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Technology, global value chains and functional specialisation in Europe

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ABSTRACT

This paper provides empirical evidence on the role of 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-sector 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 country-sectors participating in GVC 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 participation in GVC per se is not related to the employment structure of a country-sector. We show that different patterns of GVC integration and functional specialisation emerge that depend on the initial patents/intangibles intensity of the country-sector integrating in GVC and those of the partners.

1. Introduction

Global Value Chains (GVCs) are forms of international production involving growing trade in intermediates and international fragmentation of the production process (Antràs, 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; López-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).

Within the literature on GVCs and 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. They argue that functional specialisation is the third and latest generation of ways to conceptualise and measure GVCs. The first one is based on gross exports of (final) products; the second generation focuses on the vertical trade specialisation, measured in terms of value added embodied in exports, which captures the international fragmentation of production. The latest, third-generation conceptualisation and measurement of GVCs builds on the second one by including the characteristics of the *functions* associated with trade specialisation, which in turn refer to the tasks 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, marketing, and managerial activities') that contribute to the trade specialisation of a given country.

More recently, a (small) number of scholars have attempted to incorporate the role of technology (Reijnders and de Vries, 2018), albeit limited to Information and Communication Technologies (ICTs) (Marcolin et al., 2016), to study the link between trade specialisation, growth, and composition of routinised and non-routinised tasks of a country, which only loosely relate to the 'functions' mentioned above.

However, technological change has a complex nature that goes beyond the introduction of ICTs and strategies of automation, and the replacement of low skilled jobs or routinised tasks (Acemoglu and Restrepo, 2017; Autor et al., 2016). Streams of literature that have attempted to incorporate

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technology in the positioning of countries in GVCs, such as the 'core-periphery' models (Prebisch, 1950; Fujita et al., 1999) and the narrative around the 'headquarters and factory economies' (Baldwin and Lopez-Gonzalez, 2015) and the 'smiling curve' (Stöllinger, 2021), also tend to convey a simplistic reading of the role of technology, i.e. firms located in high value-added-knowledge-intensive countries offshoring low-value added and routinized labour functions to technologically laggard countries.

It is not uncommon, in fact, that technology intensive countries create preferential or tighter trade links with other technology intensive countries, specialised in similar functions. At the same time, technologically laggard countries might well establish trade patterns with low technology intensive partners. Such diverse configurations of GVC participation show that, in order to study functional specialisation, it is crucial to include in the analysis not only countries' own technological level, but also that of their partners. Doing so, provides a richer and more nuanced framework to study GVC integration in the context of functional specialisation.

This paper contributes to this aim, by empirically investigating whether and how the relationship between GVC participation and functional specialisation changes in relation to the technological level of countries and sectors participating in GVCs and on that of their GVCs (backward) partners. More in particular we contribute to the literature on GVC and functional specialisation by assessing whether changes in countries' and industries' employment structure – the share of manual and managerial occupations, which we interpret in terms of functional specialisation – are related not only to the level of GVC participation, but also to the technological intensity, both of country-sectors and their partners.

To shed light on the above, we identify a few stylised conjectures that we empirically investigate, merging different industry level sources of data for a large number of 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-sector's partner, 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, concentrating mainly on the headquarter and fabrication functions as defined in Timmer et al. (2019).[1] More specifically, focusing on a sample of 21 European countries and 49 industries over the period 2000–2014, we empirically estimate the relationship between backward GVC participation and functional specialisation, 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.

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 functional upgrading (which in our approach we measure as changes from manual to managerial occupations) over time.[2]

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 and industries 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-sectors' employment structure. In particular, countries that start off with a disadvantage in patent intensity are more likely to see lower shares of employment in headquarter functions and higher shares of employment in fabrication functions, as they further integrate into GVCs. The opposite occurs for country-sectors with high patent intensity at the beginning of our observed period, which see a decrease in the share of manual workers associated with participation in GVCs.

The remainder of the paper is structured as follows. The next section provides a summary of the conceptual and empirical state of the art on GVC integration and functional specialisation, while highlighting the need to incorporate the 'quality' of GVC integration based on the technological intensity of countries/sectors. Section 3 illustrates data and empirical strategy. Section 4 discusses the results. Section 5 concludes.

2. State of the art and contribution

2.1. Background literature and evidence

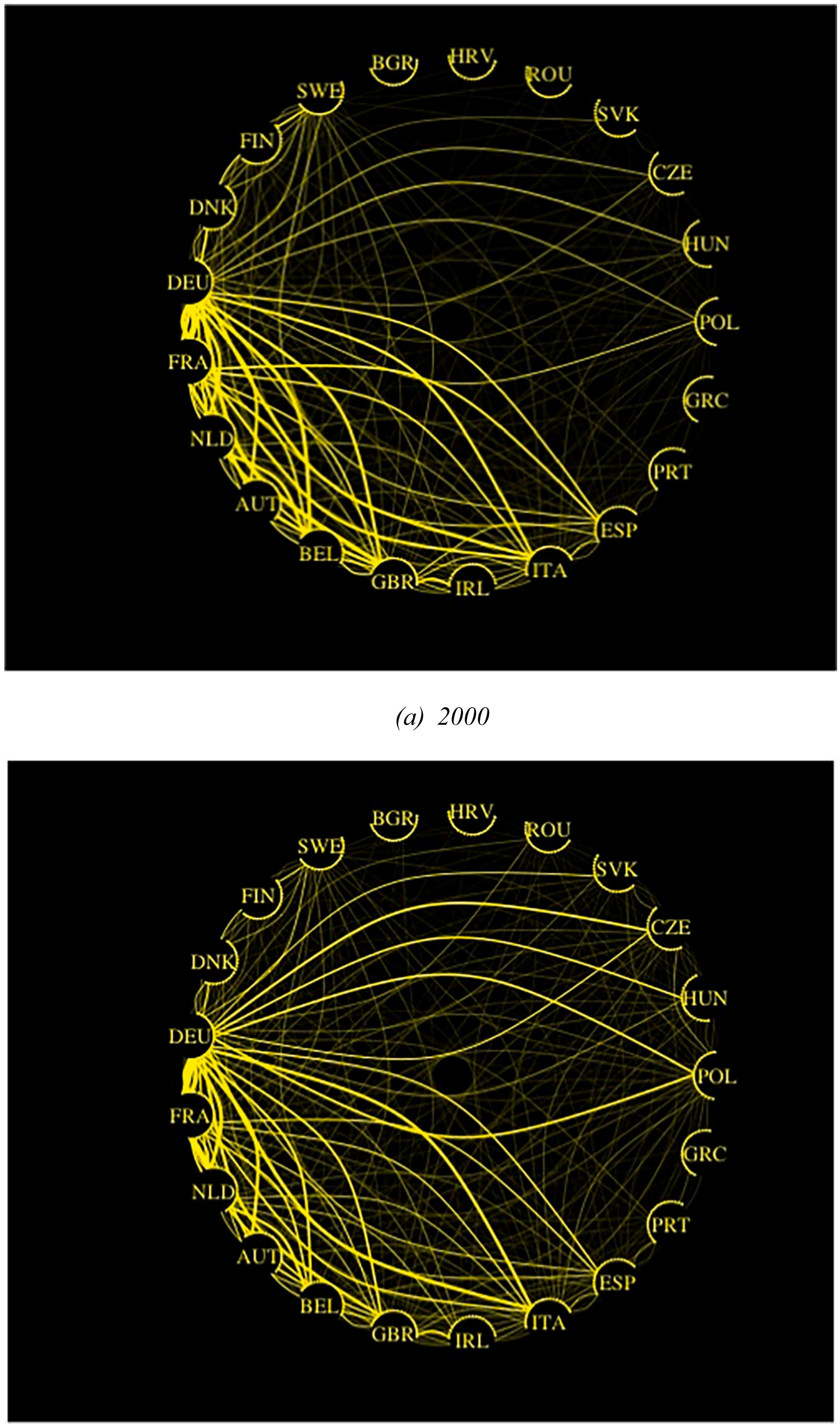
The European Single Market has considerably strengthened the integration among EU countries since its inception. Fig. 1 shows the intensification of flows of foreign value added in countries' exports (i.e. backward GVC participation as defined in Eqs. (A.1) to (A.3) in the Appendix A.1) over the period between 2000 and 2014. Two remarks are in order based on this first piece of evidence. First, Western Europe was already a rather highly integrated region in 2000, while Eastern and Southern European countries (Portugal and Greece in particular) were then comparatively much less involved in GVCs. Second, while Eastern Europe has significantly increased its participation in GVCs, this has not changed the structure of production networks that remain concentrated around Germany. Such centrality emerges also in other contributions (Amador and Cabral, 2017; Amador et al., 2018; Baldwin and Lopez-Gonzalez, 2015) and confirms the idea that European countries are structured in terms of headquarter and factory economies, an evidence supported also in terms of technology clubs (Wirkierman et al., 2021).

