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Abstract

This paper provides empirical evidence on the complex role played by technology in affecting the relationship between the participation of EU countries and industries in Global Value Chains (GVCs) and their employment structure over the period 2000-2014. The empirical analysis is based on country/industry level data for 21 EU countries on employment, trade in value added, patents and investments in intangible assets, and focusses on backward linkages within GVCs. The role of technology is analysed by taking into account both the technological intensity of offshoring industries and that of their GVC partners. We study the employment structure by looking at the shares of managers and manual workers, which reflect the "functional specialisation" of the country-sector within GVCs. We find that pre-existing asymmetries in the functional specialisation are highly persistent over time, with little sign of convergence over our observed period. Furthermore, GVC participation is not related to changes in the employment structure. However, this relationship appears to be mediated by country-industries' initial technological performance. Technological leader industries exhibit, in fact, larger shares of employment in headquarter functions, and this functional specialisation tends to be strengthened as they increase their integration into GVCs. In contrast, country-industries that start off as technological laggards see integration into GVCs accompanied by an increase in the share of employment in fabrication functions. The technological profile of the partners is also found to play a role in the relationship between GVC integration and the functional specialisation of the offshoring country/industry, although different patterns emerge depending on the nature of the partner (manufacturing vs service).

Keywords:
Global Value Chains; Employment; Technology; Intangible assets; Patents.

JEL codes:
F14, F15, O33

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1. Introduction

Global Value Chains (GVCs) are forms of international production involving growing trade in intermediates and international fragmentation of the production process (Antras, 2020). GVCs have reshaped the international division of labour and led to the emergence of headquarter and factory economies (Timmer et al., 2019, Baldwin and Lopez-Gonzalez, 2015, Lopez Gonzalez et al., 2019). In the case of Europe, for instance, Germany is a headquarter economy, with factory Eastern Europe integrating into GVCs by providing low technology 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).

Against this backdrop, the flourishing literature on GVCs has extended the Heckscher-Ohlin models by considering new forms of trade specialisation in intermediates and tasks (Grossman and Rossi-Hansberg, 2008; 2012, Antràs, 2020). Timmer et al. (2019) (see also de Vries et al, 2021) have coined the term *functional specialisation* in trade and argue that this is the third generation of ways to conceptualise and measure GVCs. The first one is the traditional trade specialisation measured in terms of gross exports of (final) products; the second generation is the vertical trade specialisation, measured in terms of value added embodied in exports, which captures the international fragmentation of production and gives a more accurate picture of trade specialisation. The latest, the third-generation conceptualisation and measurement of GVCs, builds on the second one by adding the characteristics of the *functions* associated with the trade specialisation, which in turn refers to the task and occupations involved in it. Functional specialisation, it is argued (Timmer et al., 2019), is more informative than the sectoral or vertical specialisation in trade, particularly in the context of trade in value added, as it (loosely) considers the factors (tangible and intangible capital and labour) and the functions/activities ('fabrication' and 'R&D and managerial activities') that contribute to the particular specialisation of a country.

The concept and measurement of *functional specialisation* in trade blends nicely with (and might add to) a whole strand of literature that has looked at the employment and skills impact of *offshoring*, a subset of GVC integration, which is the effects of import of foreign value added on the relocation of jobs abroad (Autor et al., 2016). The large body of evidence has not yielded univocal results, but a key insight emerging from this literature is the skill-bias effect of offshoring. This suggests that it is mostly low-skilled and highly routinised jobs that are likely to be offshored, driven by cost-reducing strategies (Becker et al., 2013; Timmer, 2013; Bramucci et al., 2017).

More recently, a (very small) number of contributions to the literature on offshoring and employment have attempted to incorporate the role of technology (Reijnder and de Vries, 2018), albeit limited to ICT (Marcolin et al., 2016), into the link between offshoring and the growth and composition of routinised and non-routinised tasks. Reijnders and de Vries (2018) consider technological change in this context not only as limited to automation, but also simply as an alternative cost-cutting strategy to the offshoring one, i.e. firms would decide either to automate and therefore replace routinised tasks and save on costs or to offshore and therefore access cheaper routinised occupations abroad.

However, technological change has a more complex nature that goes beyond the effects of strategies of automation and replacement of routinised tasks, which have dominated the most recent literature on the effects of technology on occupations, tasks and skills (Acemoglu and Restrepo, 2017; Autor et al., 2015). Technical change is associated with investments in tangible and intangible capital, which might be complementary to, rather than substitutive of, certain occupations, and at the same time affect strategies of insertion in GVCs (Alsawami et al., 2020).

Also, in a trade context, it is not only firms' strategies that affect automation, offshoring and jobs replacement. These decisions are highly path-dependent and are affected by the structural differences in countries' technological development, and the initial asymmetries in technological specialisation. A whole stream of literature, based on the technology-gap approach to trade (Dosi et al., 1990, 2015), has studied the effects of (persistent) technological asymmetries on countries' trade performance, albeit not in the recent context of international fragmentation of production process. Yet, in a GVC context, technological asymmetries are even more likely to influence the conditions with which countries, sectors and firms position themselves along GVCs (Simonazzi et al., 2013; Altzinger and Landesmann, 2008).

The aim of this paper is to analyse the effects of GVC insertion on the opportunities of employment upgrading by taking into account countries-sectors technological asymmetries as affecting the quality of such GVC insertion. We therefore add to both the recent concept of functional specialisation of trade and the well-established technology-gap literature in a threefold way.

First, we explicitly consider the dynamics of *functional specialisation of GVCs* as a process of *employment upgrading* – that is, a shift in countries' and industries' employment structure from fabrication activities (intensive in manual workers) to R&D and headquarter activities (intense in managerial occupations) that might (or might not) be due to the process of insertion in GVCs. In studying this process, we consider countries' initial employment structures and how they affect their opportunities to be gainfully inserted in GVCs.

Second, to add to the technology gap literature, we account for the initial *countries' technology asymmetries* as affecting the association between the 'quality' of insertion in GVCs and the functional specialisation mentioned above. We do so by studying the relationship between GVC integration and employment composition and by considering both the initial position of countries and industries in terms of technological intensities, as well as the technological intensity of their GVC partners.

Third, from a methodological perspective, this paper contributes to the literature by complementing existing measures of GVC integration with measures of patent and intangible assets intensity of partner countries and industries. In doing so, we provide a novel and rich empirical mapping that characterises the quality of country-industries' participation in GVCs.

To draw this multifaceted picture of trends in GVC participation, technology, and employment in European countries, we combine several data sources: the World Input-Output Database (WIOD) for standard GVC participation measures, OECD-REGPAT and INTANINVEST for patent and intangible intensities, respectively, and the EU Labour Force Survey (LFS) for employment across occupations and sectors. We then use GVC participation measures to weight the average patent and intangible intensity of each country-industry's partners, providing new insights on the technological quality of GVC participation.

We explore how these measures relate to the distribution of jobs across different occupational categories, focusing mainly on headquarter and fabrication functions as defined in Timmer et al (2019).[1] More specifically, we empirically estimate the relationship between backward GVC participation and functional specialisation (the share of manual and managerial occupations), taking into account the initial technological position of the countries and industries importing value added in GVCs and the quality (knowledge intensity) of their partners.

We focus on a sample of 21 European countries and 49 industries over the period 2000-2014. The EU has experienced several interesting dynamics that have reinforced the North-South and East-West divides, including the integration of Eastern European Countries (EEC) and the long-term industrial leadership of the core EU countries. These phenomena have led to the concentration of the highest value added segments of GVCs in continental Europe – particularly Germany – and the emergence of new peripheries (Wirkierman et al., 2021).

Our analysis yields three key results. First, despite a sustained process of economic integration and increasing GVC participation, involving particularly Eastern European countries, functional specialisation is highly persistent over time, with no sign of convergence in employment upgrading over time.

Second, rather than the intensity of GVC participation, it is its quality, and specifically the intensity in intangible assets of GVC partners, that is relevant for the country-sectors employment structure. We find in fact that, in the manufacturing sector, countries that import value added from intangible intensive partners also tend to employ higher shares of managers and lower shares of manual workers – i.e. a specialisation in headquarter functions and away from fabrication functions.

Third, initial conditions in terms of technological positioning matter, as they affect how GVC participation and its quality are related to the country-industries' employment

[1] We should point out that while we use the same classification of occupations into functions as Timmer et al. (2019), we do not use indexes of functional specialisation computed in the same way as the authors do. This is because we look at employment shares rather than Balassa indexes based on wage bills. This being said, we are confident that employment shares are still an effective proxy of the functions being carried out, the type of activities available to workers within each country-industry and therefore of its position in GVCs.

upgrading trajectory. In particular, countries that start off with an advantage in patent intensity are more likely to see their share of employment in headquarter functions increase as they further integrate into GVCs. The opposite occurs for country-industries that are lagging behind in patent intensity at the beginning of our observed period.

These findings are of great relevance for policy. The current economic crisis triggered by the pandemic has laid bare the importance of the European Union coordinating policy efforts for the economic recovery. Further economic integration – which might exacerbate existing asymmetries - needs to be accompanied by appropriate policies to foster the economic cohesion and mitigate these effects.

The remainder of the paper is structured as follows. The next section embeds our research questions in the extant literature and highlights the aimed conceptual contribution of the paper. Section 3 illustrates in detail the data and measurements of GVC integration, our novel proxies of 'quality' of GVC integration based on the technological profiles of countries/sectors, and functional specialisation. Section 4 offers a rich and detailed descriptive empirical mapping of the dimensions above in the 21 EU countries considered. Section 5 explains the econometric strategy to test the research questions put forward in Section 2. Section 6 discusses the results also in view of our descriptive evidence. Section 7 summarises the results and concludes the paper.

2. Background literature and research questions

The empirical literature on the effects of the participation in GVCs on employment has grown significantly in recent years, yielding, nevertheless, mixed results. The first set of studies has focused on the relationship between offshoring, often proxied as import penetration, and employment. While some studies find a positive effect (Hijzen and Swaim 2007), others find no effect (Amiti and Wei, 2005; 2009) or a negative impact (OECD, 2007).

More related to our contribution is the literature that has looked at how offshoring affects the composition of employment across skill groups; the evidence is not conclusive but does point to the increase in the share of the wage bill of high-skilled workers (Feenstra and Hanson 1996; 1999; Strauss-Kahn, 2003; Hijzen et al., 2005; Falzoni and Tajoli, 2012; Crinò, 2012; Foster-McGregor et al, 2013). Interestingly, Foster-McGregor et al. (2016) present evidence that partially contradicts the idea of skill-biased offshoring, showing an unexpectedly larger negative effect on employment of highly educated workers in high-income countries. The authors explain this result by suggesting that companies in high-income countries have started to offshore high-technology functions too. A more recent strand of work has highlighted the role of task routinisation, rather than skill requirement. In this work, theoretical predictions and empirical results are quite aligned, suggesting that routine intensive tasks are more likely to be offshored (Becker et al 2013, Hogrefe, 2013, Baumgarten et al 2013, Ottaviano 2015).

The nexus between GVC participation, of which offshoring is a key component, the knowledge and technological endowments of countries and the ensuing occupational outcomes has received, so far, little attention. The effect of offshoring and participation in GVCs on employment composition has in general been investigated without taking into account the asymmetries in the technological capabilities of the countries and industries involved in the process.

The research on offshoring mostly overlooks the evidence emerging from the literature on technological trajectories and how they shape the conditions of countries entering GVCs, which has highlighted that the specific trajectory that a country-industry takes depends to a large extent on the initial conditions of the country and the co-evolution of different factors such as the strategies and technological endowments of firms and industries and the qualitative structure of the national innovation systems in which they are embedded (Pietrobelli and Rabellotti, 2011; Jona and Meliciani, 2018; Lema et al. 2019). These contributions highlight the importance played by technology and knowledge assets in affecting the potential benefits stemming from the participation in GVCs. They also incorporate the main insights of the technology-gap approach to trade (Dosi et al. 1988, 1990, 2015; Fagerberg, 1994; Cohen 2010; Laursen and Meliciani 2010; Maggi, 2017) and apply them to the new context of international fragmentation of production and GVCs. However, here the employment effects of the new technology-shaped patterns of international production (i.e. GVCs) have remained under-investigated.

Relevant to the purpose of this paper is also the growing body of literature using a political economy lens to look at asymmetries in GVC integration in Europe. Milberg and Winkler (2011) link the bargaining power of countries joining GVCs to the quality of their institutions, which, they argue, play a significant role in shaping how gains associated with GVC participation are distributed. Similarly, Simonazzi et al. (2013) and Celi et al. (2018) take a structural approach to the international production based on a geo-political economic framework. This literature understands phenomena such as offshoring and restructuring of GVCs as the outcome of changes in the hierarchical organisation of value chains. These are in turn the result of changes in the relationship between firms, sectors and, crucially, geographically identifiable locations. Concerning Europe's specific case, these authors recognise that the core of the European economy – i.e. the manufacturing network with Germany at the centre – has deployed a geo-economic strategy to strengthen its productive and technological capabilities and therefore consolidate its market share. This strategy relies both on the offshoring of production phases of intermediate products that can be purchased at low prices from Eastern European countries and the core's technological advantage that has been strengthened over time.[2] Although the contributions above discuss the geo-political asymmetries at length, they rarely explicitly consider the role that technology has in furthering these asymmetries.

The first contributions to highlight asymmetries in power and their relationship with the distribution of gains along GVCs are those of Gereffi (1994) and Gereffi et al (2005). This seminal work provided the (qualitative) foundation of the notion of functional specialisation that has more recently emerged in the literature (Timmer et al 2019 and De Vries et al 2021). The concept of functional specialisation mentioned in the introduction resonates with and builds upon the growing (quantitative) empirical evidence on flows in value added. Such evidence shows that within macro-regions, some economies play a central role as headquarters while others remain in the periphery as factory economies (Baldwin and Lopez-Gonzalez, 2015, Amador et al. 2018). However, also this literature on GVCs and functional specialisation has so far overlooked the role of technology.[3] In particular, the aspect of how initial technological

[2] See also Grodzicki and Geodecki (2016) and Stöllinger (2016).

[3] This is especially true for the most recent contributions that have identified headquarters and factory economies based on flows in value added. In contrast, the original literature on GVC placed some

asymmetries are related to country-industries' positioning in GVCs, their employment structure and, ultimately, their functional specialisation seems unexplored so far.

Marcolin et al. (2016) is the first contribution directly relating technology and GVC participation to the dynamics of occupations, finding "complex interactions between the routine content of occupations, skills, technology, industry structure and trade, which do not allow for a neat identification of "winners" and "losers" in a GVC context" (Marcolin et al., 2016 p.3). The complexity of such interactions is further explored by a recent work by Marcolin and Squicciarini (2018) that, in line with the empirical agenda of our contribution, addresses two main questions: a) how the skill composition of a country's workforce shapes the specialisation and positioning along the global value chain, and b) the way in which GVC specialisation and positioning both determine, and are determined by, investment in selected knowledge-based capital assets, and what this entails for policy. All in all, Marcolin and Squicciarini (2018) confirm the complexity of the interplay between GVC, technology and employment and the difficulty of drawing clear-cut policy implications and guidelines on how to get the most from countries' participation in GVCs. Nonetheless, this contribution has the merit of defining the main issues and relationships at stake, providing relevant hints on the main channels through which technology and knowledge-based assets can shape the GVC-employment relationship.

The contribution proposed in this paper aims at shedding further and novel light on these channels, therefore positioning itself within the literature on GVC functional specialisation, technology-gap and asymmetries and the effects of offshoring on the composition of employment. While we do not aim at formulating formal testable hypotheses, we however identify a few stylised conjectures that are worth investigating empirically in the context of the gaps in the literature identified above.

