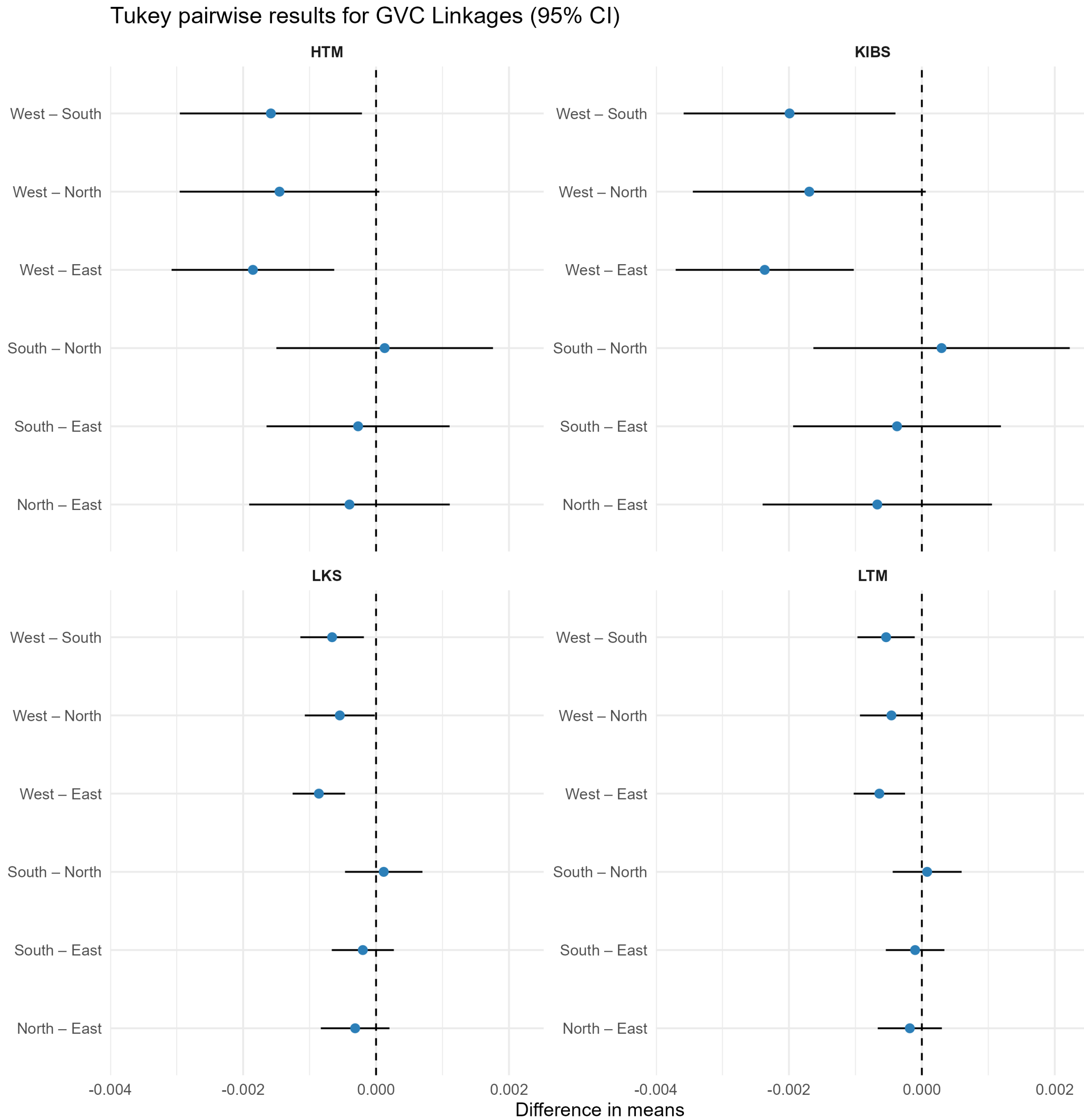
Table B.5: Descriptive Statistics of the Composition of the Decomposition

Variable	Mean	SD	Min	Max	Median
GVC reallocation	17.00	13.29	0.03	63.47	13.90
GVC Intang Intensity	21.67	12.21	2.07	73.22	21.19
Intang Stock	24.52	15.69	0.23	65.97	22.76
GVC Linkages	36.81	20.19	0.12	82.60	35.49

Notes: This table shows the descriptive statistics of the composition of the shares displayed in Table B.4. The share of each term is computed as the absolute value of the term divided by the absolute sum of the four components of the decomposition.