Within this stream of work, Simonazzi et al. (2013) and Celi et al. (2018) propose a geo-political economic framework to explain the structure of the European international production. This literature interprets the restructuring of GVCs as the outcome of changes in the hierarchical organisation of value chains. In Europe's specific case, they 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 consolidate its market share. This strategy relies both on the offshoring of production 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 (see also Grodzicki and Geodecki (2016) and Stöllinger (2016)). The various contributions by Durand and Milberg (2020) Kummritz et al. (2017), Milberg and Winkler (2011, 2013) link the bargaining power of countries joining GVCs to the quality of their institutions, which, it is argued, play a significant role in shaping how gains associated with GVC participation are distributed.

Seminal contributions have highlighted earlier that value added is not equally distributed along GVCs and that this depends on the activities (and functions) that each actor within a value chain carries out (Gereffi, 1994; Gereffi et al., 2005). This pioneering 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).

[1] We should point out that while we use the same classification of occupations into functions as in Timmer et al. (2019), we do not use indexes of functional specialisation computed in the same way as these authors do. This is because we look at employment shares rather than Balassa indexes based on wage bills. 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-sector and therefore of its position in GVCs.

[2] We are fully aware that a more qualitative literature (stemming from the seminal contribution of Gereffi et al., 2005) has been grappling with the concept of upgrading and how elusive it is to accurately measure it at the firm level (Ambos et al., 2021; McWilliam et al., 2020). Our analysis however takes place at a more aggregate level, and we therefore base our approach on the emerging literature on functional specialisation referenced above, which we are convinced provides meaningful measures, as discussed at length in Section 3.



(a) 2000

(b) 2014

Fig. 1. Backward linkages network over time 2000 and 2014.
Source: authors' calculations using WIOD data.

This latter 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 – mostly specialising in R&D, marketing, and management functions - while others remain in the periphery as factory economies (Baldwin and Lopez-Gonzalez, 2015; Amador et al., 2018; Kordalska et al., 2022; Stöllinger, 2021) – mostly specialising in fabrication functions.

There seems to be a nexus between the political economy of GVCs integration, particularly in Europe, and the concept of functional specialisation, that is linked to the structure of employment in countries that specialise in different functions. We show this in Fig. 2 below, that depicts fairly stable patterns in the share of managers and manual workers across EU macro regions[3] over the past two decades. The share

[3] 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.

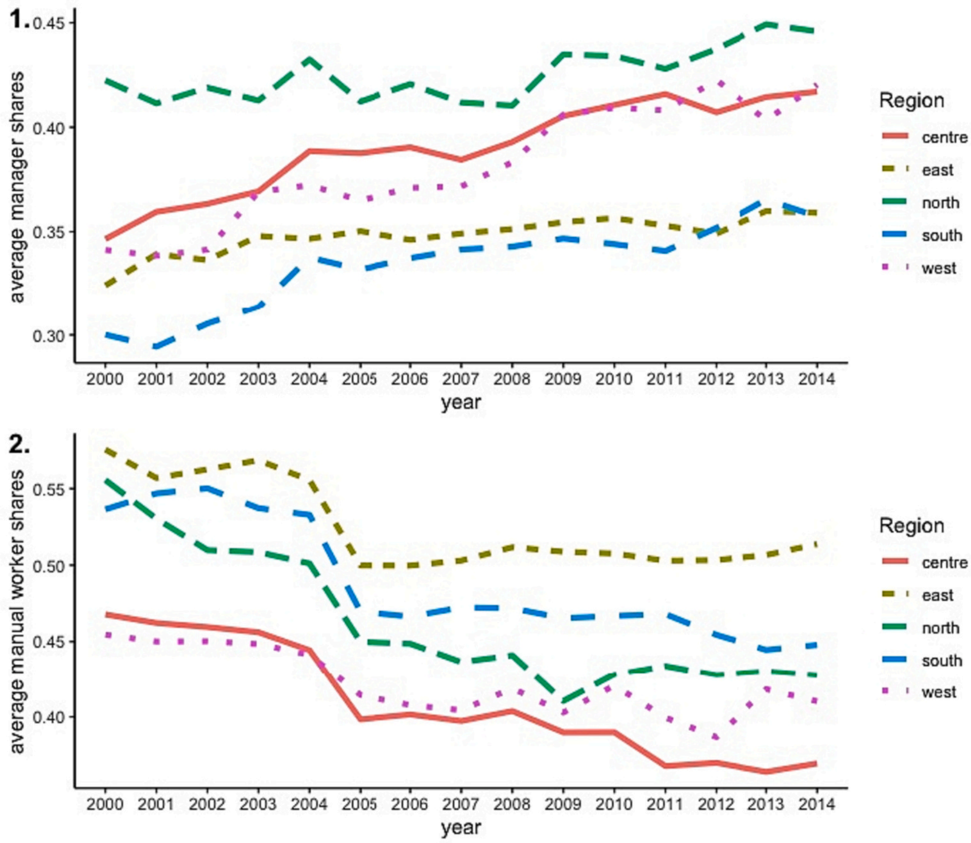


Fig. 2. Shares of managers and manual workers across regions and macro-sectors over time.
Source: authors' calculations using LFS data – unweighted average across macro regions for the share of managers and manual workers.

of managers (R&D, marketing, and managerial functions, see Section 3 for a detailed methodological discussion) seems to remain higher in levels and stable, when not growing, in the Northern, Western and Centre EU regions, while the share of manual workers (associable to fabrication functions) has a specular opposite picture.

There is in fact a declining share of manual workers in all regions, but this trend stops in Eastern Europe from 2005 onwards. While Eastern European countries have significantly increased their participation in GVCs, they have done so specialising in fabrication 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 Central Europe.[4]

Surprisingly, despite much of the heterogeneity in EU GVC participation and functional specialisation is conducible to, and possibly exacerbated by, technology, the literature above focuses mainly on their geo-political or functional/employment nature.

Also, the functional specialisation literature tends to overlook the heterogeneity of initial technological intensity of countries that integrate with each other, despite the existence of European technology clubs (Wirkierman et al., 2021 among others) that might be further reinforced by processes of GVC integration.

The role of path dependence and absorptive capacity and the prevalence of absolute advantages (based on technology) with respect to cost advantages in shaping firms', industries' and countries' international competitiveness has been extensively taken into account and empirically tested within the technology gap approach to trade (Dosi et al., 1988, 1990, 2015; Soete, 1981; Fagerberg, 1994; Amable and Verspagen, 1995; Cohen, 2010; Laursen and Meliciani, 2010; Maggi, 2017). However, the literature has left these issues underinvestigated in the context of global value chains with few exceptions (Pietrobelli and Rabellotti, 2011; Jona-Lasinio et al., 2019; Lema et al., 2019) and has overlooked the implications in terms of employment structure.