Leading technological industries and countries might, on the one hand, offshore low value-added functions and further strengthen their functional specialisation in knowledge intensive and managerial functions. On the other hand, these same

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emphasis on asymmetries in technological and productive capabilities but focused mostly on the distribution of value added gains and much less on the employment structure at the country or industry level.

industries could also offshore knowledge intensive functions (Foster-McGregor et al, 2013; Bramucci et al. 2017) due to technological competition from foreign partners. In this case the effects on the employment structure are less straightforward. Industries and countries may enter an innovation race and improve, in the long run, their share of knowledge intensive functions, although there is empirical evidence that foreign technological competition can reduce turnover, sales and employment in firms in the short run (Gagliardi 2019, Kemeney 2009, Wiggins and Ruefli, 2005).

Different strategies and patterns of participation in GVCs can also be found among less innovative industries. These might, on the one hand, remain 'trapped' in their specialisation in low value added functions or, on the other hand, benefit from the interaction with partners by providing them with knowledge intensive inputs, thereby facilitating access opportunities for technological (and functional) upgrading.

Finally, the relationships between industries within GVCs can differ depending on whether manufacturing industries import value added from other manufacturing industries or from service industries. In fact, competition effects are more likely to occur in the first case, while importing value added especially from service sectors with high levels of intangible capital can be beneficial for upgrading due to knowledge and skill complementarities (Meliciani and Savona, 2015).

In summary, integrating into GVCs with technology intensive partners could lead to employment upgrading through processes of spillover, learning and technology upgrading; or, in contrast, to competition/substitution effects (especially when both the importer and exporter have high technological capabilities) and to reinforcing initial asymmetries (especially when the importer has lower technological capabilities than the partner). We empirically investigate these conjectures below, considering patterns of GVC integration for both technological leaders and laggards among European country-industries.

3. Measuring GVC integration, its technological quality and employment upgrading

In light of the literature discussed in the previous section, we aim to make three key contributions exploring the nexus between GVCs, technology and employment. First, we frame employment upgrading as shifts in the employment structure towards headquarter and away from fabrication functions. Second, we offer a rich empirical picture of country-industries' technological position and that of their GVC partners. Third, we operationalise the latter in terms of patent and intangible assets intensity.

To investigate the relationship between GVC participation, technology and employment structure, we compile a country-industry level dataset, combining a range of sources. This section discusses them in turn, starting from the traditional measures of GVC participation, then the data used to capture technological positioning and finally looking at the data on employment shares, which we use to proxy for employment upgrading.

3.1 Measures of GVC integration

In order to measure countries' participation in GVCs, we rely on the 2016 release of the WIOD dataset, which covers the years 2000-14 for 43 countries and 51 industries.[4] The literature on input-output tables has developed a range of approaches to capturing industries and countries' participation in GVCs and the degree of fragmentation of production chains (for a review of conceptual and methodological issues see Bontadini and Saha, 2021 and Borin & Mancini, 2020). We follow Borin and Mancini (2020), which expand the approach of Johnson (2018) to what Koopman, Wang, and Wei (2014) refer to as foreign value added in gross export, also known in the literature as backward GVC participation:

$$BWD_s = \sum_{r \neq s} V_r B_{r,s}^s E_s \qquad (1)$$

[4] In our empirical analysis we aggregate some of these industries in order to make it possible to match information for NACE rev. 1 industries for the years 2000-07 from the EU Labour Force Survey. As a result we end up with 49 industries. We focus on manufacturing and service industries, of which a complete list is provided in the Appendix.

Where V_r is a diagonalised vector of value added as a share of total output in country-sector r. $B^{s}_{r,s}$ is a modified version of the traditional Leontieff inverse that captures all inter-sectoral linkages among all countries and industries, taking into account however that foreign intermediate demand for country-sector s is also present in the vector of gross export E_s:

$$B^{s}_{r,s} = (I - A^{s})^{-1} \tag{2}$$

Where A^{s} is a matrix of technical coefficients in which all rows corresponding to country-sectors have been turned to 0, as discussed in Borin and Mancini (2020). BWD_s informs us of how relevant foreign inputs are for the production of gross exports. As such, this can also be interpreted as a measure of offshoring, i.e. segments of value chains that have been relocated abroad. BWD_s is expressed in absolute terms and in order to account for size effects, we divide it by country-industry total output:

$$Bwdint_s = \frac{BWD_s}{Output_s} \tag{3}$$

We prefer to use output as denominator rather than export or value added. This is because at the country-industry level, value added can be very small or even negative and it would be a less stable measure of productive capabilities than gross output. Concerning exports, we prefer to use output to have a more accurate understanding of how different inputs feed into country-industries' productive process as a whole, and not just production that satisfies foreign demand.

3.2 The technological quality of GVC integration

The key intention of this paper is to put the quality of GVC participation at the centre of our analysis. This requires having a measure of partners' knowledge and technology intensity.

In order to achieve this, we first turn to patent data. Using the REGPAT dataset compiled by the OECD, we retrieve the number of patent applications filed with the

EPO, across technological classes identified at 4-digits of the international patent classification (IPC). We translate IPC classes into NACE rev. 2 2-digit industries using the crosswalk developed by Lybbert and Zolas (2014). We identify the country of development of each patent based on the country of residence of the inventor, rather than the applicant, which is provided in REGPAT. This is relevant because we are interested in knowing where the innovative capabilities are located rather than the location of the company that seeks market protection through patenting. We then compute patent stocks K_{ijt} with the perpetual inventory method:

$$K_{ijt} = PAT_{ijt} + (1 - \delta)K_{ijt-1} \qquad (4)$$

we calculate the initial value of the stock K_{ijt_0} as follows:

$$K_{ijt_0} = \frac{PAT_{ijt_0}}{\overline{g_{ij}} + \delta} \qquad (5)$$

where PAT_{ijt} is the patent applications filed with the EPO in sector *j* from inventors in country i in year t and δ = 0.1 is the depreciation rate, set at a level in line with the literature (Verdolini and Galeotti, 2011; Keller 2002); $\overline{g_{ij}}$ is the average rate of growth of patenting in country *i* and industry *j* for the period between t_0 and $t_0 - 4$. We use t_0 = 1995 as the initial year for the computation of the patent stock, while our analysis starts from 2000 to minimise the impact of the initial stock on the levels of stock we use in the analysis.

Patents have been used extensively in the literature to capture technological capabilities and are a straightforward and intuitive measure of innovation output. However, they only capture the technological dimension of knowledge and are not relevant for all industries in the same way. This is particularly the case with services that have virtually no patenting activity and, as a result, are not included in the crosswalk from IPC classes to industries by Lybbert and Zolas (2014).

To compensate for this, we use the approach of complementing patent stocks by looking at estimates of investments in intangible capital from the INTANINVEST dataset

(Corrado et al 2016). These measures expand the boundaries of what we consider as technological capabilities by including knowledge that has been accumulated over time through a broader set of activities and that is therefore relevant for services too. Intangible capital includes in fact several assets, ranging from those that are included in the national accounts (such as R&D, software and databases) to those that are not, such as investments in brand, design, organisational capital, training and financial innovation.[5]

However, data on intangible assets present one major limitation, as they are available only at 1 digit of NACE rev. 2 industries. This means that there is no variation across manufacturing industries within each country.[6] Moreover, intangible assets have been computed only for a subset of high-income economies, covering most of European countries, the US and Japan. As a result, when we use this measure to capture the quality of a country-industry's partner, this is only restricted to countries that are included in the INTANINVEST dataset.[7]

It is also worth stressing that while data on intangibles are obviously related to innovative activity that would also be captured by the patenting activity, they are not directly comparable to our measures of patent stocks, since they are computed in millions of national currency, while patent stocks use the number of patent applications.

We are therefore faced with both conceptual and empirical trade-offs in our two sources of data. On the one hand, patent stocks are a well-known measure of technological

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[5] The INTANINVEST dataset contains information on investment in three broad categories of assets that can be broken down as follows:

1. Computerised information: (i) purchased and (ii) own-account software, plus (iii) databases.
2. Innovative property: (i) R&D (ii) design (iii) mineral exploration (iv) Financial innovation and (v) artistic originals.
3. Economic competencies: (i) advertising (ii) marketing research (iii) purchased and (iv) own-account organisational capital and (v) training.

Assets that are split between purchased and own-account refer to whether investment in these assets is achieved by purchasing services from other industries or by hiring personnel providing these services from within the sector itself. For a detailed discussion of what each of these assets represents and how it is computed we refer the interested reader to Corrado et al (2016).

[6] All of the manufacturing sector is lumped under division C in NACE rev. 2 classification at 1-digit of disaggregation.

[7] Table A1 reports the list of countries we include in our final sample. It should be noted however that among Easter European countries, we only have data on intangible assets for Hungary, Slovakia and the Czech Republic.

capabilities, are available for all countries and at the desired level of disaggregation, but they are only relevant for manufacturing industries. On the other hand, intangible assets cover a broader group of knowledge-related activities that are relevant for services and manufacturing alike, but for the latter they are available only for the manufacturing sector as a whole.

In an effort to reconcile these issues, we resolve to use patent data for the manufacturing sectors and measures of intangible assets for service industries and compute the following intensity measures:

$$Patint_{ijt} = \frac{K_{ijt}}{Output_{ijt}} \quad if\ j\ \in manufacturing \quad (6)$$

$$Intanint_{ijt} = \frac{Intan_{ijt}}{Output_{ijt}} \quad if\ j\ \in services \quad (7)$$

While this choice is certainly dictated by the data availability issues discussed above, it also makes sense conceptually. Manufacturing and services are in fact starkly different activities, whose quality can hardly be measured with a unique indicator. It therefore seems appropriate to use the patent as a relatively narrow-defined measure of technological capabilities, while we rely on intangibles that have broader conceptual boundaries to assess the quality of services industries.

Now that we have derived measures of knowledge intensity for both manufacturing and service country-industries, we can combine them with the GVC participation indicators discussed above to obtain a measure of the technological quality of GVC participation. Conceptually speaking, we can think of the quality of a country-sector's GVC backward participation as the quality of the partners with which the country-sector engages. To obtain a unique measure of this we look at the average quality of a country-industry's backward linked partners. For manufacturing partners we compute:

$$BwdPatent_s = \sum_{r\neq s} Patint_r * \frac{BWD_{r,s}}{\sum_{r\neq s} BWD_{r,s}} \quad (8)$$

While for service partners we compute:[8]

$$BwdIntant_s = \sum_{r \neq s} Intantint_r * \frac{BWD_{r,s}}{\sum_{r \neq s} BWD_{r,s}} \quad (9)$$

In this way, we have two measures of quality of GVC participation. For each country-industry s, we compute the average patent intensity of manufacturing backward-linked partners, weighted on the strength of the backward linkages. For service backward-linked partners we compute the same average using, instead, intangible intensity as our measure of quality.

3.3 Functional specialisation and employment upgrading

We use data on employment across country-industries from the European Union Labour Force Survey (LFS). We use this source of data to compute shares of employment in managers and manual workers, which we equate to headquarter and fabrication functions, respectively, following Timmer et al. (2019). In Table A11 in the Appendix we report what occupations have been grouped into the broader function of managers and which ones we have considered as manual workers. These two terms are rather broad, so some further characterisation is in order. The occupations that we label as managers identify the location of skills (hence the inclusion of the occupations "Professionals" as well as "Technicians and associate professionals") and decision-making about how the production is organised across countries and industries (hence the inclusion of "Legislators, senior officials and managers"). In this sense, we use the general term "managers" to proxy for what the literature has more broadly referred to as headquarter functions (Timmer et al., 2019, Baldwin and Lopez-Gonzalez, 2014). Conversely, we use the occupations that refer to manual work as a proxy for fabrication activities – which characterise what Baldwin and Lopez-Gonzalez (2014, p.15) refer to as a 'factory economy'– that are not characterised by a high degree of decision-making with respect to the value chain to which they contribute.

[8] Two clarifications on the notation are in order. First, we use subscripts *r* and *s* instead of *i* and *j* because they refer to different things. In the former case, we separate the two subscripts with a comma to indicate two separate country-sectors (*r* and *s*) with value added flowing from *r* to *s*. In the latter case, we do not use a comma as we indicate a unique country-sector identified by country *i* and sector *j*. Second, in equations 8 and 9 we use $BWD_{r,s}$ to indicate the foreign value added from *r* that is embodied in export of *s*. This is a bilateral measure of backward GVC as indicated by the double subscript *r* and *s*. The denominator in equations 8 and 9 $\sum_{r \neq s} BWD_{r,s}$ in contrast refers to the total backward GVC participation of country-industry *s* and it is therefore equal to BWD_s from equation 1.

We have already discussed how the notion of functional specialisation is particularly appealing for our analysis because it conceptually links occupations with business functions within GVCs. From an empirical point of view, we believe this is a meaningful classification for two key reasons. First, it loosely corresponds to the distinction between skilled (white collar) and unskilled (blue collar) workers. Second, it also matches business functions that are likely to be co-located as a consequence of the new international division of labour (Lanz et al., 2011; Timmer et al., 2019). This in turn is informative of the position each country-sector occupies within GVCs, with managerial functions appropriating a larger share of value added, determining the location of other functions and corresponding, ultimately, to GVC upgrading (Gereffi, 1994; Gereffi et al., 2005). As a result, an increase in the share of managers can be interpreted as an increase in the capability intensity of a country-sector and as a shift in function, and therefore position, within GVCs.

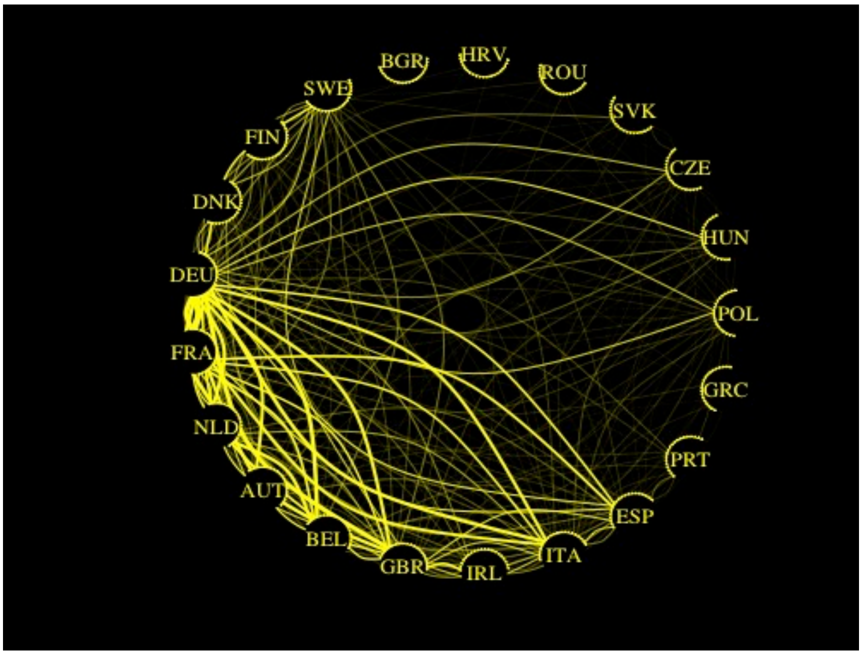
4. Descriptive evidence

By combining the different data sources described in the previous section, we are able to show the main trends in GVC participation, technological asymmetries and employment structure across European countries and industries.