C ANOVA – Tukey HSD Tests

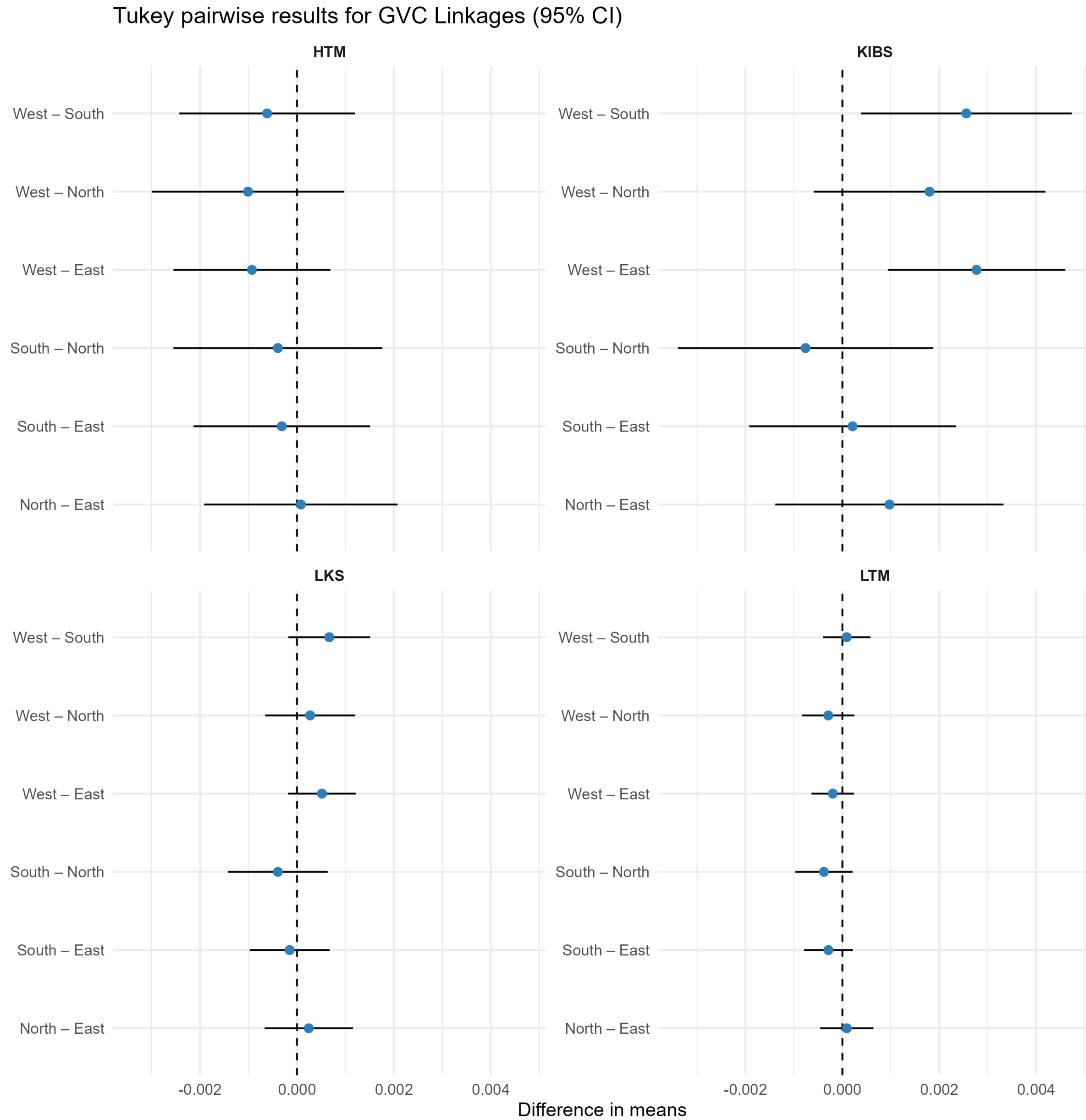
Figure C.1: Results from the ANOVA – Tukey HSD Test on GVC Intensity (Term 3)



Notes: This figure displays the Tukey-adjusted pairwise mean differences in the GVC intensity component (Term 3) between European regions, separately by macro sector. Each dot represents the estimated difference in means, with horizontal lines indicating the 95% confidence interval. The vertical dashed line marks zero, corresponding to no difference between regional means. Estimates are rescaled $\times 10^6$ for readability. A difference is statistically significant if its confidence interval does not overlap zero.

Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.

Figure C.2: Results from the ANOVA – Tukey HSD Test on Income mix (Term 4)



Notes: This figure displays the Tukey-adjusted pairwise mean differences in the income mix component (Term 4) between European regions, separately by macro sector. Each dot represents the estimated difference in means, with horizontal lines indicating the 95% confidence interval. The vertical dashed line marks zero, corresponding to no difference between regional means. Estimates are rescaled $\times 10^6$ for readability. A difference is statistically significant if its confidence interval does not overlap zero.
Source: Authors' calculations based on OECD ICIO and EUKLEMS-INTANProd data.