The persistence of technological asymmetries is clearly shown in Fig. 3, where we plot the evolution of patent and intangible asset intensity of macro-regions over the 2000–2014 period (see Appendix A.2 for a detailed discussion of the measures used to compile the Figure). The figure shows the persistence of wide technological and knowledge-based gaps 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.[5] Furthermore, despite Eastern Europe having significantly increased its level of participation in GVCs over our observed period (see Fig. 1), this process has not been paralleled by a reduction of its technological divide from the most advanced EU countries.

[4] We explore these patterns also at the country level in Fig. 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 Fig. A1.

[5] Fig. A.1 in the Appendix A.1 reports country-level descriptive evidence coherent with this.

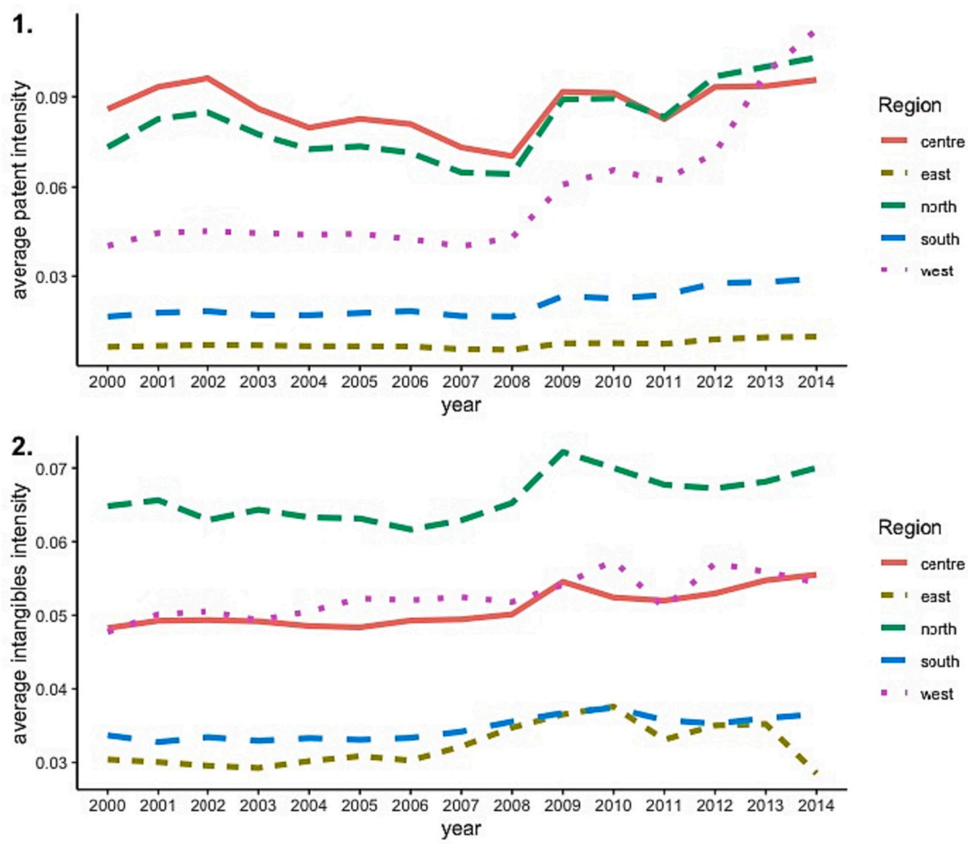


Fig. 3. Patent and intangibles intensity across regions and macro-sectors over time.
Source: authors' calculations using REGPAT and INTANINVEST data – unweighted average across macro regions for patent and intangible intensity.

2.2. Beyond the state of the art: contribution and conjectures

The evidence presented in the previous subsection has shown two main stylized facts: a) an increasing integration of production in the EU through the extension and deepening of GVCs; b) the persistence of gaps across EU countries, and macro-regional areas in technology and functional specialisation. This twofold trend is broadly consistent with what envisaged by the literature on the hierarchical structure of international production in Europe mentioned above.

In addition to the evidence above, the most recent literature on international business (IB) studying innovation within GVCs has highlighted the presence of a high degree of heterogeneity in the organisational structures of GVCs. Looking at knowledge sourcing activities in particular, this literature has emphasised the importance of horizontal – rather than vertical – linkages among knowledge intensive actors (Turkina and Van Assche, 2018, Ambos et al., 2021). This suggests that GVC participation and technology may interact in a more complex way than a simple vertical integration with knowledge intensive activities geographically concentrated in few high-tech sectors. Fig. 4 puts forward a first piece of evidence supporting the importance of considering linkages among knowledge-intensive actors in GVCs. The figure plots patent and intangible asset intensity of country-sectors and the average of the same measure of their partners (which we discuss in detail in Section 3 below) and clearly shows that knowledge and technology-intensive country-sectors tend to engage in GVCs participation with similar partners.

As a result, the nexus between GVCs, technology and functional specialisation may be more complex than the literature on functional specialisation has so far suggested.

This paper aims to unpack the role of technology by empirically investigating whether and how the relationship between GVC participation and functional specialisation (the share of manual and managerial occupations) changes in relation to the technological level of countries and sectors participating in GVCs and on that of their GVCs (backward) partners.

While we do not aim at putting forward formal testable hypotheses, we discuss a few stylised conjectures showing that it is hard to have clear-cut ex-ante expectations and that this requires a heuristic approach in our empirical analysis.

Let us first examine the case of technological leaders engaging with lower-tech partners. The literature discussed above suggests that leaders usually offshore low value-added functions and further strengthen their functional specialisation in knowledge intensive and managerial functions. This can mean two possible things for technological laggards. On the one hand, they might 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. This might represent an opportunity for functional upgrading in laggard countries. Both the literature on functional specialisation and the (more established) literature on GVCs have shown that while GVC participation does offer some opportunities for upgrading, this is far from being automatic and very much depends on firms' (and industries) capabilities and the governance under which GVCs are taking place (Gereffi et al., 2005; Giuliani et al., 2005).

However, Fig. 4 above shows that another relevant case concerns GVC linkages among technological leaders themselves. While here too it is hard to formulate clear hypotheses, the literature has identified two mechanisms that are likely to be at play. On the one hand, some contributions have hinted at the possible offshoring of knowledge intensive functions (Foster-McGregor et al., 2013; Bramucci et al., 2021) and that foreign technological competition can reduce turnover, sales and employment in firms in the short run (Gagliardi, 2019, Kemeny, 2011, Wiggins and Ruefli, 2005). On the other hand, the IB literature mentioned above highlights the importance of GVC linkages to connect local pockets of knowledge and increase the global sourcing of knowledge (Bathelt and Li, 2020, Turkina and Van Assche, 2018), often coordinated by large multinational companies (MNCs). This stream of literature has found that technological knowledge is sourced from different pools both within and outside the firm boundaries of MNCs (Ambos et al., 2021). These strategies might be due to asset seeking behaviour, as well as labour cost savings with regard to knowledge intensive functions. At any rate, the effects of participation in GVCs on the employment structure are far from being straightforward. On the one hand, a technological leader engaging with other knowledge-intensive partners might suffer from a substitution effect, reducing its share of managers; on the other hand it might also benefit from complementary effects resulting from more complex strategies of knowledge