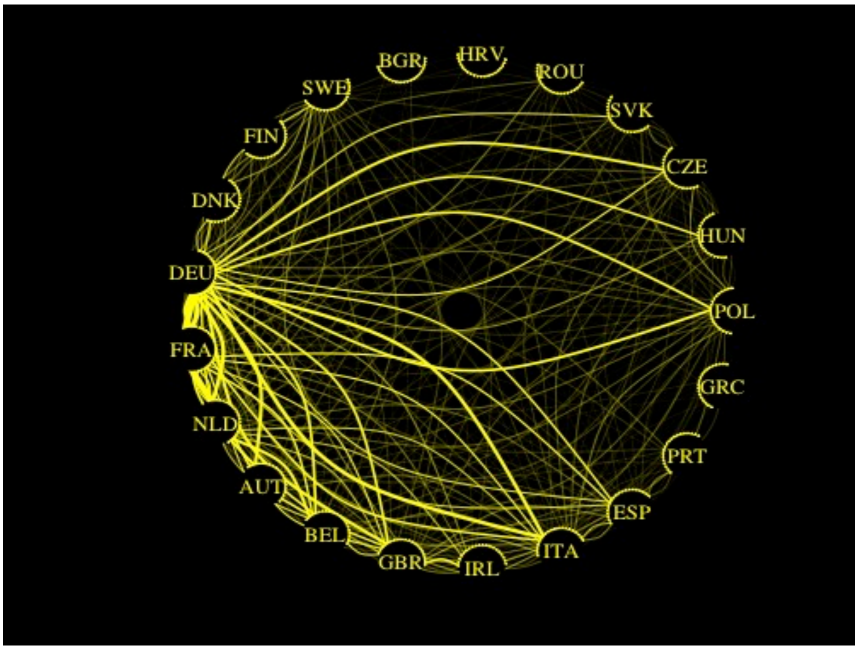
The first key aspect of GVCs is that this phenomenon has brought about increasingly complex production networks across countries. The European Single Market has led to a high level of integration among countries that has grown considerably over the past 20 years. Figure 1 shows how backward linkages (as measured in equation 3) have grown over time, from 2000 to 2014. Three key features emerge from this evidence. First, Western Europe was already a rather highly integrated region in 2000, while at the time Eastern and Southern European countries (Portugal and Greece in particular) were comparatively much less involved in GVCs. Second, Germany is at the centre of the production networks in Europe, a centrality that emerged from other contributions (Amador & Cabral, 2017; Amador et al., 2018; Baldwin & Lopez-Gonzalez, 2014).

Third, while Eastern Europe has significantly increased its participation in GVCs, this has not changed the structure of production networks that remain concentrated around Germany.

Figure 1 – Backward linkages network over time 2000 and 2014



(a) 2000



(b) 2014

Source: authors' calculations using WIOD data

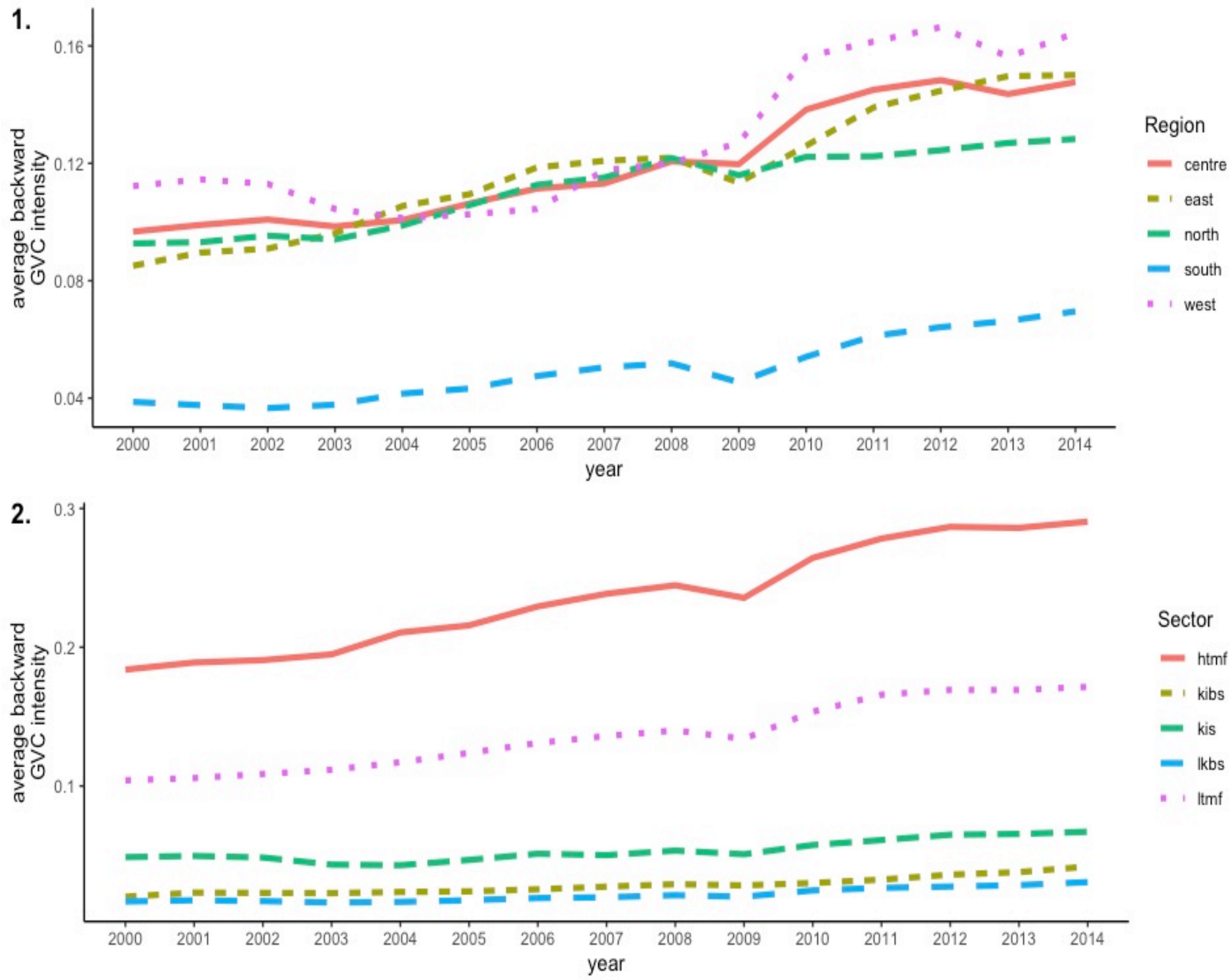
Building on the geographical patterns emerging from Figure 1, and in order to facilitate the discussion of the descriptive evidence in this section we focus on regions and macro sectors in Europe. We aggregate European countries in 5 main macro-EU-regions: Centre, North, South, East and West. We do the same with sectors, aggregating industries in five main groups: high-tech manufacturing (HTM), low-tech manufacturing (LTM), knowledge intensive business services (KIBS), knowledge intensive services (KIS) and low-knowledge business services (LKBS).[9]

Figure 2 reports the evolution of macro-regions and macro-sectors' backward GVC participation.[10] We find support to the evidence that in 2000 Eastern and Southern Europe occupy rather peripheral, i.e. less connected, positions in Europe's GVC network. However, these two regions show starkly different dynamics. Southern Europe remains by large the region with the lowest integration across the continent in 2014, while Eastern Europe moves up from fourth to second position.

Some clear sectoral patterns emerge as well, setting manufacturing and services apart from each other. The former shows a much higher level of GVC participation, with high-tech sectors participating in GVCs almost twice as much as low-tech sectors. By contrast, service industries show shorter value chains, with much lower shares of import of foreign value added.

[9] We provide details of how countries and industries are grouped into regions and macro-sectors in the Appendix in Tables A1 to A3. We have chosen to group the UK and Ireland into the group "West" as these two economies share, along with their geographical proximity, similar industrial structures and a strong specialisation in services. The classification of macro-sectors based on knowledge and technology intensity follows the list provided by Eurostat.
[10] In Appendix A we also report country-level evidence, looking at mean, median and long-term change across countries for all the variables in Figures 2 to 4.

Figure 2 – Backward linkages across regions and macro-sectors over time



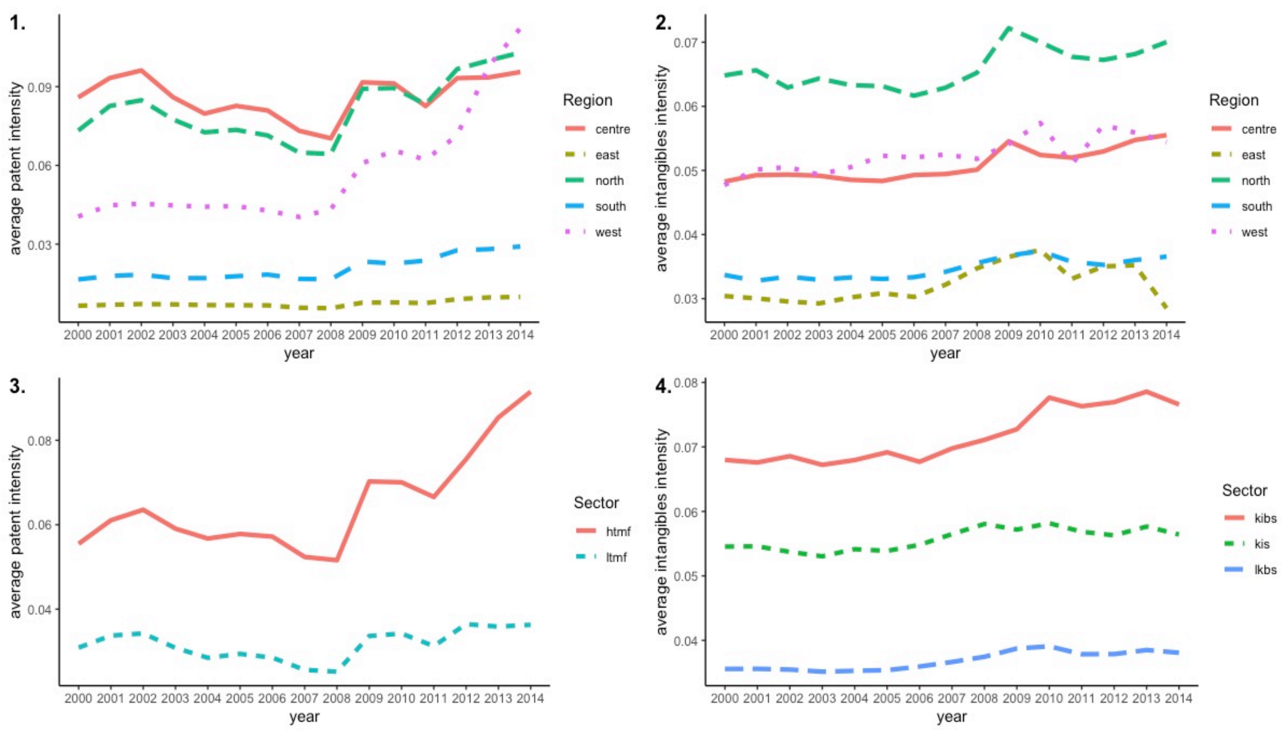
Source: authors' calculations using WIOD data – unweighted average across macro regions and sectors for backward GVC intensity.

All in all, Figures 1 and 2 show a general trend of growing GVC participation in Europe, which is particularly noticeable in Eastern European countries. Has the increasing integration been accompanied by a technological and functional upgrading? Figure 3 shows the dynamics of the average patent and intangible capital intensity of macro-regions and macro-sectors over the 2000-2014 period. The figure shows the persistence of wide technological and knowledge-based asymmetries across regional areas and sectors. Southern and Eastern Europe set themselves apart from the rest of the continent, with lower levels of both patent and intangibles intensities, both at the beginning and end of the examined period. Furthermore, despite Eastern Europe having significantly increased its level of participation in GVCs over our observed period (Figure 2), this process has not been paralleled by a reduction of its technological gap from the most advanced EU countries.

To provide a more granular example of these patterns we also present country-level evidence in the Appendix,[11] in an effort to unveil more cross-country heterogeneity. In Figure A1, we find evidence consistent with Figure 3: the Czech Republic and Italy are consistently at the bottom for patent intensity. This pattern also persists, though much less starkly, when we look at intangible intensity. In fact, we can see that Germany's average intensity in intangible is just above that of Italy's and the Czech Republic's – in contrast, Sweden and France rank at the top both in terms of patent and intangible intensities.

Finally, returning to macro-sectors in Figure 3, we also find rather stark and persistent differences. There is a clear, and increasing, gap between high and low-tech manufacturing in terms of patent intensity and the same applies between KIBS and other service industries, as emerges from the indicator measuring the intensity in intangible assets.

Figure 3 – Patent and intangibles intensity across regions and macro-sectors over time



Source: authors' calculations using REGPAT and INTANINVEST data – unweighted average across macro regions and sectors for patent and intangible intensity.

[11] See Tables A6-A10 and Figure A1 in the Appendix.

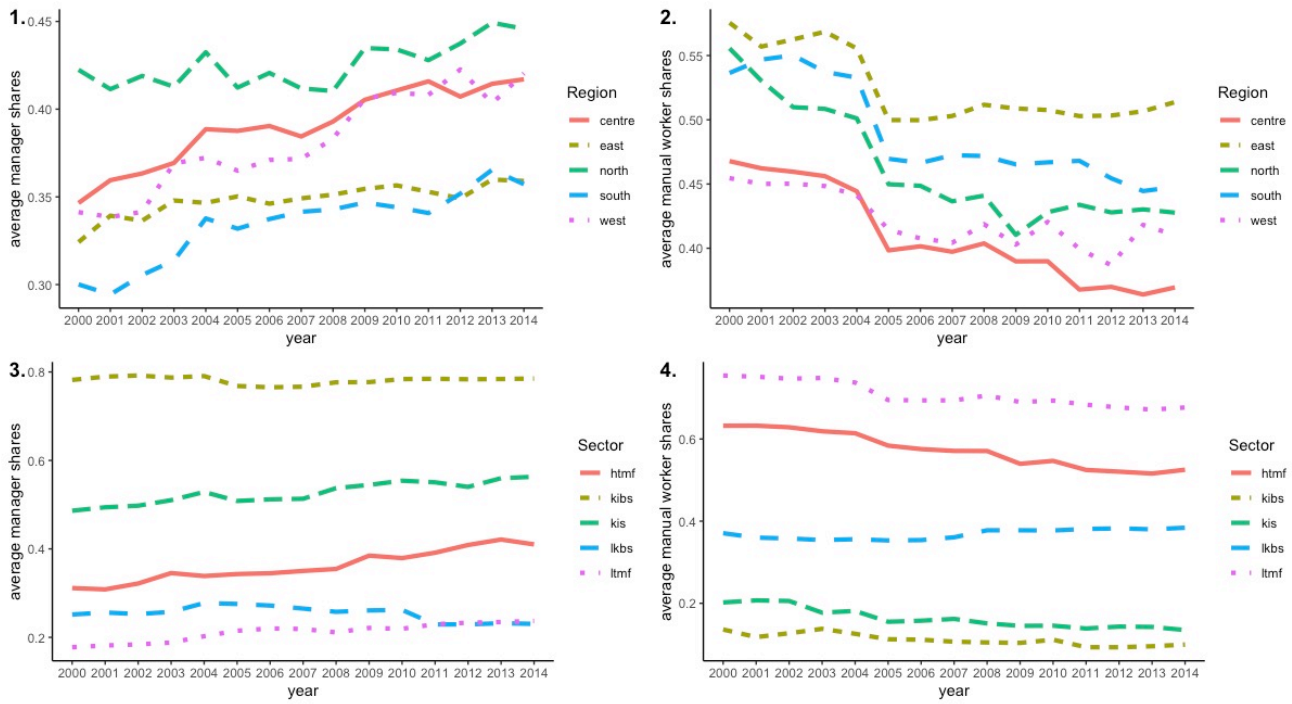
Given the persistence of technological asymmetries, it is also important to assess whether these are also reflected in terms of employment structure, which, as discussed in the previous section, is the key variable of interest in our analysis as it speaks to skills and business functions that take place across countries and industries.