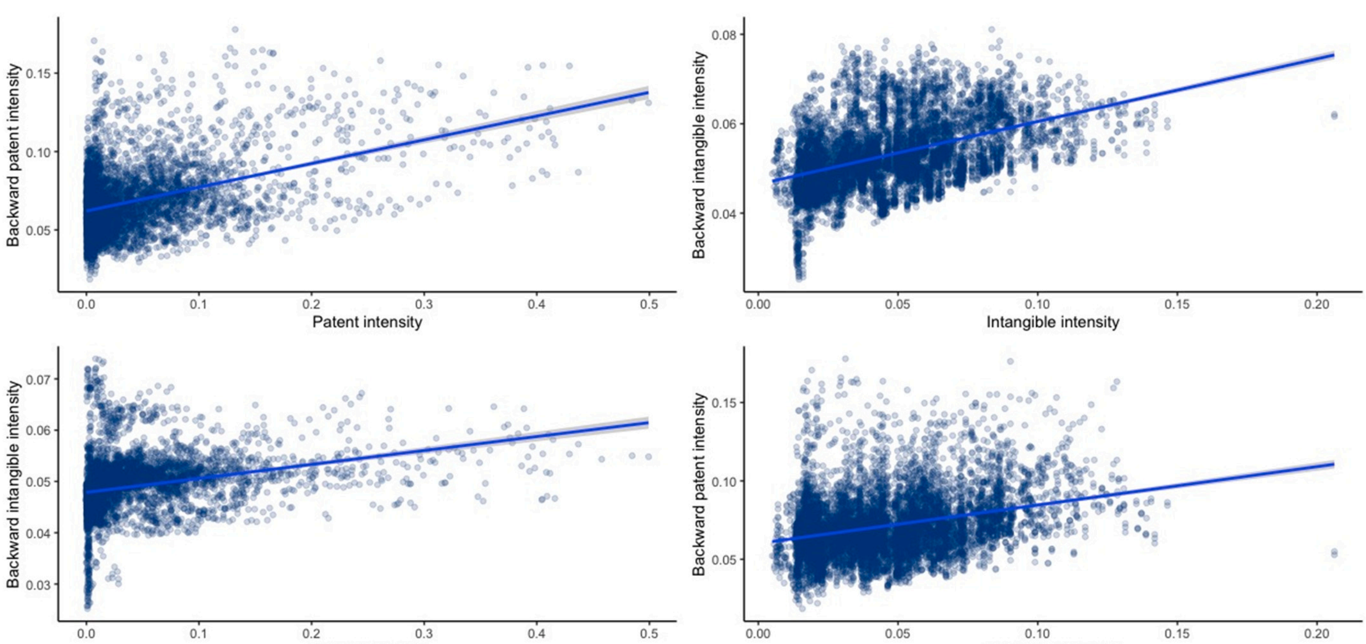


Fig. 4. Patent and intangible intensity of country-sectors and their GVC partners.
Source: authors' calculations using REGPAT, INTANINVEST, and WIOD data. Patent intensity is the ratio of patent stocks and output for manufacturing industries. Intangible intensity is investment in intangible assets per unit of output. Backward patent intensity is the average patent intensity of the partners of each country-sector, weighted using backward GVC linkages, as detailed in Eq. (1). Backward intangible intensity is the same average computed using intangible intensity of partners, as detailed in Eq. (2).

sourcing coordinated by MNCs leading to increases in the share of managers and R&D personnel in all country-sectors involved.

In summary, integrating into GVCs could be associated with changes in employment structure through several mechanisms. Among technologically uneven partners, changes in employment structure may be driven by processes of functional specialisation reinforcing initial asymmetries but can also result in functional upgrading due to spillover and learning effects. Among technological leaders there could be both competition mechanisms or horizontal fragmentation coordinated by knowledge sourcing strategies of MNCs. We empirically investigate these conjectures below by testing whether the relationship between GVC integration and functional specialisation depends on the initial technological level of countries and industries (distinguishing between technological leaders and laggards) and the quality (knowledge intensity) of their partners.

3. Data and empirical strategy

3.1. Data and measurement

In order to study the relationship between GVC participation, functional specialisation and technology we rely on a range of measures and data sources. We discuss these in turn, while we refer the reader to the Appendix A.1 for a detailed methodological discussion.

Our key interest lies with functional specialisation. We use data on employment across country-sectors 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).[6] 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, 2015). Conversely, we use the occupations that refer to manual work as a proxy for fabrication activities – which characterise what Baldwin and Lopez-Gonzalez (2015, 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.

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 functional 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.

Our analysis combines the concept of functional specialisation, with more traditional notion of GVC participation *tout court*, for which the literature has put forward an array of measures. Our approach follows Borin and Mancini (2020) in computing backward GVC participation of each country-sector, using the WIOD dataset, covering the period 2000–14, for 43 countries and 51 industries. Backward participation is a measure of the foreign value added embodied in the gross export of a given country-sector. In other words, backward participation in GVC captures the penetration of foreign value added in a country-sector's economy. The traditional approach in the literature is to normalise backward participation with gross exports.

We however prefer to use total output to normalise this with total output for two key reasons. First, we are interested in how important GVC participation is with respect to a country-sector total economic activity. It is important to bear in mind that large economies rely more on their own domestic market than smaller ones. As a result, GVC backward participation is likely to be more important in small, rather than large economies and it is important that our measure reflects that. Second, our measure of functional specialisation relies on employment shares of a country-sector's entire labour force. It is therefore important to also normalise GVC participation with a measure based on the entirety of a country-sector economic activity.

Beyond GVC participation, we are also interested in assessing country-sectors' technological capabilities. Our first data source for this is the OECD's REGPAT dataset, which we use to compute patent stocks for each country-sector, normalising this by output, consistently with what we did for GVC participation.

Patents are a well-established measure of innovation output and proxy for technological capabilities. They, however, also come with some limitations. First, patents capture a kind of technological capabilities that is only relevant for manufacturing industries: services are in fact much less patentable activities, due to their intangible nature. Second, as a result of the above, crosswalks that allow allocating patents to industries only exist for the manufacturing sector (Lybbert and Zolas, 2014). We therefore resort to measures of investment in intangible assets provided by the INTANINVEST dataset (Corrado et al., 2016) to capture technological capabilities in services. While we discuss these in some detail in the Appendix A.2, it is worth highlighting that intangible assets include a broad range of knowledge-intensive assets, going from R&D activities to market research and organisational capital. These are closely related to what the literature on functional specialisation has referred to as headquarter activities (Timmer et al., 2019).

Now that we have derived measures of knowledge intensity for both manufacturing and services country-sectors, 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 technological intensity of a country-sector's backward linked partners. For manufacturing partners, we compute:

$$\mathrm{BwdPatent}_s = \sum_{r \neq s} \mathrm{Patint}_r * \frac{\mathrm{BWD}_{r,s}}{\sum_{r \neq s} \mathrm{BWD}_{r,s}} \tag{1}$$

While for service partners, we compute:

$$\mathrm{BwdIntant}_s = \sum_{r \neq s} \mathrm{Intantint}_r * \frac{\mathrm{BWD}_{r,s}}{\sum_{r \neq s} \mathrm{BWD}_{r,s}} \tag{2}$$

where $BWD_{r,s}$ is the backward GVC linkage between country s and its partner r; $Patint_r$ and $Intantint_r$ are the patent and intangible asset intensity of the partner r, respectively. In this way, we have two measures of quality of GVC participation. For each country-sector s, we compute the average patent intensity of manufacturing backward-linked

[6] In this respect it should be noted that Timmer et al. (2019) look at four functional specialisations: (i) marketing, (ii) R&D, (iii) management and (iv) fabrication. They however ground these in the distinction between headquarter and fabrication functions (Timmer et al., 2019, p.11) and show empirically that fabrication function follows a significantly different pattern from the other three they also refer to as headquarter specialisation (Timmer et al., 2019 p. 14).

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. By combining all the data sources discussed above we obtain a sample of 21 industries in 49 countries over the period 2000–14.

3.2. Empirical strategy

Our discussion in Section 2 has highlighted two key aspects. First, despite growing GVC integration, functional specialisation among countries and industries has shown remarkable persistence over time. Second, the relationship between technological capabilities, functional specialisation and GVC participation goes beyond simple headquarter and factory dynamics and it is hard to have clear ex-ante expectations.

We therefore explore these relationships with an empirical framework that accommodates both persistence in functional specialisation and GVC participation between technologically unequal partners, as well as among technological leaders themselves.

It is worth pointing 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 persistence of country-sectors' initial functional specialisation captured by the employment structure, which is one of the key stylised facts underscored by the literature. Second, we also investigate how functional specialisation correlates with GVC participation and its quality, which we capture with our novel measures of patent and intangible intensity discussed in the previous section. Third, we focus on how initial technological capabilities mediate the relationship between GVC participation, its quality and country-sectors functional specialisation, i.e. whether the sign of these correlations changes from technological leaders to technological laggards.

We focus here on manufacturing industries alone, while also taking into account their linkages with service industries, because GVC participation is most relevant for them (see Fig. A.2 in Appendix).

Based on the discussion above, our econometric test deals with these issues explicitly as follows:

$$ln(y_{ijt}) = \alpha + \sum_t \beta_t ln(\bar{y}_{ijt_0}) + \delta_1 TopDecile_{ijt_0} + \beta_1 ln(Bwd_{ijt}) + \gamma_1 TopDecile_{ijt_0} * ln(Bwd_{ijt}) + \beta_2 ln(BwdPatent_{ijt}) + \gamma_2 TopDecile_{ijt_0} * ln(BwdPatent_{ijt}) + \beta_3 ln(BwdIntangibles_{ijt}) + \gamma_3 TopDecile_{ijt_0} * ln(BwdIntangibles_{ijt}) + \beta_4 ln(Patint_{ijt}) + \delta_2 ln(Capital_{ijt_0}) + \kappa_i + \varphi_j + \tau_t \quad (3)$$

Our outcome variable (y_{ijt}) is either the share of managers or of manual workers in the country-sector *ij* at time t (2006–2014) proxying for functional specialisation. We control of country, sector and year fixed effects (κ_i, φ_j, and τ_t, respectively) that should net out from our analysis the role of country, industry and time idiosyncrasies. We also add the pre-sample mean (2000–05)[7] of the outcome variable $\bar{y}_{ij,t0}$ to account for time-invariant effects that shape country-sectors' initial functional specialisation.[8] This choice, rather than the classical fixed effect estimators, to absorb country-sectors' pre-existing conditions is in line with the literature dealing with highly persistent variables (Blundell et al., 1995, 2002). More importantly for our purpose here, interacting the pre-sample mean with time dummies allows us to confirm whether there is persistence of functional specialisation of country-sectors.

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. This is crucial for our purpose since it allows us to identify technological leaders and laggards.

In particular, we construct a dummy variable $TopDecile_{ijt_0}$ taking value one if the pre-sample mean of the country-sector 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 laggardness.[9] We interact this dummy with the measures of GVC participation (Bwd_{ijt}) as well as the two measures for backward patent and intangible intensity ($BwdPatent_{ijt}$ and $BwdIntangibles_{ijt}$).[10] These interactions tell us whether GVC participation and its technological quality correlate differently to functional specialisation, depending on whether we are looking at technology leaders or laggards.

We provide a list of country-sectors that rank in the two top and bottom deciles in the Appendix (Tables A.4 and A.5). 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 textiles (sector C13-C15). In contrast, no sector from the region Centre is included in the two bottom deciles, while relatively patent intensive 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.

Finally, we add two control variables to our specification. First, while the initial technological position matters, as country-sectors 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-sectors' own patent intensity during our period of analysis (2006–2014) as described in Appendix A.1. Additionally, we include a measure of capital intensity, measured as the average over the pre-sample period, which we compute as a country-sector's total capital stock, retrieved from EUKLEMS, divided by total employment, from EULFS.

[7] 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.

[8] 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 (Tables 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, which under the assumption that labour markets are determined nationally, fully accounts for relative wages.

[9] 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.

[10] Recall from Eqs. (1) and (2) that backward patent intensity is computed for each country-sector, 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 technological quality of manufacturing and service partners, respectively, which is why we include them both in our analysis.

4. Results

Table 1 reports our main results on the relationship between GVC participation, technology, and functional specialisation. 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.

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 period (see Fig. 2), the initial employment structure remains a strong predictor of future employment shares.

Our results also confirm our conjecture that country-sectors' initial technological capabilities mediate the relationship between GVC participation and functional specialisation. In fact, GVC participation in and of itself appears to be unrelated to the shares of managers or manual workers. However, we find evidence of a different relationship for country-sectors that start off in 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 technological leaders 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.[11] This is in line with the evidence put forward by the literature on headquarter and factory economies in GVC, suggesting that technological leaders reinforce their specialisation in headquarter functions as they further integrate in GVCs (Baldwin and Lopez-Gonzalez, 2015, Simonazzi et al., 2013, Amador and Cabral, 2017).

But does the relationship between GVC integration and the structure of employment vary also according to the quality of the partner? Specifications (2, 3, 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, 8).

We find that the quality of manufacturing partners, i.e. backward patent intensity (*Bwd Patent* in the Table), is significantly related to the share of managers only for top decile country-sectors, leading to a decrease in the share of this occupational category (columns 2 and 4). It therefore appears that country-sectors among the top technological performers (high patent intensity) see their share of managers reduce as they engage with technology intensive suppliers.

While our empirical approach does not aim at gauging clear-cut causal relationships, this is evidence of the complexity of the relationship between technology and GVC participation. The literature we discussed in Section 2 suggests two possible mechanisms. On the one hand, it is possible that 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).

On the other hand, it is also possible that the negative coefficient we find is the result of a horizontal fragmentation of knowledge sourcing activities. The literature on IB has emphasised that MNCs can expand into foreign markets to access local pockets of knowledge (Ambos et al., 2021; Bathelt and Li, 2020) and that the negative relationship between functional specialisation in managerial activities and the quality of manufacturing GVC partners may be linked to a coordinated strategy across multiple locations, rather than simple competition.

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 (*Bwd Intangibles* in the Table) 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, 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 Intangibles*) 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 between the quality of the service inputs imported and the employment structure of manufacturing industries. This contrasts with 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; López-Gonzalez et al., 2019). Furthermore, it is in line with the knowledge-sourcing hypothesis developed in the IB literature, whereby manufacturing industries engage with knowledge-intensive service providers to access specific pools of knowledge, with an increase in headquarter specialisation due to complementary knowledge intensive activities along the GVC.

In sum, three findings emerge from the evidence discussed so far. First, employment structure and therefore functional specialisation are highly persistent over time, 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 country-sectors' initial technological position matters greatly: 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. Finally, the quality of GVC participation, especially of foreign service providers, is related to shifts in the employment structure towards managerial functions.

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. In Eq. (3), 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.

The results for this second specification are reported in Table 2 and are essentially in line with the main results emerged from Table 1. Functional specialisation remains highly persistent over time. GVC participation alone is not significantly correlated to the employment structure. However, as technological laggards 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-sectors 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. This result is in line with the

[11] 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.

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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.741	0.741	0.742	0.743	0.822	0.822	0.825	0.825

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Top decile patent* is a dummy taking value 1for country-sectors that were in the top decile in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country, sector, and year fixed effects. Robust standard errors in parentheses ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

core findings of the headquarter-factory literature but expands it by explicitly integrating the technological dimension as a key mediating element of GVC participation and functional specialisation.