In Figure 4 we look at the evolution of shares of managers and manual workers across regions and macro-sectors over our observed period. Concerning the former, we find common trends that maintain, and in some cases even increase, the initial differences in the employment structure. Looking at the share of managers in panel A of Figure 4, we find not only that Eastern and Southern European countries have the lowest average shares of this occupational category, but that over time the gap with Centre and Western regions increases. Overall, these core EU regions are those that have experienced the largest increase in the share of managers, suggesting that many sectors in the most advanced areas of the EU have further strengthened their specialisation in headquarter functions and therefore upgraded their functional specialisation (Timmer et al., 2019).

Concerning manual workers, we find a declining share of this component of the labour force in all regions, but this trend stops in Eastern Europe from 2005 onwards. This once again suggests that while Eastern European countries have significantly increased their participation in GVCs, this rapid integration has not been accompanied by a process of functional upgrading, i.e a shift away from fabrication and towards headquarter functions. Southern Europe, in contrast, does experience a steady decline in its share of manual workers, but the relevance of this component of the labour force remains consistently higher than in the other three macro-regions, especially the West and Centre EU.[12]

[12] We explore these patterns also at the country level in Figure A1 in the Appendix. The Czech Republic follows a similar trend to that of the Eastern Europe region, decreasing its share in manual workers but experiencing an increase again after the global financial crisis. Concerning manager shares, we find Germany to have a rather remarkable pattern, with a share in managers comparable to that of Italy and the Czech Republic. While this is somewhat surprising, it can be explained by looking at the sectoral composition of both Germany, Italy and the Czech Republic, all three of which are much more concentrated around manufacturing industries rather than services, compared to the other three countries in Figure A1.

Figure 4 – Shares of managers and manual workers across regions and macro-sectors over time



Source: authors' calculations using LFS data – unweighted average across macro regions and sectors for patent and intangible intensity.

This resonates with the fact that when we look at the employment structure across macro-sectors in Figure 4 (Panels 3 and 4), we find that services have much higher shares of managers than manufacturing, while the opposite is true for manual workers. Among the two manufacturing macro-sectors, high-tech industries show higher shares of managers and lower ones of manual workers, which is consistent with the fact that the category of managers includes scientists and researchers, occupations that are closely related to R&D activity.

The descriptive evidence presented in this section suggests that most countries and sectors have increased their participation in GVCs. However, both geographical and sectoral asymmetries persist starkly, with three key pieces of evidence emerging.

First, the increased GVC participation has not altered the centre of gravity of the production network – notably Germany – and it has mostly concerned manufacturing industries. Second, cross country and cross sector asymmetries, both in terms of patent and intangible intensities, persist and there is no sign of convergence. Third, while the share of managers increases across the board, the relative position of countries and industries has remained unchanged. Western and Central regions have experienced the largest increase in manager shares, suggesting a concentration of headquarter functions in this part of the continent, while Eastern Europe has remained specialised in fabrication functions with by far the largest share of manual workers.

In sum, the descriptive evidence discussed here is in line with the literature emphasising the existence of asymmetries in the international division of labour, both across countries and industries (Chen et al., 2017 Stöllinger, 2016, Mudambi 2007). Such asymmetries are persistent over time and concern both technological intensity and the employment structure, suggesting that, despite growing economic integration, the geographical and sectoral distribution of functions has remained, broadly speaking, unchanged.

In our discussion we have also looked at country-level patterns, which, while consistent with the evidence for macro-regions, also show a significant degree of cross-country variability and the importance of sectoral composition. In an effort to account for these factors in our analysis, we perform an econometric exercise to further probe into the structural features that emerged from the descriptive analysis.

5. GVCs, technology and employment in Europe

The evidence discussed in the previous section points to the existence of asymmetries both in terms of employment structure (share of managers and manual workers) and technological intensity (patents and intangible assets). We are therefore interested in assessing the extent to which these asymmetries shape the relationship between GVCs participation and employment outcomes (shares of managers and manual workers).

To do so, we perform an econometric test focusing on the period 2006-2014, while we use the preceding years in our sample (2000-2005) to construct pre-sample means (PSM)[13] of both employment structures and technological capabilities. Because we have seen that GVC

[13] Information on employment for Poland is only available from 2004 onwards and as a result we only rely on the years 2004 and 2005 to compute the PSM for this specific country.

participation is most relevant for manufacturing industries and these sectors also exhibit a higher variation in the share of managers and manual workers, we focus this part of our empirical analysis only on manufacturing industries, while taking into account also their linkages with service industries.

We would like to point out from the outset that our econometric exercise, rather than aiming at assessing the existence of causal relationships, pursues three specific goals that are in line with our aimed contributions, as discussed in section 2. First, we explicitly look at the degree of persistency of country-industries' initial functional specialisation captured by the employment structure. Second, we also investigate how the employment structure correlates with GVC participation and its quality, which we capture with our novel measures of patent and intangible intensity. Third, we focus on how initial technological asymmetries mediate the relationship between GVC participation, its quality and country-industries functional specialisation, i.e. whether the sign of these correlations changes from technological leaders to technological laggards. Based on the discussion above, our econometric test deals with these issues explicitly as follows:

$$\begin{aligned}\ln(y_{ijt}) = \; & \alpha + \sum_t \beta_t \ln(\bar{y}_{ijt_0}) + \delta_1 TopDecile_{ijt_0} + \\ & \beta_1 \ln(Bwd_{ijt}) + \gamma_1 TopDecile_{ijt_0} * \ln(Bwd_{ijt}) + \\ & \beta_2 \ln(BwdPatent_{ijt}) + \gamma_2 TopDecile_{ijt_0} * \ln(BwdPatent_{ijt}) + \\ & \beta_3 \ln(BwdIntangibles_{ijt}) + \gamma_3 TopDecile_{ijt_0} * \ln(BwdIntangibles_{ijt}) + \\ & \beta_4 \ln(Patint_{ijt}) + \delta_2 \ln(Capital_{ijt_0}) + \kappa_i + \varphi_j + \tau_t \qquad (10)\end{aligned}$$

Our outcome variable (y_{ijt}) is either the share of managers or that of manual workers in country-industry *ij* at time t (2006-2014), proxying for functional specialisation. We control for country, sector and year fixed effects (κ_i,φ_j and τ_t, respectively) and add the pre-sample mean (2000-05) of the outcome variable. The fixed effects should net out from our analysis the role of country, industry and time idiosyncrasies, while the pre-sample mean takes into account the time-invariant effects that shape country-industries' initial asymmetries in terms of employment structure.[14] Furthermore, interacting the pre-sample mean with time dummies allows us to control for the persistency of initial conditions over time, which is relevant for assessing whether there has been a convergence or divergence of the employment structure across country-industries over time. Finally the choice to use pre-sample means, rather than the classical fixed effect estimators, to absorb country-industries' pre-existing conditions is in line with the literature dealing with highly persistent variables (Blundell et al., 1995; 2002).

The use of pre-sample means of our outcome variable, coupled with our set of fixed effects, also allows us to include in our regression dummy variables for country-sectors' initial positioning in terms of technological capabilities, which traditional fixed effects would otherwise absorb. In particular, we capture initial technological asymmetries with a dummy variable $TopDecile_{ijt_0}$ taking value one, if the pre-sample mean of the country-industry patent intensity ranks in the top decile. We also present the results using a dummy for the bottom decile, used as a proxy of technological backwardness.[15] We interact this dummy with the measures of GVC participation, as well as the two measures of quality for backward patent and intangible intensity.[16] Given the persistency of initial positions in terms of patent intensity (see Figure 3) using dummies based on the pre-sample period is an appropriate strategy to study how initial technological asymmetries affect the relationship between GVC participation and employment.

We provide a list of country-industries that rank in the two top and bottom deciles in the Appendix (Table A4 and A5). What is worth noting here is that this ranking seems to be driven not only by sectoral determinants but also, and crucially, by country-level characteristics suggesting that technological asymmetries also reflect the differences in the strength of national innovation systems. More specifically, no sector from Eastern Europe is included in the top 2 deciles, while this is the case for low-tech sectors from Germany, e.g. the manufacture of

[14] We do not include in our specification a measure of relative wages as they are not readily available at this level of industrial disaggregation. However, they should be partly taken into account by our fixed effects and the inclusion of the PSM. In the Appendix (Table B5 and B6) we also test a more demanding specification using country-year and industry-year fixed effects that account for all country and industry level time trends.

[15] We have also tested our results by including both dummies with the respective interactions and they remained unchanged. We do not report them in the interest of space, but they are available upon request.

[16] Recall from equations 8 and 9 that backward patent intensity is computed for each country-industry, based on the patent intensity of its *manufacturing* partners, while backward intangible intensity is based only on *service* partners. As a result, these two variables capture the quality of manufacturing and service partners, respectively, which is why we include them both in our analysis.

textiles (sector C13-C15). In contrast, no sector from the region Centre is included in the two bottom deciles, while relatively high-tech sectors such as the automotive industry (C29) from Eastern European countries – e.g. Poland, Romania and Slovakia – rank in the bottom decile for patent intensity.

We also include measures of GVC participation and of the quality of GVC partners, distinguished between manufacturing and service partners. This is important because manufacturing industries importing value added from other manufacturing partners are more likely to experience a competition effect (Gagliardi 2019), while importing value added especially from service sectors with high levels of intangible capital can be beneficial for upgrading due to knowledge and skill complementarities (Meliciani and Savona, 2015).

Finally, we add two control variables to our specification. First, we take into account the fact that while the initial technological position matters, as country-industries engage with GVCs, their technological intensity is also likely to evolve over time and that this could impact their employment structure in turn. For this reason, we control for country-industries' own patent intensity during our period of analysis (2006-2014) as computed in equation 6 above. Additionally, we include a measure of capital intensity, measured for the pre-sample period, which we compute as a country-industry's total capital stock, retrieved from EUKLEMS, divided by total employment, from EULFS.

6. Results

We first only include traditional measures of backward GVC participation and its interaction with initial technological intensity (column 1 and 5) and we progressively add our measures of technological quality of GVC participation, both in terms of patent intensity of foreign manufacturing suppliers and intangibles intensity of foreign service suppliers.

Table 1 – GVC participation, quality and employment structure: results controlling for the initial technological intensity (top decile)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.505***	0.509***	0.498***	0.503***	0.695***	0.697***	0.678***	0.682***
	(0.0387)	(0.0391)	(0.0385)	(0.0389)	(0.0428)	(0.0424)	(0.0426)	(0.0423)
2007*PSM	0.535***	0.537***	0.529***	0.531***	0.706***	0.708***	0.689***	0.692***
	(0.0377)	(0.0377)	(0.0375)	(0.0375)	(0.0505)	(0.0497)	(0.0510)	(0.0504)
2008*PSM	0.460***	0.462***	0.453***	0.455***	0.598***	0.599***	0.577***	0.580***
	(0.0514)	(0.0509)	(0.0513)	(0.0508)	(0.0512)	(0.0509)	(0.0505)	(0.0502)
2009*PSM	0.390***	0.397***	0.382***	0.390***	0.602***	0.604***	0.578***	0.583***
	(0.0403)	(0.0408)	(0.0402)	(0.0406)	(0.0487)	(0.0477)	(0.0480)	(0.0472)
2010*PSM	0.437***	0.442***	0.432***	0.438***	0.615***	0.617***	0.592***	0.597***
	(0.0385)	(0.0387)	(0.0386)	(0.0387)	(0.0524)	(0.0518)	(0.0506)	(0.0503)
2011*PSM	0.444***	0.448***	0.438***	0.443***	0.673***	0.674***	0.648***	0.652***
	(0.0488)	(0.0489)	(0.0490)	(0.0490)	(0.0559)	(0.0548)	(0.0549)	(0.0539)
2012*PSM	0.392***	0.397***	0.383***	0.389***	0.689***	0.691***	0.660***	0.665***
	(0.0435)	(0.0436)	(0.0438)	(0.0438)	(0.0550)	(0.0548)	(0.0537)	(0.0536)
2013*PSM	0.414***	0.421***	0.404***	0.411***	0.636***	0.638***	0.606***	0.611***
	(0.0713)	(0.0716)	(0.0718)	(0.0720)	(0.0530)	(0.0525)	(0.0520)	(0.0517)
2014*PSM	0.378***	0.385***	0.366***	0.374***	0.667***	0.669***	0.636***	0.641***
	(0.0551)	(0.0560)	(0.0549)	(0.0556)	(0.0536)	(0.0534)	(0.0523)	(0.0525)
Bwd GVC	0.00246	-0.000217	0.00218	-0.000438	0.0146*	0.0146*	0.0134	0.0135
	(0.0127)	(0.0126)	(0.0127)	(0.0126)	(0.00832)	(0.00842)	(0.00830)	(0.00839)
Top decile patent$_{t0}$	0.0441	-0.200	0.734*	0.583	-0.110***	-0.0955	-1.308***	-1.271***
	(0.0421)	(0.129)	(0.424)	(0.444)	(0.0265)	(0.103)	(0.321)	(0.347)
Top decile patent$_{t0}$ *Bwd GVC	0.0226	0.0272	0.0167	0.0235	-0.0377***	-0.0380***	-0.0405***	-0.0414***
	(0.0224)	(0.0225)	(0.0222)	(0.0222)	(0.0123)	(0.0122)	(0.0121)	(0.0119)
Bwd Patent		-0.0690		-0.0640		-0.00110		-0.00337
		(0.0627)		(0.0629)		(0.0271)		(0.0267)
Top decile patent$_{t0}$ *Bwd Patent		-0.0972**		-0.119**		0.00561		0.0167
		(0.0486)		(0.0488)		(0.0374)		(0.0375)
Bwd intangibles			0.644***	0.640***			-0.253**	-0.255**
			(0.208)	(0.208)			(0.115)	(0.114)
Top decile patent$_{t0}$ *Bwd Intangibles			0.236*	0.285**			-0.401***	-0.403***
			(0.141)	(0.136)			(0.106)	(0.105)
Patents	-0.0286**	-0.0284**	-0.0212*	-0.0210*	0.0104*	0.0104*	0.00744	0.00737
	(0.0123)	(0.0122)	(0.0127)	(0.0126)	(0.00615)	(0.00616)	(0.00636)	(0.00637)
Capital$_{t0}$	0.0441***	0.0440***	0.0443***	0.0441***	-0.0334***	-0.0334***	-0.0329***	-0.0329***
	(0.0145)	(0.0145)	(0.0143)	(0.0143)	(0.00609)	(0.00609)	(0.00599)	(0.00599)
Constant	-0.980***	-1.168***	0.966	0.782	-0.0156	-0.0182	-0.801**	-0.814**
	(0.107)	(0.210)	(0.648)	(0.685)	(0.0405)	(0.0851)	(0.354)	(0.353)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.741	0.741	0.742	0.743	0.822	0.822	0.825	0.825

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The interaction of the pre-sample mean of the outcome variable (shares of managers and manual workers) with time trends is always positive and significant, throughout our results, which is consistent with the descriptive evidence of the strong persistence of the employment structure over time. Despite significant changes in the share of managers and manual workers that occurred over our observed time period throughout countries and industries, the initial employment structure remains a strong predictor of future employment shares, with little evidence of a convergence among countries-sectors located in the centre and periphery of the EU. This also confirms the descriptive evidence in Figure 4, discussed in the previous sections.