The (average) patent intensity of foreign manufacturing suppliers does not seem to be related to employment structure and this also applies to country-sectors in the bottom decile for patent intensity. In contrast, the quality of service providers (*Bwd Intangibles*) 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 technological laggards.

It is also worth highlighting that while our results do not ascertain causal relationships, we find associations that are not economically negligeable. For example, our results suggest that 1 % increase in the intangible intensity of backward partner would be associated to 0.64 % (see Table 1) increase in the share of managers and a 0.26 % decrease in the share of manual workers (see Table 2).

In Table A12 in the Appendix we report descriptive statistics of our key variables, which allows us to make some back of the envelop calculations to give a more concrete sense of the economic relevance of our results. We find in fact that a one standard deviation increase in backward intangible intensity is associate to an increase of 13 % of a standard deviation in the share of managers and a decrease of 9 % of a standard deviation in the share of manual workers.[12]

Finally, the key results are robust against 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). This provides reassurance that our results are not driven by the choice of thresholds to define technological leadership and laggardness.[13] We also weight our results on sectors' total employment to make sure that our

[12] These quantifications are derived by multiplying the ratio of the standard deviations of the explanatory and outcome variable (available in Table A12) by the coefficients of *Bwd Intangibles* from Tables 1 and 2 for the share of managers and manual workers, respectively.

[13] It is important to stress here that in our approach we model technological laggardness and leadership as binary, rather than continuous. This is to say that a country-industry either is or isn't a technological leader or laggard and there is not a spectrum on which country-industries fall in a continuous way. We leave the exploration of this alternative way of looking at technology and GVCs to future research.

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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.744	0.745	0.746	0.746	0.828	0.828	0.830	0.830

Note: PSsM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Bottom decile patent* is a dummy taking value 1for country-sectors that were in the bottom decile in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country, sector, and year fixed effects. Robust standard errors in parentheses ***p < 0.01, **p < 0.05, *p < 0.1

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 B.

5. Conclusion

This contribution has looked at the interplay between GVC integration and technology and their linkages with 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 occupations (which we proxy with manual and managerial occupations) associated with the participation in GVCs. We articulate the concept of functional specialisation by looking at how the technology intensity of countrysectors and their partners contribute to explain the heterogeneity of GVC integration and changes in employment structures.

Section 2 has shown 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 structure, in which Germany remains a pivotal player. Albeit over the short time span of 15 years, we show that the gaps across EU countries and sectors in terms of technology and functional specialisation, have not narrowed.

Our econometric analysis has confirmed the inertia of employment structure and shown that the latter is not related to the participation in GVC per se, suggesting that there is no automatic upgrading in functional specialisation that can be explicitly attributed to integration into GVCs. Importantly, we show that different patterns of GVC integration and functional specialisation do emerge depending on the initial technological performance of the country-sector integrating in GVC and on the technological capabilities of the partners. We do so by merging a range of data sources, that have so far never been used together to measure technological capabilities in GVCs. The data does come with some limitations in terms of coverage and level of aggregation. In dealing with these constraints, our choices are both methodologically and conceptually motivated, and in line with the emerging literature on functional specialisation and technology (Timmer et al., 2019). In this respect, while some caution is warranted in interpreting our results, our work provides further motivation for additional efforts in compiling more disaggregate data covering GVC, technology and employment.

Most of our econometric results are in line with the literature on headquarter and factory economies and consistent with the evidence presented in Section 2. Our estimates show that technological leaders tend to reinforce their functional specialisation as they further integrate in GVCs (in particular reducing the share of manual workers) while for technological laggards integration into GVCs is accompanied by an increase in the share of employment in fabrication functions and a reduction of the share of managers. In addition, technological laggard countries-sectors do not see increases in their manager shares when they integrate with patent-intensive manufacturing GVC partners. These findings seem to suggest 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 have increased their specialisation in fabrication and, arguably, low value-added functions.

Our econometric estimates also show the presence of a more complex and fine-grained picture of the relationships between GVC participation and functional specialisation. This is compatible with an international fragmentation of production that does not only occur "vertically" (between high and low technology firms, sectors and countries) but also horizontally. In particular we find that technological leaders tend to increase the quality of their employment structure when they integrate with knowledge intensive service industries while they see their share of managers reduce as they engage with patent-intensive manufacturing suppliers. These findings are consistent with the most recent literature on international business highlighting the presence of different organisational structures and strategies underpinning innovation within GVCs (Ambos et al., 2021).

The policy implications deriving from this contribution can be conveyed through two messages.

First, countries and industries' initial technological performance constrains their ability to benefit from GVC integration. This implies that the processes of participation in GVCs should be accompanied and possibly preceded by policies favouring the development of skills and technological capabilities, to facilitate a better positioning of firms, sectors and countries within GVCs (López-Gonzalez et al., 2019). By introducing policies that will strengthen country-sectors' 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, thus, headquarter functions. This does not necessarily mean adopting industrial policies to actively shape countries' existing comparative advantage (Lin and Chang, 2009; Warwick, 2013; Cherif and Hasanov, 2019; Chang and Andreoni, 2020) but also to provide the necessary level of skills and technological capabilities which are complementary to managerial occupations.

Second, the evidence put forward in this paper calls for the adoption of a more systemic approach to EU industrial policies. These should be based on a detailed analysis of the patterns 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 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.

Based on the contribution of this paper, a sensible research agenda on functional specialisation in GVCs should be attentive to at least two fundamental dimensions.

First, technological asymmetries in both levels and quality across countries should be unpacked even further by taking into account the geopolitics of GVC integration. The actual potential for countries, particularly developing and emerging countries, to change their functional specialisation along GVCs is related to trade strategy as much as domestic decisions in terms of industrial and technology policy. A thorough investigation on how integrated structural and trade policy might actually allow functional upgrading in the midst of the new geopolitical equilibria is certainly a fruitful line of research.

Second, the role of intangibles and services as a leverage for functional upgrading would deserve more research effort. This is true for instance when countries are trying to 'move away' from natural resources specialisations (Savona and Bontadini, 2023) by trying to develop competences in backward linked knowledge intensive services. This might open up further opportunities for functional specialisations in sectors that are neither "R&D" nor "fabrication", but something entirely novel. This is all the more true when we consider the novel opportunities linked to digitalisation and the emergence of 'green' GVCs. We trust that novel data will allow this investigation.

Credit author statement

All authors have equally contributed to the production of this research.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Appendix A. Methods and grouping of countries, industries and occupations

In this Appendix we discuss, first, in more detail our methodological approach to computing the measures of GVC participation (A.1) and those of technological capabilities (A.2) that we combine to obtain the variables in our empirical analysis. Second, we detail how we have grouped countries and industries into macro-regions and industries, which we use in our discussion in Section 2, along with additional descriptive evidence we reference in the text (A.3).

A.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.[14] 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 and Mancini, 2020). We follow Borin and Mancini (2020), which expand the approach of Johnson (2018) to what Koopman et al. (2014) refer to as foreign value added in gross export, also known in the literature as backward GVC participation:

$$BWD_s = \sum_{r \neq s} V_r B^s_{r,s} E_s \tag{A.1}$$

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:

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

where A^s is a matrix of technical coefficients in which all rows corresponding to country-sector s 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. BWD_s is expressed in absolute terms and in order to account for size effects, we divide it by country-sector total output:

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

We prefer to use output as denominator rather than export or value added. This is because at the country-sector 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-sectors' productive process as a whole, and not just production that satisfies foreign demand.