Concerning the relationship between the GVC participation and the employment structure, our results show that the shares of managers or manual workers are not related to the level of integration in and of itself. However, we find evidence of a different relationship for country-industries that start off among the top decile for patent intensity. The negative and statistically significant coefficient of the interaction term (Top decile patent *Bwd GVC) in columns 5-8 suggests that country-industries with high patent intensity do see their share of manual workers decrease as they expand their backward GVC participation, while we find no such evidence for the share of managers.[17] This is consistent with the results of the literature on the "skill-biased effect of offshoring" (Strauss-Kahn, 2003; Hijzen et al., 2005; Falzoni and Tajoli, 2012; Crinò, 2012 and Foster-McGregor et al., 2013).

But does the relationship between GVC integration and the structure of employment vary also according to the quality of the partner? Specifications (2), (3) and (4) look at this question for the share of managers, taking into account the patent intensity of GVC (manufacturing) partners, the intangible intensity of GVC (service) partners and both of them, respectively. The same analysis is reported for the share of manual workers in columns (6), (7) and (8).

We find that the quality of manufacturing partners, i.e. backward patent intensity, is significantly related to the share of managers only for top decile country-industries, leading to a decrease in the share of this occupational category (columns 2 and 4). It therefore appears

[17] Naturally, whether a country-sector ranks in the top decile is going to be driven by both country and sector-level features that will also impact both GVC participation and employment structure. These are however controlled for by the inclusion of country and sector fixed effects in our specification. As a result, the dummy is capturing the role of being among the top decile and therefore having a technological advantage, depurated from other country and sector time-invariant effects.

that the country-industries that are among the top technological performers (high patent intensity) see their share of managers reduced as they engage with high-technology suppliers. While our empirical approach does not aim at gauging clear-cut causal relationships, this evidence is suggestive of a competition mechanism: as technological leaders increase their integration with other patent intensive partners, some of the managerial positions are offshored towards these new partners. This conjecture is also in line with the evidence put forward by Foster-McGregor et al. (2016), as well as with the micro level evidence on the negative effect of foreign technological innovation on domestic employment (Gagliardi 2019).

When we turn to the relationship between the employment structure of manufacturing industries and the quality of the imported service inputs, we find that the content in knowledge-based intangible assets of these inputs has a positive relationship with the share of managers and a negative one with the share of manual workers. As manufacturing country-sectors engage with service providers with high intangible intensity (Bwd Intangibles), they tend to have larger shares of headquarter (managers) functions and smaller ones of fabrication (manual workers) functions. Interaction terms are statistically significant both for manager shares (positive sign) and manual worker shares (negative sign). The positive and significant interaction between the quality of partners and the dummy for the top decile (Top decile patent$_{t0}$ *Bwd Intang) suggests that technological leaders in the manufacturing industries draw even larger benefits, in terms of employment structure, from the quality of their service providers.

We thus find evidence of complementarity, rather than competition, between the quality of the service inputs imported and the employment structure of manufacturing industries. This is in contrast to the results for the quality of manufacturing GVC partners, but it confirms the importance of the link between services and manufacturing industries, for which a growing body of evidence is emerging in the literature (Evangelista et al. 2013; Meliciani and Savona 2015; Lopez-Gonzalez et al., 2019).

In sum, three findings emerge from the evidence discussed so far. First, employment structure and therefore functional specialisation are highly persistent over time and have shown no sign of convergence, despite significant increases in GVC participation throughout Europe. Second, GVC participation in and of itself does not seem to be related to countries' employment structure. In contrast, the quality of GVC participation, especially of foreign service providers, does matter for shifting the employment structure towards managerial functions. Finally, the country-industries' initial technological position matters also: those that start off as technological leaders are likely to have larger shares of their workforce in managerial (headquarter) functions and smaller shares in fabrication functions as they further integrate into GVCs.

We complement the evidence on the importance of being a technological leader by exploring whether having a technological disadvantage also plays a role in affecting the relationship between GVC participation and employment structure. We replace our $TopDecile_{ijt_0}$ dummy with $BottomDecile_{ijt_0}$ taking value 1 if a manufacturing country-sector is in the bottom decile in terms of patent intensity.

Table 2 – GVC participation, quality and employment structure: results controlling for the initial technological intensity (bottom decile)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.486***	0.483***	0.479***	0.476***	0.703***	0.703***	0.697***	0.698***
	(0.0383)	(0.0383)	(0.0381)	(0.0382)	(0.0449)	(0.0449)	(0.0449)	(0.0449)
2007*PSM	0.518***	0.516***	0.511***	0.509***	0.715***	0.715***	0.708***	0.709***
	(0.0370)	(0.0368)	(0.0368)	(0.0366)	(0.0525)	(0.0524)	(0.0529)	(0.0529)
2008*PSM	0.443***	0.441***	0.436***	0.434***	0.607***	0.608***	0.600***	0.601***
	(0.0502)	(0.0496)	(0.0499)	(0.0494)	(0.0513)	(0.0512)	(0.0512)	(0.0513)
2009*PSM	0.373***	0.371***	0.366***	0.364***	0.613***	0.613***	0.607***	0.608***
	(0.0393)	(0.0392)	(0.0390)	(0.0389)	(0.0484)	(0.0484)	(0.0484)	(0.0485)
2010*PSM	0.421***	0.419***	0.418***	0.416***	0.630***	0.631***	0.627***	0.628***
	(0.0371)	(0.0370)	(0.0370)	(0.0369)	(0.0520)	(0.0521)	(0.0512)	(0.0513)
2011*PSM	0.428***	0.428***	0.424***	0.424***	0.689***	0.690***	0.685***	0.686***
	(0.0474)	(0.0472)	(0.0473)	(0.0472)	(0.0542)	(0.0542)	(0.0537)	(0.0537)
2012*PSM	0.378***	0.376***	0.371***	0.369***	0.707***	0.708***	0.701***	0.702***
	(0.0428)	(0.0426)	(0.0428)	(0.0426)	(0.0534)	(0.0533)	(0.0530)	(0.0529)
2013*PSM	0.400***	0.400***	0.391***	0.391***	0.654***	0.655***	0.647***	0.648***
	(0.0706)	(0.0704)	(0.0708)	(0.0706)	(0.0518)	(0.0518)	(0.0514)	(0.0515)
2014*PSM	0.364***	0.364***	0.354***	0.354***	0.685***	0.686***	0.677***	0.678***
	(0.0549)	(0.0551)	(0.0545)	(0.0546)	(0.0524)	(0.0524)	(0.0517)	(0.0518)
Bwd GVC	0.00853	0.00761	0.00829	0.00684	0.00890	0.00926	0.00761	0.00782
	(0.0128)	(0.0129)	(0.0132)	(0.0131)	(0.00836)	(0.00842)	(0.00866)	(0.00866)
Bottom decile patent$_{t0}$	0.0380	-0.195	-0.160	-0.169	-0.0520*	-0.100	0.295	0.288
	(0.0566)	(0.275)	(0.602)	(0.598)	(0.0270)	(0.150)	(0.383)	(0.384)
Bottom decile patent $_{t0}$ *Bwd GVC	-0.0416**	-0.0471**	-0.0445**	-0.0516**	0.0265**	0.0255**	0.0283**	0.0260**
	(0.0186)	(0.0200)	(0.0186)	(0.0204)	(0.0110)	(0.0121)	(0.0111)	(0.0120)
Bwd Patent		-0.0757		-0.0690		0.00686		0.00375
		(0.0621)		(0.0623)		(0.0266)		(0.0262)
Bottom decile patent $_{t0}$ *Bwd Patent		-0.0743		-0.104		-0.0155		-0.0356
		(0.0877)		(0.0954)		(0.0442)		(0.0471)
Bwd intangibles			0.720***	0.711***			-0.380***	-0.380***
			(0.184)	(0.185)			(0.107)	(0.107)
Bottom decile patent $_{t0}$ *Bwd Intang,			-0.0615	0.0421			0.111	0.145
			(0.199)	(0.218)			(0.123)	(0.136)
Patents	-0.0137	-0.0132	-0.00693	-0.00628	-0.00532	-0.00542	-0.00847	-0.00848
	(0.0124)	(0.0123)	(0.0127)	(0.0126)	(0.00646)	(0.00650)	(0.00657)	(0.00658)
Capital $_{t0}$	0.0482***	0.0489***	0.0486***	0.0495***	-0.0363***	-0.0361***	-0.0361***	-0.0358***
	(0.0144)	(0.0144)	(0.0142)	(0.0141)	(0.00598)	(0.00595)	(0.00585)	(0.00582)
Constant	-0.966***	-1.182***	1.206**	0.980	-0.0634	-0.0445	-1.222***	-1.212***
	(0.106)	(0.209)	(0.582)	(0.623)	(0.0413)	(0.0842)	(0.330)	(0.329)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.744	0.745	0.746	0.746	0.828	0.828	0.830	0.830

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results for this second specification are reported in Table 2 and are essentially in line with the three main results emerged from Table 1. GVC participation alone is not significantly correlated to the employment structure. However, as the country-industries that at the beginning of our observed period were in the bottom decile for patent intensity further integrate into GVC (Bottom decile $patent_{t0}$ *Bwd GVC), we observe lower shares of employment in managerial functions and more in fabrication functions (see the negative and significant interaction term for the share of managers and positive and significant interaction coefficient for the share of manual workers). This suggests that the country-industries that have started to integrate into GVCs from the lower rungs of the technological ladder have mainly specialised in fabrication functions, without managing to upgrade to headquarter positions.

The (average) patent intensity of foreign manufacturing suppliers does not seem to be related to employment structure and this also applies to country-industries in the bottom decile for patent intensity. In contrast, the quality of service providers, i.e. backward intangible intensity, exhibits a positive coefficient, confirming the results in Table 1. However, the interaction term is not statistically significant, indicating that the relationship is not different for the country-industries that are in the bottom decile for patent intensity.

Finally, the key results are subjected to a range of robustness checks, which we present in the Appendix. We construct our dummy variables for being leaders or laggards in technological intensity using the two, rather than the first, top and bottom deciles (Tables B1 and B2). We also weight our results on sectors' total employment to make sure that our results are not driven by sectors that account for very small shares of total employment (Tables B3 and B4). Finally, we also test a more demanding specification using country-year and industry-year fixed effects (Tables B5 and B6). This is an attempt to check for changes in demand and/or policy, such as labour market reforms and relative wages that affect all sectors within the same country, or changes in sectors' technology that affect all countries, which we discuss more at length in the Appendix.

7. Summary and conclusion

Our paper has looked at the interplay between GVC and technology and its impact on the employment structure in the EU. We build on the concept of functional specialisation to look at changes in the share of employment in headquarter and fabrication occupation, which we interpret in terms of employment upgrading (or lack thereof) associated with the participation in GVCs.

Our empirical analysis shows that European economies have considerably increased their economic integration between 2000 and 2014, but this process has not shifted the centre of gravity of the EU production landscape, in which Germany remains a pivotal player. Also, looking at the intensity in technology and intangible assets, as well as the employment structure, we find the persistence of stark country (and sectoral) technological asymmetries, with no sign of any substantial process of convergence in the employment structure.

We expand these descriptive insights by focusing on manufacturing industries and taking into full account the persistence of the employment structure and the role of initial technological positioning to explore how they affect the relationship between GVC participation, its technological quality and employment structure.

In our econometric analysis, we find confirmation of the highly inertial and structural dimension of employment composition, suggesting that there is no automatic convergence across countries and industries in terms of functional specialisation that can be explicitly attributed to integration into GVCs. Moreover, GVC participation alone has no significant relationship with the employment structure, but is mediated by country-industries' initial technological strength.

Specifically, country-sectors that are leading in terms of patent intensity have lower employment shares in fabrication functions as they integrate into GVCs. They also seem to experience competition from other patent intensity manufacturing partners, towards which they offshore managerial positions. In contrast, higher intensity in intangible assets from GVC partners in services is associated with higher shares of managers and lower shares of manual workers, and these relationships are stronger for the country-industries endowed with strong technological capabilities.

Country-sectors characterised by poor technological performance show an opposite specular pattern. They exhibit lower shares of employment in managerial functions and larger ones in fabrication activities. This suggests that the European countries and sectors that have joined GVCs with limited technological capabilities have not been able to upgrade their employment structures. On the contrary, they seem to have been pushed towards a specialisation in fabrication and, arguably, low value-added functions.

In sum, we find no evidence of convergence in employment structures across the European continent. This has important implications for policies, especially in the current context in which Europe is facing a double dip recession with the aftermath of the financial crisis and the shock of the Covid pandemic, and is about to deploy considerable resources to foster the recovery. The health crisis has highlighted the deep interdependencies that link European countries. Economic integration to the degree achieved in Europe is arguably irreversible and has afforded significant opportunities for development, but it has not reduced the initial technological asymmetries and gaps in the quality of employment structures of EU countries.

More specifically, the policy implications deriving from this contribution can be conveyed through three key messages. First, the evidence presented seems to suggest that the significant extension and deepening of GVCs in Europe has not helped to achieve the EU cohesion targets. While peripheral regions in Europe, especially Eastern Europe, have successfully integrated into GVCs and have seen their income increase, their occupational structure has not undergone the same sweeping upgrading. As a result, the structure of Europe's production network has remained unchanged with Germany (and other countries in the North-West part of the continent) at its core and the peripheral regions specialising in fabrication activities. This has great policy relevance because it means that GVC integration has made different jobs available in different regions, providing different occupational opportunities. Within the current context of the health emergency, it is also important to stress that managerial positions are more likely to be carried out remotely, while manual work usually requires workers to be on site. Obviously this has major implications with respect to how severely these occupations have been affected by the COVID-19 pandemic and the measures countries have implemented to contrast the pandemic (Savona, 2020; Adam-Prassl et al., 2020).

Second, and in relation to the previous point, countries and industries' initial technological advantages constrain their ability to benefit from GVC integration, which should therefore be accompanied and possibly preceded by policies favouring the upgrading of skills and technological capabilities to facilitate processes of integration that are less asymmetrical. By introducing policies that will strengthen country-industries' technological capabilities, as (if not before) they integrate into GVCs, policymakers will be able to increase the probability that GVC integration will also be accompanied by a change in the employment structure, with a shift towards managerial occupations and headquarter functions. Since considerable resources are about to be used to sustain the recovery from the pandemic, policymakers should therefore bear in mind that building technological advantages in key sectors will also allow countries and sectors to benefit from further integration in the global economy.

Finally, the evidence put forward in this paper calls for the adoption of a more systemic approach to EU cohesion policies. This should be based on a detailed analysis of the pattern and the effects of the ongoing changes in the geography of production in Europe and include the possibility of implementing pan-European policies to govern such processes, ensuring that the benefits of economic integration are distributed more evenly across European countries and industries. Our analysis has in fact provided additional evidence of the fact that production within Europe is highly interconnected across countries and that the persisting asymmetries along GVCs can be hard to tackle at the national level alone. This therefore warrants a broader approach.