A.2. Technological capabilities, patent stock and intangible assets

We also devise a measure of GVC partners' knowledge and technology intensity. Using the REGPAT dataset compiled by the OECD, we retrieve the number of patent applications filed with the European Patent Office (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[15]:

$$K_{ijt} = PAT_{ijt} + (1 - \delta) K_{ijt-1} \tag{A.4}$$

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

$$K_{ijt_0} = \frac{PAT_{ijt_0}}{\bar{g_{ij}} + \delta} \tag{A.5}$$

where PAT_{ijt} is the patent applications filed with the EPO in sector j from inventors in country i in year t and $\delta = 0.1$ is the depreciation rate, set at a level in line with the literature (Verdolini and Galeotti, 2011; Keller, 2002); $\bar{g_{ij}}$ 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.

As discussed in the main text, 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 complement 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.

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

[14] 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.

[15] Two clarifications on the notation are in order. First, we use subscripts i and j instead of r and s because they refer to different things. In the latter 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 former case, we do not use a comma as we indicate a unique country-sector identified by country i and sector j. Second, in Eqs. (1) and (2) in the main text we use $|B\bar{W}D_{r,s}$ 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 Eqs. (1) and (2) $|\sum_{r \neq s} \bar{B}WD_{r,s}$ in contrast refers to the total backward GVC participation of country-sector s and it is therefore equal to $|B\bar{W}D_s$ from Eq. (A.3).

there is no variation across manufacturing industries within each country.[16] 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-sector's partner, this is only restricted to countries that are included in the INTANINVEST dataset.[17]

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 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:

$$Patint_{ijt} = \frac{K_{ijt}}{Output_{ijt}} \text{ if } j \in manufacturing \tag{A.6}$$

$$Intanint_{ijt} = \frac{Intan_{ijt}}{Output_{ijt}} \text{ if } j \in services \tag{A.7}$$

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 patents as a relatively narrow-defined measure of technological capabilities in the manufacturing sector, while we rely on intangibles that have broader conceptual boundaries to assess the quality of services industries.

A.3. Grouping of countries, sectors, and technological leaders and laggards

This section of the appendix reports the grouping of countries in regions (Table A1) and industries in macro-sectors (Tables A2 and A3) that we use to present the descriptive evidence in section 2. We also show which country-sectors rank in the top and bottom two deciles of the distribution of patent intensity among manufacturing industries (Tables 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 Sections 3 and 4.

We also report some key descriptive evidence on the distribution and evolution of the variables used in Figs. 1 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
C10-C12	Manufacture of food products, beverages and tobacco products
C13-C15	Manufacture of textiles, wearing apparel and leather products
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials
C17	Manufacture of paper and paper products
C18	Printing and reproduction of recorded media
C20-C21	Manufacture of chemicals and pharmaceutical products
C22	Manufacture of rubber and plastic products

(continued on next page)

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

[17] Intangible assets have received growing attention in the literature and here we follow Corrado et al. (2016) approach and rely on the INTANINVEST dataset to retrieve 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).

Table A2 (*continued*)

NACE	Description
C23	Manufacture of other non-metallic mineral products
C24	Manufacture of basic metals
C25	Manufacture of fabricated metal products, except machinery and equipment
C26	Manufacture of computer, electronic and optical products
C26	Manufacture of computer, electronic and optical products
C26	Manufacture of computer, electronic and optical products
C27	Manufacture of electrical equipment
C28	Manufacture of machinery and equipment n.e.c.
C29	Manufacture of motor vehicles, trailers and semi-trailers
C30	Manufacture of other transport equipment
C31-C32	Manufacture of furniture; other manufacturing

Table A3
Service industries.

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

Table A4
Manufacturing country-sectors 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-sectors 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

(*continued on next page*)

Table A7 (*continued*)

Country	Mean	Median	Change	Percentage change
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.

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

Table A12
Descriptive statistics.

	Obs.	Minimum	p25	p50	Mean	p75	Maximum	St. dev.
Share of managers	2575	0.01	0.20	0.26	0.29	0.37	1.00	0.14
Share of manual workers	2573	0.13	0.53	0.64	0.62	0.72	0.98	0.15
Share of managers (log)	2575	−4.69	−1.63	−1.34	−1.34	−0.99	0.00	0.51
Share of manual workers (log)	2573	−2.04	−0.64	−0.45	−0.52	−0.33	−0.02	0.29
Bwd GVC	2575	0.00	0.08	0.18	0.20	0.29	0.72	0.14
Bwd patent	2575	0.03	0.05	0.06	0.06	0.07	0.16	0.02
Bwd intangibles	2575	0.04	0.05	0.05	0.05	0.05	0.07	0.01
Bwd GVC (log)	2575	−7.73	−2.49	−1.72	−1.98	−1.24	−0.33	1.07
Bwd patent (log)	2575	−3.58	−2.97	−2.79	−2.79	−2.63	−1.80	0.28
Bwd intangibles (log)	2575	−3.24	−3.07	−3.00	−3.00	−2.94	−2.60	0.10

Note. The table reports the descriptive statistics based on results in column 4 in Table 1.

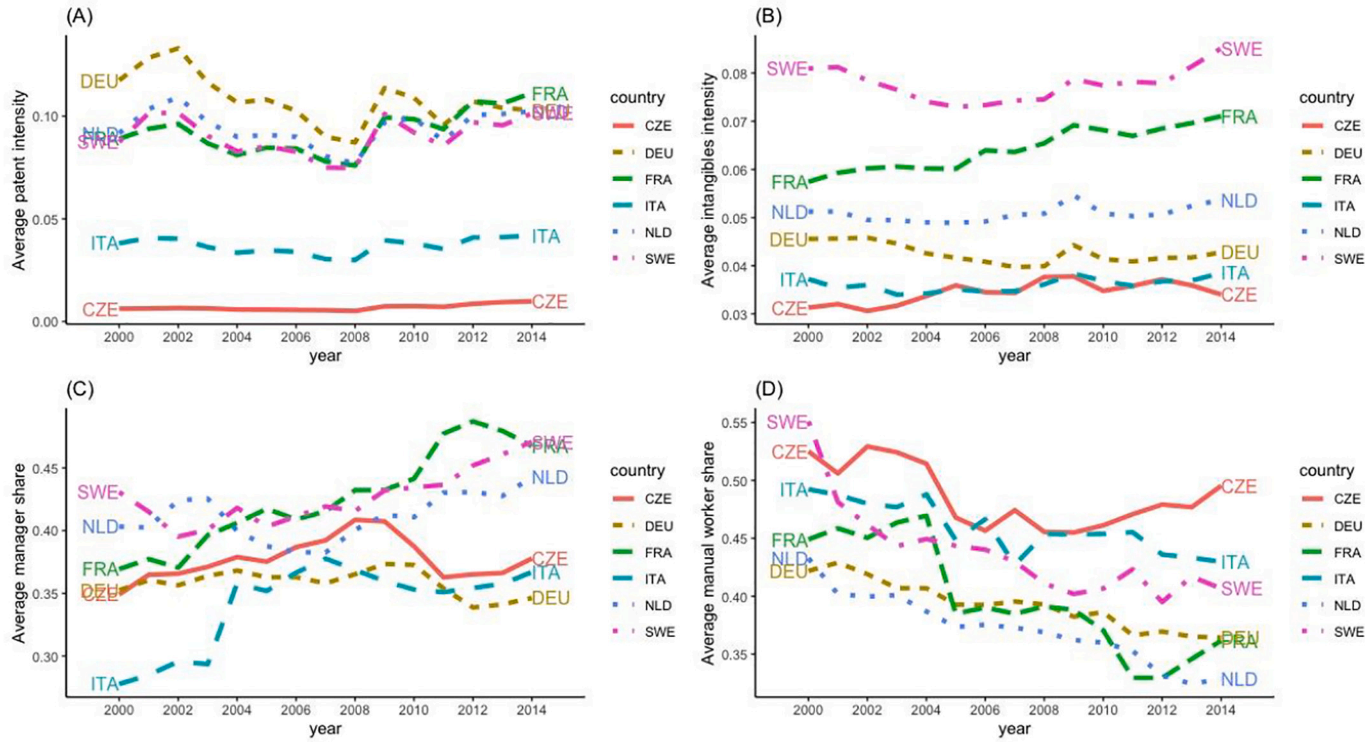

Fig. A.1. Patent, intangibles intensity and shares of managers and manual workers across selected countries and over time.
Source: authors' calculations using REGPAT, INTANINVEST and LFS data – unweighted average across macro regions and sectors for patent and intangible intensity.

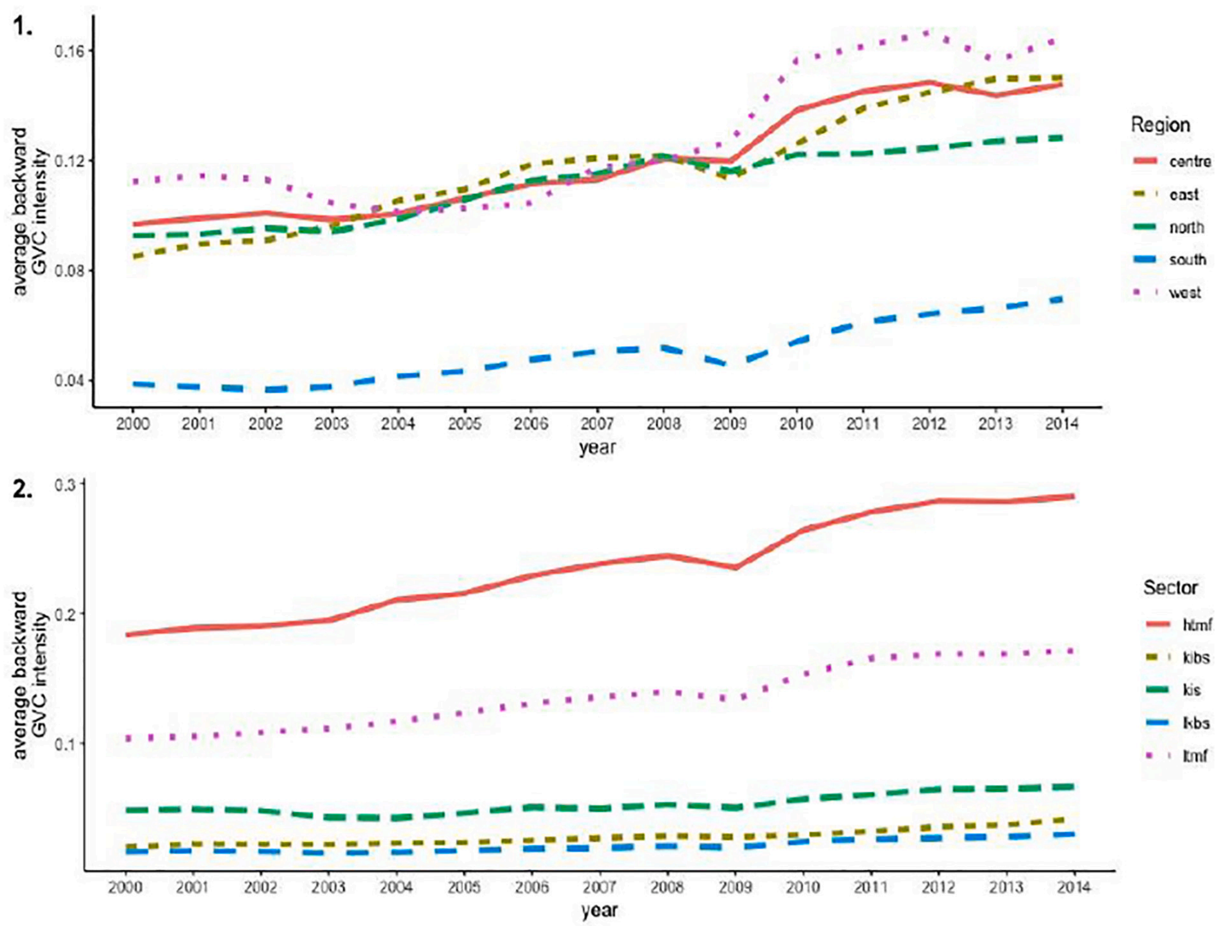

Fig. A.2. Backward linkages across regions and macro-sectors over time.
Source: authors' calculations using WIOD data – unweighted average across macro regions and sectors for backward GVC intensity.

Appendix B. Robustness checks

This section reports and briefly discusses some robustness checks of our results from the econometric analysis presented in Section 4 in the main text.

While appropriate for identifying leaders and laggards in patent intensity, the choice of using a dummy taking value one when a country-sector ranks in the top (or bottom) decile is somewhat arbitrary. We therefore replicate our results, setting the threshold to identify country-sectors 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-sector is in the top 20 % for patent intensity. As we enlarge the group of country-sectors 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-sectors 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 (Table 1 in the main text) we find a negative sign, suggesting a competition/substitution effect, whereby technological leaders offshore managerial occupations to other technologically intensive GVC partners. Now we find no evidence of this effect and in contrast we find that country-sectors 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-sectors 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-sectors 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-sectors 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-sectors 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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.741	0.741	0.743	0.743	0.824	0.825	0.826	0.827

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Top decile patent* is a dummy taking value 1 for country-sectors that were in the 2 top deciles in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country, sector, and year fixed effects. 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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.742	0.743	0.744	0.745	0.825	0.825	0.828	0.828

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Bottom decile patent* is a dummy taking value 1 for country-sectors that were in the 2 bottom deciles in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country, sector, and year fixed effects. 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-sectors 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***

(*continued on next page*)

Table B3 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual workers			
	(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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.766	0.767	0.768	0.769	0.840	0.840	0.842	0.842

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Top decile patent* is a dummy taking value 1 for country-sectors that were in the top decile in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country, sector, and year fixed effects and weight our results on country-sectors' total employment. 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)

(*continued on next page*)

Table B4 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual workers			
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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.770	0.770	0.771	0.771	0.845	0.845	0.846	0.846

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Bottom decile patent* is a dummy taking value 1 for country-sectors that were in the bottom decile in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country, sector, and year fixed effects and weight our results on country-sectors' total employment. 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 Tables B5 and B6). In our main model, this only applies to country-sectors that were in the top 10 % for patent intensity, while now this appears to be the case for all country-sectors.

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-sectors 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)

(continued on next page)

Table B5 (*continued*)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Managers				Manual workers			
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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.789	0.790	0.790	0.791	0.861	0.862	0.862	0.863

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Top decile patent* is a dummy taking value 1 for country-sectors that were in the top decile in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country-year, and industry-year fixed effects. 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	2575	2575	2575	2575	2589	2589	2589	2589
R-squared	0.793	0.794	0.793	0.795	0.868	0.868	0.868	0.868

Note: PSM is the pre-sample mean of the outcome variable, either the share of managers or manual workers, computed over the period 2000–05. *Bwd GVC* is backward GVC participation as described in Eq. (3); *Bwd Patent* is the patent intensity of manufacturing GVC partners as computed in Eq. (1), *Bwd Intangibles* is intangibles intensity of GVC partners as in Eq. (2). *Bottom decile patent* is a dummy taking value 1 for country-sectors that were in the bottom decile in terms of their average patent intensity over the period 2000–05. *Patents* is patent stock divided by output and *Capital* is capital intensity computed as total capital to labour ratio, averaged over the period 2000–05. We include country-year, and industry-year fixed effects. Robust standard errors in parentheses ***p < 0.01, **p < 0.05, *p < 0.1

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