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Appendix A – Grouping of countries, industries and occupations

This section of the appendix reports the grouping of countries in regions (Table A1) and industries in macro-sectors (Table A2 and A3) that we use to present the descriptive evidence in section 4. We also show which country-industries rank in the top and bottom two deciles of the distribution of patent intensity among manufacturing industries (Table A4 and A5, respectively). This ranking is used to construct our dummy variables $TopDecile_{ijt_0}$ and $BottomDecile_{ijt_0}$ which we use in turn in our econometric analysis as discussed in section 5.

We also report some key descriptive evidence on the distribution and evolution of the variables used in Figure 2 to 4, this time at the country level. These can be found in Tables A6 to A10.

Table A1 – Countries and regions

Region	Centre	East	North	South	West
Country	Austria Belgium Germany France The Netherlands	Bulgaria The Czech Republic Croatia Hungary Poland Romania Slovakia	Denmark Finland Sweden	Spain Greece Italy Portugal	Great Britain Ireland

Table A2 – Manufacturing industries

NACE	Description	Macro sector
C10-C12	Manufacture of food products, beverages and tobacco products	LTMF
C13-C15	Manufacture of textiles, wearing apparel and leather products	LTMF
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	LTMF
C17	Manufacture of paper and paper products	LTMF
C18	Printing and reproduction of recorded media	LTMF
C20-C21	Manufacture of chemicals and pharmaceutical products	HTMF
C22	Manufacture of rubber and plastic products	LTMF
C23	Manufacture of other non-metallic mineral products	LTMF
C24	Manufacture of basic metals	LTMF
C25	Manufacture of fabricated metal products, except machinery and equipment	LTMF
C26	Manufacture of computer, electronic and optical products	HTMF
C26	Manufacture of computer, electronic and optical products	HTMF
C26	Manufacture of computer, electronic and optical products	HTMF
C27	Manufacture of electrical equipment	HTMF
C28	Manufacture of machinery and equipment n.e.c.	HTMF
C29	Manufacture of motor vehicles, trailers and semi-trailers	HTMF
C30	Manufacture of other transport equipment	HTMF
C31-C32	Manufacture of furniture; other manufacturing	LTMF

Table A3 – Service industries

NACE	Description	Macro sector
G45	Wholesale and retail trade and repair of motor vehicles and motorcycles	LKBS
G46	Wholesale trade, except of motor vehicles and motorcycles	LKBS
G47	Retail trade, except of motor vehicles and motorcycles	LKBS
H49	Land transport and transport via pipelines	LKBS
H50	Water transport	KIS
H51	Air transport	KIS
H52	Warehousing and support activities for transportation	LKBS
I	Accommodation and food service activities	LKBS
J61-H53	Post and telecommunication	KIS
J62-J63	Computer programming, consultancy and related activities; information service activities	KIBS
K64	Financial service activities, except insurance and pension funding	KIS
K65	Insurance, reinsurance and pension funding, except compulsory social security	KIS
K66	Activities auxiliary to financial services and insurance activities	KIS
M-N	Business services	KIBS
M72	Scientific research and development	KIBS
R-S	Other service activities	KIS

Table A4 – Manufacturing country-industries in the top two deciles for patent intensity

Country	NACE	Decile
AUT	C20-C21; C26; C30	Tenth decile
BEL	C26	
DEU	C13-C15; C17; C20-C21; C23; C26; C31-C32	
DNK	C20-C21; C26	
FIN	C20-C21; C23; C26	
FRA	C20-C21; C23; C26; C27; C28; C31-C32	
GBR	C20-C21; C26	
ITA	C26	
NLD	C23; C26; C27	
SWE	C13-C15; C20-C21; C22; C23; C26; C31-C32	
AUT	C22; C23; C28; C31-C32	Ninth Decile
BEL	C17; C20-C21	
DEU	C22; C24; C27; C28; C30	
DNK	C17; C23; C24; C27; C29	
FIN	C27; C29; C31-C32	
FRA	C17; C24	
GBR	C17; C23; C28	
GRC	C26	
HUN	C20-C21	
ITA	C20-C21	
NLD	C17; C20-C21; C22; C24; C28	
SWE	C27; C28	

Table A5 – Manufacturing country-industries in the bottom two deciles for patent intensity

Country	NACE	Decile
BGR	C13-C15	First Decile
CZE	C16; C18	
ESP	C18	
GRC	C18	
HRV	C16	
HUN	C18	
IRL	C18	
POL	C10-C12; C16; C18; C22; C25; C29	
PRT	C10-C12; C13-C15; C16; C17; C18; C25	
ROU	C10-C12; C13-C15; C16; C17; C18; C22; C24; C25; C29; C31-C32	
SVK	C16; C18; C24; C29	
BGR	C10-C12; C18; C23; C24; C25; C29	Second Decile
CZE	C10-C12; C22; C25; C29	
FIN	C18	
GRC	C10-C12; C13-C15	
HRV	C10-C12; C13-C15; C25; C30	
HUN	C13-C15; C16; C29	
POL	C13-C15; C17; C24; C30; C31-C32	
PRT	C22; C23; C27; C29	
ROU	C30	
SVK	C10-C12; C17; C22; C25	

Table A6 – Country-level descriptive evidence on GVC backward participation

Country	Mean	Median	Change	Percentage change
AUT	0.13	0.13	0.04	36.61
BEL	0.18	0.16	0.08	51.18
BGR	0.08	0.08	0.11	543.87
CZE	0.12	0.12	0.07	76.86
DEU	0.07	0.07	0.03	59.98
DNK	0.15	0.16	0.05	37.61
ESP	0.05	0.05	0.02	36.54
FIN	0.09	0.09	0.04	62.07
FRA	0.08	0.08	0.04	54.13
GBR	0.06	0.06	0.02	35.86
GRC	0.03	0.02	0.02	81.09
HRV	0.10	0.10	0.05	57.98
HUN	0.18	0.17	0.08	53.41
IRL	0.20	0.18	0.09	49.13
ITA	0.04	0.04	0.02	70.59
NLD	0.14	0.12	0.07	66.23
POL	0.09	0.09	0.04	65.32
PRT	0.08	0.08	0.06	130.75
ROU	0.07	0.07	0.01	18.93
SVK	0.18	0.18	0.09	72.19
SWE	0.10	0.10	0.02	21.61

The table reports the distribution and long-term change of country-level averages over time and across industries.

Table A7 – Country-level descriptive evidence on patent stock intensity

Country	Mean	Median	Change	Percentage change
AUT	0.07	0.07	-0.01	-7.02
BEL	0.07	0.06	0.04	73.78
BGR	0.01	0.01	0.01	80.91
CZE	0.01	0.01	0.00	58.35
DEU	0.11	0.11	-0.01	-12.45
DNK	0.09	0.08	0.05	75.41
ESP	0.02	0.02	0.02	113.31
FIN	0.06	0.06	0.02	35.96
FRA	0.09	0.09	0.02	25.03
GBR	0.07	0.07	0.01	14.53
GRC	0.02	0.02	0.02	176.09
HRV	0.01	0.01	0.01	83.30
HUN	0.01	0.01	0.00	-13.31
IRL	0.04	0.02	0.13	681.82
ITA	0.04	0.04	0.00	9.46
NLD	0.09	0.10	0.01	11.69
POL	0.00	0.00	0.01	350.83
PRT	0.01	0.01	0.01	417.46
ROU	0.00	0.00	0.00	257.37
SVK	0.00	0.00	0.00	-1.73
SWE	0.09	0.09	0.01	15.85

The table reports the distribution and long-term change of country-level averages over time and across industries.

Table A8 – Country-level descriptive evidence on intangible assets intensity

Country	Mean	Median	Change	Percentage change
AUT	0.052	0.050	0.012	25.15
BEL	0.045	0.044	0.011	27.95
BGR				
CZE	0.034	0.035	0.003	8.74
DEU	0.043	0.042	-0.003	-6.11
DNK	0.058	0.056	0.006	11.75
ESP	0.031	0.029	0.006	19.47
FIN	0.062	0.061	0.005	8.47
FRA	0.064	0.064	0.014	23.69
GBR	0.059	0.059	-0.008	-12.84
GRC	0.033	0.033	-0.005	-13.04
HRV				
HUN	0.035	0.033	-0.010	-31.00
IRL	0.046	0.045	0.022	69.27
ITA	0.036	0.036	0.001	3.46
NLD	0.051	0.051	0.002	4.80
POL				
PRT	0.039	0.039	0.009	27.12
ROU				
SVK	0.028	0.027	0.002	7.06
SWE	0.078	0.078	0.004	5.17

The table reports the distribution and long-term change of country-level averages over time and across industries. Poland, Romania, Croatia and Bulgaria are missing from the INTANINVEST dataset.

Table A9 – Country-level descriptive evidence on the share of managers

Country	Mean	Median	Change	Percentage change
AUT	0.36	0.38	0.17	73.87
BEL	0.39	0.39	0.05	13.64
BGR	0.34	0.34	-0.01	-3.22
CZE	0.38	0.38	0.03	8.22
DEU	0.36	0.36	-0.01	-1.75
DNK	0.44	0.44	-0.01	-2.71
ESP	0.35	0.35	0.05	15.04
FIN	0.42	0.41	0.04	9.42
FRA	0.43	0.42	0.10	26.55
GBR	0.41	0.41	0.07	18.93
GRC	0.33	0.32	0.02	7.21
HRV	0.36	0.35	0.05	13.13
HUN	0.33	0.33	0.03	9.93
IRL	0.35	0.35	0.08	27.84
ITA	0.34	0.35	0.09	32.15
NLD	0.41	0.41	0.04	9.79
POL	0.38	0.38	0.04	11.49
PRT	0.32	0.31	0.07	21.93
ROU	0.32	0.32	0.04	12.92
SVK	0.35	0.35	0.01	2.75
SWE	0.43	0.42	0.04	9.30

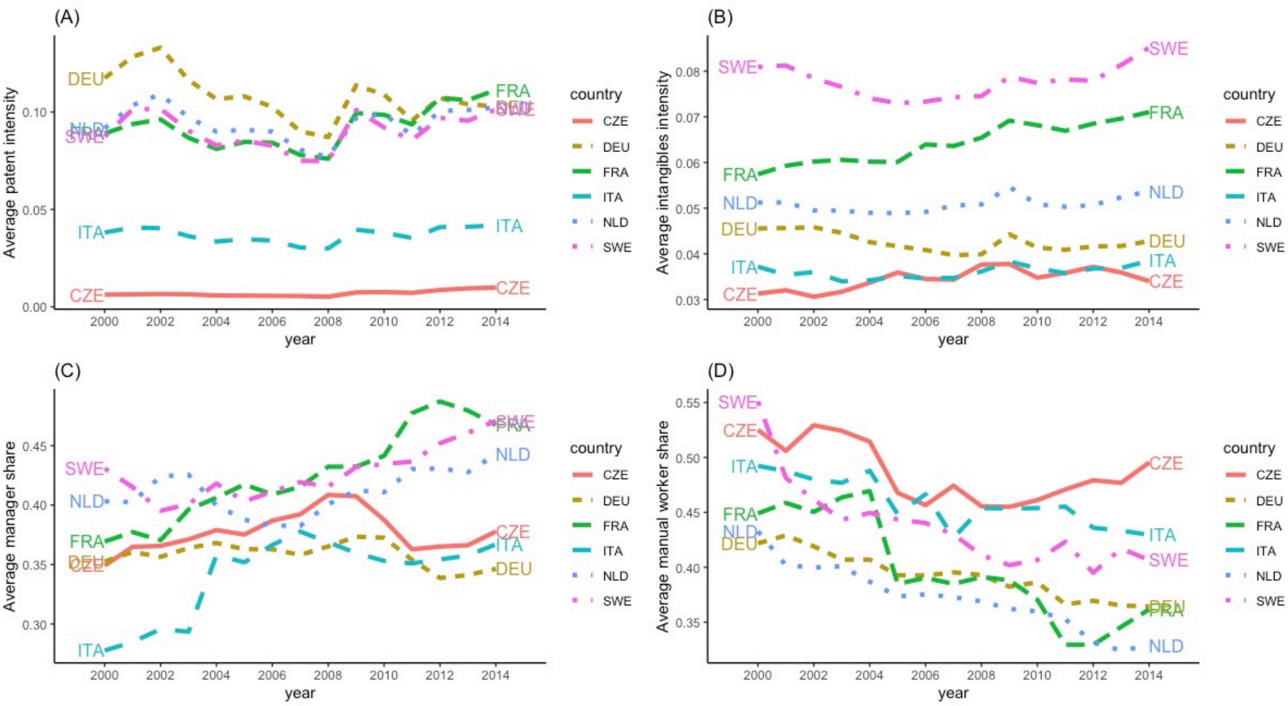
The table reports the distribution and long-term change of country-level averages over time and across industries. Information on employment in Poland is only available from 2004 onwards, therefore long-term changes for this country refer to the period 2004-14.

Table A10 – Country-level descriptive evidence on the share of manual workers

Country	Mean	Median	Change	Percentage change
AUT	0.43	0.41	-0.13	-25.41
BEL	0.46	0.44	-0.12	-22.20
BGR	0.54	0.54	-0.07	-11.28
CZE	0.49	0.48	-0.03	-5.66
DEU	0.39	0.39	-0.06	-13.61
DNK	0.49	0.45	-0.18	-28.38
ESP	0.47	0.45	-0.09	-16.85
FIN	0.47	0.46	-0.07	-13.56
FRA	0.40	0.39	-0.09	-19.46
GBR	0.39	0.39	-0.05	-12.78
GRC	0.49	0.46	-0.11	-18.87
HRV	0.51	0.51	-0.01	-2.08
HUN	0.52	0.51	-0.02	-2.80
IRL	0.45	0.45	-0.03	-6.92
ITA	0.46	0.45	-0.06	-12.76
NLD	0.37	0.37	-0.10	-24.05
POL	0.50	0.50	-0.11	-18.79
PRT	0.54	0.54	-0.10	-17.54
ROU	0.56	0.55	-0.09	-13.87
SVK	0.53	0.51	-0.07	-11.83
SWE	0.44	0.43	-0.14	-26.20

The table reports the distribution and long-term change of country-level averages over time and across industries. Information on employment in Poland is only available from 2004 onwards, therefore long-term changes for this country refer to the period 2004-14.

Figure A1 – Patent, intangibles intensity and shares of managers and manual workers across selected countries and over time



Source: authors' calculations using REGPAT, INTANINVEST and LFS data – unweighted average across macro regions and sectors for patent and intangible intensity.

Table A11 – Occupations and functions

ISCO label	ISCO88	Function
Legislators, senior officials and managers	01	Managers
Professionals	02	Managers
Technicians and associate professionals	03	Managers
Craft and related trades workers	07	Manual workers
Plant and machine operators and assemblers	08	Manual workers
Elementary occupations	09	Manual workers

Appendix B – Robustness checks

This section reports and briefly discusses some robustness checks of our results from the econometric analysis presented in section 5 and discussed in section 6 in the main text.

Naturally, the choice of using a dummy taking value one when a country-industry ranks in the top (or bottom) decile, while appropriate for identifying leaders and laggards in patent intensity, is somewhat arbitrary. We therefore replicate our results, setting the threshold to identify country-industries in the top and bottom for patent intensity as the second and ninth (rather than first and tenth) decile.

Table B1 reports our results looking at the interaction between a dummy taking value one if a country-industry is in the top 20% for patent intensity. As we enlarge the group of country-industries we consider leaders in patent intensity, the interaction term loses statistical significance, suggesting that the relationship between GVC backward participation and the share of managers is no longer different for this larger group of technological leaders from the rest of country-industries in our sample.

Interestingly, we also find a change in significance for the interaction of our dummy variable with the backward patent intensity, which captures the technological quality of backward linked GVC partners. In our main model we find a negative sign, suggesting a competition/substitution effect that leads technological leaders to offshore managerial occupations to other technologically intensive GVC partners. Now we find no evidence of this effect and in contrast we find that country-industries in the top 20% for patent intensity that import value added from other patent intensive partners tend to have lower shares of manual workers. This evidence hints at a possible spillover effect that we discussed in section 4: as country-industries with a solid technological base participate in GVC with other technological intensive partners, they also shift their employment structures away from fabrication activities.

Concerning the relationship between intangible intensity of backward linked GVC partners and employment structure, we find overall consistent results with our preferred specification, with the exception of the loss of significance of the interaction term for the share of managers (columns 3 and 4).

Table B2 replicates the results for Table 2 in the main text, thus focusing on the country-industries in the bottom 20% (rather than 10%) for patent intensity. We find our main results to be robust and there are two additional features at play too. First, country-industries in the bottom 20% see their share of managers decrease as they import value added from high patent intensity partners (columns 2 and 4) and higher shares of manual workers as they integrate with service GVC partners that are intensive in intangibles. Overall, this confirms the idea that country-industries that are lagging in technological intensity stand to reap smaller benefits, in terms of employment structure, from integrating in GVCs with partners of high technological quality.

Table B1 – GVC participation, quality and employment structure in the top two deciles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.507***	0.504***	0.500***	0.497***	0.718***	0.689***	0.699***	0.671***
	(0.0387)	(0.0390)	(0.0385)	(0.0389)	(0.0413)	(0.0436)	(0.0413)	(0.0437)
2007*PSM	0.538***	0.535***	0.531***	0.529***	0.729***	0.706***	0.709***	0.688***
	(0.0375)	(0.0375)	(0.0374)	(0.0373)	(0.0489)	(0.0499)	(0.0496)	(0.0507)
2008*PSM	0.463***	0.461***	0.456***	0.454***	0.622***	0.600***	0.599***	0.579***
	(0.0513)	(0.0508)	(0.0512)	(0.0507)	(0.0497)	(0.0509)	(0.0494)	(0.0506)
2009*PSM	0.392***	0.389***	0.384***	0.382***	0.624***	0.589***	0.599***	0.566***
	(0.0401)	(0.0406)	(0.0401)	(0.0405)	(0.0461)	(0.0484)	(0.0459)	(0.0486)
2010*PSM	0.439***	0.437***	0.435***	0.433***	0.641***	0.610***	0.618***	0.588***
	(0.0382)	(0.0386)	(0.0384)	(0.0387)	(0.0498)	(0.0519)	(0.0486)	(0.0511)
2011*PSM	0.447***	0.446***	0.441***	0.441***	0.700***	0.674***	0.675***	0.650***
	(0.0487)	(0.0489)	(0.0490)	(0.0491)	(0.0520)	(0.0528)	(0.0510)	(0.0521)
2012*PSM	0.395***	0.393***	0.387***	0.385***	0.716***	0.686***	0.688***	0.659***
	(0.0434)	(0.0435)	(0.0438)	(0.0438)	(0.0520)	(0.0526)	(0.0508)	(0.0517)
2013*PSM	0.417***	0.416***	0.407***	0.406***	0.662***	0.631***	0.632***	0.603***
	(0.0713)	(0.0714)	(0.0719)	(0.0720)	(0.0501)	(0.0522)	(0.0496)	(0.0521)
2014*PSM	0.380***	0.380***	0.369***	0.369***	0.692***	0.662***	0.661***	0.632***
	(0.0551)	(0.0557)	(0.0550)	(0.0555)	(0.0513)	(0.0531)	(0.0506)	(0.0530)
Bwd GVC	0.00396	0.00250	0.00306	0.00160	0.0104	0.00950	0.00963	0.00879
	(0.0120)	(0.0119)	(0.0119)	(0.0119)	(0.00721)	(0.00725)	(0.00716)	(0.00720)
Top decile patent$_{t0}$	0.0340	0.0952	0.310	0.358	-0.0379	-0.288***	-1.003***	-1.231***
	(0.0415)	(0.105)	(0.390)	(0.400)	(0.0319)	(0.0846)	(0.255)	(0.277)
Top decile patent $_{t0}$ *Bwd GVC	-0.000606	-0.00128	-0.00105	-0.00189	0.00984	0.00530	0.00817	0.00386
	(0.0236)	(0.0234)	(0.0234)	(0.0233)	(0.0195)	(0.0189)	(0.0194)	(0.0189)
Bwd Patent		-0.0818		-0.0752		0.0240		0.0224
		(0.0629)		(0.0631)		(0.0264)		(0.0260)
Top decile patent $_{t0}$ *Bwd Patent		0.0233		0.0137		-0.0903***		-0.0859***
		(0.0383)		(0.0384)		(0.0296)		(0.0296)
Bwd intangibles			0.675***	0.664***			-0.258**	-0.248**
			(0.205)	(0.205)			(0.114)	(0.114)
Top decile patent $_{t0}$ *Bwd Intangibles			0.0933	0.0976			-0.322***	-0.319***
			(0.129)	(0.128)			(0.0828)	(0.0818)
Patents	-0.0316***	-0.0310***	-0.0240*	-0.0235*	0.0120**	0.0130**	0.00820	0.00920
	(0.0120)	(0.0120)	(0.0125)	(0.0124)	(0.00604)	(0.00608)	(0.00624)	(0.00628)
Capital $_{t0}$	0.0425***	0.0428***	0.0424***	0.0426***	-0.0314***	-0.0327***	-0.0293***	-0.0306***
	(0.0145)	(0.0145)	(0.0144)	(0.0144)	(0.00595)	(0.00597)	(0.00584)	(0.00587)
Constant	-0.984***	-1.218***	1.056*	0.808	-0.00968	0.0547	-0.817**	-0.728**
	(0.106)	(0.212)	(0.636)	(0.670)	(0.0407)	(0.0833)	(0.352)	(0.349)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.741	0.741	0.743	0.743	0.824	0.825	0.826	0.827

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B2 – GVC participation, quality and employment structure in the bottom two deciles

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.492***	0.486***	0.485***	0.479***	0.687***	0.684***	0.683***	0.682***
	(0.0386)	(0.0387)	(0.0385)	(0.0385)	(0.0447)	(0.0448)	(0.0449)	(0.0451)
2007*PSM	0.524***	0.520***	0.517***	0.513***	0.698***	0.697***	0.693***	0.693***
	(0.0371)	(0.0368)	(0.0368)	(0.0365)	(0.0527)	(0.0526)	(0.0532)	(0.0532)
2008*PSM	0.449***	0.446***	0.442***	0.439***	0.591***	0.590***	0.585***	0.585***
	(0.0503)	(0.0494)	(0.0499)	(0.0491)	(0.0532)	(0.0531)	(0.0530)	(0.0530)
2009*PSM	0.379***	0.372***	0.370***	0.365***	0.597***	0.593***	0.590***	0.590***
	(0.0397)	(0.0393)	(0.0394)	(0.0390)	(0.0503)	(0.0503)	(0.0502)	(0.0504)
2010*PSM	0.426***	0.421***	0.422***	0.418***	0.614***	0.611***	0.610***	0.610***
	(0.0375)	(0.0371)	(0.0373)	(0.0369)	(0.0536)	(0.0537)	(0.0524)	(0.0526)
2011*PSM	0.434***	0.432***	0.429***	0.427***	0.673***	0.672***	0.668***	0.668***
	(0.0477)	(0.0472)	(0.0475)	(0.0471)	(0.0558)	(0.0558)	(0.0549)	(0.0550)
2012*PSM	0.383***	0.378***	0.375***	0.370***	0.691***	0.689***	0.684***	0.683***
	(0.0429)	(0.0424)	(0.0428)	(0.0423)	(0.0551)	(0.0551)	(0.0539)	(0.0539)
2013*PSM	0.405***	0.402***	0.395***	0.392***	0.638***	0.636***	0.629***	0.629***
	(0.0704)	(0.0698)	(0.0706)	(0.0700)	(0.0531)	(0.0531)	(0.0522)	(0.0524)
2014*PSM	0.369***	0.366***	0.357***	0.355***	0.669***	0.667***	0.659***	0.659***
	(0.0550)	(0.0551)	(0.0546)	(0.0547)	(0.0533)	(0.0533)	(0.0526)	(0.0527)
Bwd GVC	0.0142	0.0145	0.0175	0.0159	0.00903	0.00881	0.00384	0.00417
	(0.0136)	(0.0136)	(0.0141)	(0.0141)	(0.00933)	(0.00934)	(0.00966)	(0.00967)
Bottom decile patent$_{t0}$	-0.0172	-0.539**	-0.866	-0.957	-0.0539***	0.105	1.134***	1.139***
	(0.0410)	(0.233)	(0.610)	(0.601)	(0.0201)	(0.0998)	(0.423)	(0.421)
Bottom decile patent $_{t0}$ *Bwd GVC	-0.0341**	-0.0396***	-0.0403***	-0.0436***	0.0121	0.0137	0.0186**	0.0188**
	(0.0143)	(0.0148)	(0.0146)	(0.0149)	(0.00834)	(0.00845)	(0.00873)	(0.00871)
Bwd Patent		-0.0739		-0.0689		0.0146		0.0141
		(0.0623)		(0.0625)		(0.0269)		(0.0264)
Bottom decile patent $_{t0}$ *Bwd Patent		-0.176**		-0.158**		0.0538*		0.00850
		(0.0770)		(0.0805)		(0.0318)		(0.0305)
Bwd intangibles			0.791***	0.765***			-0.461***	-0.459***
			(0.186)	(0.187)			(0.108)	(0.108)
Bottom decile patent $_{t0}$ *Bwd Intang,			-0.273	-0.151			0.384***	0.377***
			(0.197)	(0.204)			(0.135)	(0.138)
Patents	-0.0172	-0.0174	-0.00967	-0.00979	-0.00618	-0.00601	-0.0100	-0.0101
	(0.0127)	(0.0127)	(0.0131)	(0.0130)	(0.00659)	(0.00667)	(0.00671)	(0.00679)
Capital $_{t0}$	0.0447***	0.0488***	0.0457***	0.0492***	-0.0336***	-0.0348***	-0.0344***	-0.0345***
	(0.0144)	(0.0144)	(0.0141)	(0.0142)	(0.00601)	(0.00600)	(0.00574)	(0.00580)
Constant	-0.940***	-1.173***	1.449**	1.153*	-0.0827*	-0.0368	-1.489***	-1.441***
	(0.107)	(0.210)	(0.589)	(0.630)	(0.0429)	(0.0849)	(0.334)	(0.334)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.742	0.743	0.744	0.745	0.825	0.825	0.828	0.828

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

The results from our preferred specification are not weighted and as such it is possible that they are driven by economically small country-industries that do not account for a large proportion of total employment across Europe. To make sure that the implications of our results apply to large shares of Europe's labour force, we replicate our results, weighting on industries' shares of total employment across countries, finding rather similar results.

Table B3 – GVC participation, quality and employment structure in the top decile, weighted for sectors' total employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.533***	0.535***	0.527***	0.528***	0.699***	0.706***	0.684***	0.693***
	(0.0376)	(0.0375)	(0.0374)	(0.0372)	(0.0391)	(0.0382)	(0.0390)	(0.0382)
2007*PSM	0.563***	0.561***	0.557***	0.556***	0.710***	0.715***	0.695***	0.702***
	(0.0368)	(0.0364)	(0.0367)	(0.0362)	(0.0481)	(0.0471)	(0.0489)	(0.0479)
2008*PSM	0.492***	0.491***	0.485***	0.484***	0.620***	0.624***	0.602***	0.608***
	(0.0530)	(0.0522)	(0.0528)	(0.0519)	(0.0487)	(0.0480)	(0.0481)	(0.0474)
2009*PSM	0.440***	0.445***	0.432***	0.438***	0.632***	0.640***	0.611***	0.622***
	(0.0398)	(0.0399)	(0.0397)	(0.0397)	(0.0454)	(0.0441)	(0.0450)	(0.0437)
2010*PSM	0.484***	0.487***	0.480***	0.483***	0.657***	0.664***	0.636***	0.645***
	(0.0388)	(0.0387)	(0.0389)	(0.0387)	(0.0525)	(0.0518)	(0.0511)	(0.0505)
2011*PSM	0.482***	0.483***	0.477***	0.477***	0.739***	0.744***	0.716***	0.724***
	(0.0432)	(0.0430)	(0.0434)	(0.0432)	(0.0543)	(0.0529)	(0.0539)	(0.0525)
2012*PSM	0.457***	0.459***	0.449***	0.450***	0.764***	0.771***	0.738***	0.747***
	(0.0432)	(0.0428)	(0.0433)	(0.0428)	(0.0543)	(0.0538)	(0.0538)	(0.0533)
2013*PSM	0.464***	0.467***	0.453***	0.457***	0.694***	0.701***	0.667***	0.676***
	(0.0537)	(0.0535)	(0.0538)	(0.0535)	(0.0526)	(0.0516)	(0.0521)	(0.0512)
2014*PSM	0.483***	0.487***	0.472***	0.476***	0.734***	0.741***	0.706***	0.715***
	(0.0693)	(0.0694)	(0.0694)	(0.0694)	(0.0504)	(0.0496)	(0.0500)	(0.0494)
Bwd GVC	0.00125	-0.00283	0.00282	-0.00142	0.0144**	0.0144*	0.0129*	0.0131*
	(0.0130)	(0.0127)	(0.0133)	(0.0130)	(0.00721)	(0.00747)	(0.00719)	(0.00745)
Top decile patent$_{t0}$	0.0233	-0.284**	0.761*	0.531	-0.0826***	-0.0216	-1.223***	-1.148***
	(0.0433)	(0.126)	(0.429)	(0.446)	(0.0263)	(0.0968)	(0.316)	(0.337)
Top decile patent$_{t0}$ *Bwd GVC	0.0113	0.0163	0.00579	0.0124	-0.0277**	-0.0286**	-0.0322***	-0.0334***
	(0.0240)	(0.0241)	(0.0236)	(0.0236)	(0.0128)	(0.0127)	(0.0122)	(0.0121)
Bwd Patent		-0.0638		-0.0640		-0.00649		-0.00588
		(0.0577)		(0.0578)		(0.0253)		(0.0252)
Top decile patent$_{t0}$ *Bwd Patent		-0.122***		-0.144***		0.0240		0.0318
		(0.0468)		(0.0475)		(0.0348)		(0.0347)
Bwd intangibles			0.645***	0.656***			-0.170*	-0.174*
			(0.182)	(0.182)			(0.0969)	(0.0968)
Top decile patent$_{t0}$ *Bwd Intangibles			0.251*	0.295**			-0.380***	-0.382***
			(0.142)	(0.141)			(0.104)	(0.104)
Patents	-0.0236*	-0.0240**	-0.0162	-0.0165	0.00485	0.00480	0.00298	0.00288
	(0.0123)	(0.0122)	(0.0125)	(0.0124)	(0.00562)	(0.00564)	(0.00581)	(0.00583)
Capital$_{t0}$	0.0588***	0.0597***	0.0578***	0.0588***	-0.0347***	-0.0347***	-0.0337***	-0.0338***
	(0.0142)	(0.0142)	(0.0141)	(0.0141)	(0.00584)	(0.00585)	(0.00582)	(0.00583)
Constant	-0.964***	-1.155***	0.996*	0.838	-0.0171	-0.0329	-0.549*	-0.573*
	(0.0965)	(0.196)	(0.565)	(0.580)	(0.0358)	(0.0822)	(0.299)	(0.299)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.766	0.767	0.768	0.769	0.840	0.840	0.842	0.842

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B4 – GVC participation, quality and employment structure in the bottom decile, weighted for sectors' total employment

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.520***	0.517***	0.513***	0.510***	0.707***	0.707***	0.704***	0.705***
	(0.0379)	(0.0377)	(0.0377)	(0.0375)	(0.0408)	(0.0406)	(0.0407)	(0.0406)
2007*PSM	0.550***	0.547***	0.544***	0.541***	0.719***	0.719***	0.715***	0.716***
	(0.0369)	(0.0364)	(0.0368)	(0.0363)	(0.0497)	(0.0496)	(0.0501)	(0.0501)
2008*PSM	0.479***	0.477***	0.473***	0.471***	0.627***	0.627***	0.624***	0.624***
	(0.0530)	(0.0523)	(0.0527)	(0.0520)	(0.0491)	(0.0491)	(0.0490)	(0.0491)
2009*PSM	0.427***	0.425***	0.420***	0.418***	0.641***	0.640***	0.637***	0.637***
	(0.0397)	(0.0395)	(0.0395)	(0.0393)	(0.0455)	(0.0455)	(0.0455)	(0.0455)
2010*PSM	0.472***	0.470***	0.469***	0.467***	0.668***	0.668***	0.667***	0.667***
	(0.0383)	(0.0381)	(0.0383)	(0.0381)	(0.0523)	(0.0523)	(0.0517)	(0.0518)
2011*PSM	0.470***	0.469***	0.466***	0.465***	0.751***	0.751***	0.749***	0.749***
	(0.0425)	(0.0422)	(0.0425)	(0.0423)	(0.0532)	(0.0532)	(0.0529)	(0.0530)
2012*PSM	0.446***	0.444***	0.439***	0.437***	0.778***	0.778***	0.774***	0.774***
	(0.0430)	(0.0425)	(0.0428)	(0.0423)	(0.0532)	(0.0532)	(0.0532)	(0.0532)
2013*PSM	0.452***	0.451***	0.444***	0.443***	0.707***	0.707***	0.703***	0.703***
	(0.0532)	(0.0529)	(0.0531)	(0.0528)	(0.0521)	(0.0521)	(0.0519)	(0.0519)
2014*PSM	0.472***	0.471***	0.463***	0.462***	0.748***	0.747***	0.742***	0.742***
	(0.0695)	(0.0694)	(0.0693)	(0.0692)	(0.0499)	(0.0499)	(0.0495)	(0.0495)
Bwd GVC	0.00475	0.00276	0.00631	0.00386	0.00970	0.00926	0.00782	0.00753
	(0.0132)	(0.0130)	(0.0137)	(0.0134)	(0.00728)	(0.00749)	(0.00744)	(0.00762)
Bottom decile patent$_{t0}$	0.0768	-0.152	-0.184	-0.167	-0.0383	0.0215	0.501	0.502
	(0.0525)	(0.294)	(0.582)	(0.579)	(0.0268)	(0.144)	(0.419)	(0.422)
Bottom decile patent $_{t0}$ *Bwd GVC	-0.0275	-0.0339	-0.0296	-0.0365*	0.0263**	0.0277**	0.0283**	0.0275**
	(0.0188)	(0.0208)	(0.0190)	(0.0213)	(0.0113)	(0.0124)	(0.0115)	(0.0122)
Bwd Patent		-0.0623		-0.0620		-0.00852		-0.00857
		(0.0576)		(0.0577)		(0.0248)		(0.0247)
Bottom decile patent $_{t0}$ *Bwd Patent		-0.0712		-0.0889		0.0189		-0.00996
		(0.0924)		(0.106)		(0.0422)		(0.0462)
Bwd intangibles			0.697***	0.694***			-0.272***	-0.273***
			(0.164)	(0.164)			(0.0919)	(0.0920)
Bottom decile patent $_{t0}$ *Bwd Intang,			-0.0824	0.0156			0.174	0.185
			(0.189)	(0.220)			(0.134)	(0.149)
Patents	-0.00981	-0.00944	-0.00312	-0.00263	-0.00720	-0.00717	-0.00944	-0.00941
	(0.0127)	(0.0126)	(0.0129)	(0.0128)	(0.00575)	(0.00577)	(0.00589)	(0.00590)
Capital $_{t0}$	0.0623***	0.0630***	0.0617***	0.0623***	-0.0370***	-0.0371***	-0.0366***	-0.0366***
	(0.0140)	(0.0140)	(0.0139)	(0.0139)	(0.00578)	(0.00577)	(0.00574)	(0.00573)
Constant	-0.948***	-1.133***	1.164**	0.973*	-0.0545	-0.0790	-0.888***	-0.914***
	(0.0953)	(0.197)	(0.513)	(0.535)	(0.0361)	(0.0815)	(0.284)	(0.286)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.770	0.770	0.771	0.771	0.845	0.845	0.846	0.846

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Finally, we also want to test our results with more demanding fixed effects. In our preferred specification we include dummies for countries, industries and years, while now we control for country-year and industry-year fixed effects. By doing this, we can control for both policies that affect all sectors in a given country and year – such as changes in the labour market – and technological changes that occur in a given year for a specific industry across all countries – such as the diffusion of digital technologies.

The results are generally very similar to those we found in our main specification. The only main difference we detect concerns the negative and statistically significant relationship between backward patent intensity and the share of managers (see columns 2 and 4 in both Table B5 and B6). In our main model, this only applies to country-industries that were in the top 10% for patent intensity, while now this appears to be the case for all country-industries.

It then appears that as we control for country-year and industry-year fixed effects the competition/substitution mechanism we put forward in section 4 is at play not only for the country-industries in the top 10%, but along the whole distribution of patent intensity.

These results provide additional evidence in support of the conjecture that the manufacturing industries that import value added from patent intensive GVC partners are likely to experience a decline in the share of workers employed in headquarter functions that are offshored towards the GVC partners.

Interestingly, this effect is more relevant for countries in the top 10%, rather than those in the bottom 10%, suggesting that it is the technological leaders that stand to lose the most, in terms of employment structure, from other technologically advanced GVC partners.

Table B5 – GVC participation, quality and employment structure in the top decile, controlling for country-year and sector-year fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.542***	0.544***	0.536***	0.538***	0.775***	0.779***	0.761***	0.765***
	(0.0707)	(0.0704)	(0.0698)	(0.0696)	(0.0496)	(0.0501)	(0.0483)	(0.0489)
2007*PSM	0.490***	0.492***	0.484***	0.487***	0.771***	0.774***	0.755***	0.759***
	(0.0770)	(0.0766)	(0.0765)	(0.0761)	(0.0724)	(0.0720)	(0.0729)	(0.0725)
2008*PSM	0.500***	0.501***	0.493***	0.494***	0.711***	0.714***	0.692***	0.696***
	(0.135)	(0.133)	(0.135)	(0.133)	(0.0957)	(0.0955)	(0.0939)	(0.0937)
2009*PSM	0.339***	0.341***	0.333***	0.336***	0.593***	0.600***	0.580***	0.588***
	(0.0949)	(0.0940)	(0.0946)	(0.0938)	(0.118)	(0.115)	(0.116)	(0.114)
2010*PSM	0.429***	0.435***	0.425***	0.431***	0.650***	0.658***	0.633***	0.642***
	(0.0779)	(0.0772)	(0.0776)	(0.0770)	(0.121)	(0.120)	(0.119)	(0.118)
2011*PSM	0.481***	0.487***	0.478***	0.484***	0.601***	0.609***	0.587***	0.596***
	(0.0887)	(0.0879)	(0.0885)	(0.0876)	(0.132)	(0.131)	(0.131)	(0.129)
2012*PSM	0.396***	0.400***	0.391***	0.395***	0.636***	0.642***	0.619***	0.627***
	(0.0824)	(0.0819)	(0.0834)	(0.0829)	(0.0972)	(0.0967)	(0.0948)	(0.0944)
2013*PSM	0.447***	0.452***	0.441***	0.447***	0.520***	0.528***	0.504***	0.514***
	(0.140)	(0.139)	(0.141)	(0.140)	(0.120)	(0.118)	(0.118)	(0.117)
2014*PSM	0.361***	0.366***	0.357***	0.362***	0.658***	0.665***	0.642***	0.651***
	(0.0936)	(0.0939)	(0.0940)	(0.0943)	(0.0870)	(0.0877)	(0.0847)	(0.0859)
Bwd GVC	0.00524	-0.000503	0.00429	-0.00113	0.0121	0.0133*	0.0116	0.0128*
	(0.0118)	(0.0117)	(0.0118)	(0.0117)	(0.00760)	(0.00769)	(0.00760)	(0.00769)
Top decile patent$_{t0}$	0.0180	-0.252**	0.279	0.145	-0.0819***	-0.0336	-0.802**	-0.753**
	(0.0390)	(0.128)	(0.421)	(0.442)	(0.0256)	(0.102)	(0.319)	(0.352)
Top decile patent$_{t0}$ *Bwd GVC	0.00791	0.00923	0.00432	0.00769	-0.0224*	-0.0217*	-0.0246**	-0.0244**
	(0.0197)	(0.0199)	(0.0199)	(0.0201)	(0.0118)	(0.0117)	(0.0119)	(0.0117)
Bwd Patent		-0.182***		-0.176***		0.0434		0.0394
		(0.0668)		(0.0672)		(0.0286)		(0.0279)
Top decile patent$_{t0}$ *Bwd Patent		-0.104**		-0.115**		0.0178		0.0235
		(0.0486)		(0.0487)		(0.0374)		(0.0376)
Bwd intangibles			0.480**	0.441*			-0.225*	-0.217*
			(0.238)	(0.238)			(0.121)	(0.120)
Top decile patent$_{t0}$ *Bwd Intangibles			0.0904	0.144			-0.241**	-0.245**
			(0.140)	(0.135)			(0.105)	(0.104)
Patents	-0.0286**	-0.0289**	-0.0234*	-0.0240*	0.00893	0.00871	0.00656	0.00640
	(0.0118)	(0.0118)	(0.0125)	(0.0124)	(0.00588)	(0.00587)	(0.00611)	(0.00610)
Capital$_{t0}$	0.0433***	0.0435***	0.0436***	0.0436***	-0.0332***	-0.0332***	-0.0329***	-0.0328***
	(0.0138)	(0.0136)	(0.0137)	(0.0135)	(0.00578)	(0.00574)	(0.00570)	(0.00567)
Constant	-0.965***	-1.480***	0.481	-0.130	-0.0255	0.0987	-0.717*	-0.580
	(0.104)	(0.216)	(0.745)	(0.788)	(0.0387)	(0.0873)	(0.374)	(0.374)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.789	0.790	0.790	0.791	0.861	0.862	0.862	0.863

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table B6 – GVC participation, quality and employment structure in the bottom decile, controlling for country-year and sector-year fixed effects

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual Workers			
2006*PSM	0.521***	0.517***	0.516***	0.513***	0.785***	0.785***	0.780***	0.779***
	(0.0704)	(0.0701)	(0.0692)	(0.0689)	(0.0487)	(0.0485)	(0.0477)	(0.0475)
2007*PSM	0.473***	0.468***	0.468***	0.463***	0.780***	0.780***	0.772***	0.772***
	(0.0757)	(0.0751)	(0.0751)	(0.0745)	(0.0717)	(0.0711)	(0.0719)	(0.0713)
2008*PSM	0.484***	0.477***	0.477***	0.470***	0.721***	0.721***	0.711***	0.711***
	(0.133)	(0.131)	(0.133)	(0.131)	(0.0939)	(0.0934)	(0.0929)	(0.0926)
2009*PSM	0.321***	0.319***	0.316***	0.314***	0.603***	0.604***	0.601***	0.602***
	(0.0918)	(0.0910)	(0.0913)	(0.0906)	(0.115)	(0.115)	(0.114)	(0.114)
2010*PSM	0.413***	0.413***	0.410***	0.409***	0.660***	0.664***	0.656***	0.659***
	(0.0749)	(0.0742)	(0.0743)	(0.0736)	(0.119)	(0.119)	(0.118)	(0.118)
2011*PSM	0.466***	0.464***	0.463***	0.460***	0.613***	0.617***	0.612***	0.615***
	(0.0860)	(0.0852)	(0.0855)	(0.0846)	(0.129)	(0.130)	(0.129)	(0.129)
2012*PSM	0.382***	0.379***	0.377***	0.373***	0.647***	0.649***	0.645***	0.647***
	(0.0818)	(0.0813)	(0.0826)	(0.0820)	(0.0944)	(0.0941)	(0.0942)	(0.0940)
2013*PSM	0.432***	0.430***	0.428***	0.425***	0.533***	0.536***	0.531***	0.533***
	(0.138)	(0.138)	(0.139)	(0.138)	(0.117)	(0.117)	(0.116)	(0.117)
2014*PSM	0.348***	0.346***	0.344***	0.342***	0.670***	0.673***	0.669***	0.671***
	(0.0943)	(0.0942)	(0.0946)	(0.0946)	(0.0848)	(0.0843)	(0.0838)	(0.0834)
Bwd GVC	0.0110	0.00761	0.00894	0.00497	0.00688	0.00846	0.00733	0.00844
	(0.0117)	(0.0118)	(0.0120)	(0.0119)	(0.00742)	(0.00747)	(0.00769)	(0.00766)
Bottom decile patent$_{t0}$	0.0421	-0.262	0.292	0.289	-0.0615***	-0.168	-0.168	-0.177
	(0.0494)	(0.270)	(0.541)	(0.550)	(0.0217)	(0.125)	(0.306)	(0.305)
Bottom decile patent $_{t0}$ *Bwd GVC	-0.0403***	-0.0479***	-0.0417***	-0.0535***	0.0234***	0.0213**	0.0242***	0.0231***
	(0.0150)	(0.0170)	(0.0153)	(0.0173)	(0.00767)	(0.00882)	(0.00788)	(0.00890)
Bwd Patent		-0.182***		-0.173**		0.0478*		0.0429
		(0.0665)		(0.0670)		-0.028		-0.0275
Bottom decile patent $_{t0}$ *Bwd Patent		-0.0962		-0.170*		-0.0347		-0.0206
		(0.0854)		(0.0924)		(0.0374)		(0.0402)
Bwd intangibles			0.486**	0.447**			-0.277**	-0.267**
			(0.214)	(0.216)			(0.116)	(0.115)
Bottom decile patent $_{t0}$ *Bwd Intang,			0.0836	0.256			-0.036	-0.0185
			-0.178	-0.202			-0.098	-0.108
Patents	-0.0130	-0.0132	-0.00793	-0.00802	-0.00749	-0.00763	-0.0101	-0.0100
	(0.0119)	(0.0119)	(0.0124)	(0.0124)	(0.00614)	(0.00617)	(0.00631)	(0.00631)
Capital $_{t0}$	0.0473***	0.0484***	0.0475***	0.0491***	-0.0360***	-0.0356***	-0.0357***	-0.0355***
	(0.0137)	(0.0135)	(0.0135)	(0.0133)	(0.00563)	(0.00558)	(0.00553)	(0.00550)
Constant	-0.949***	-1.472***	0.515	-0.104	-0.0768**	0.0578	-0.918**	-0.767**
	(0.103)	(0.216)	(0.679)	(0.729)	(0.0389)	(0.0858)	(0.359)	(0.356)
Observations	2,575	2,575	2,575	2,575	2,589	2,589	2,589	2,589
R-squared	0.793	0.794	0.793	0.795	0.868	0.868	0.868	0.868

Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1