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ORIGINAL PAPER

Functional specialization and upgrading along global value chains in European regions: new insights from FDI data

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Abstract

The geographic dispersion of production activities has led regions to increasingly specialize in distinct value chain functions, giving rise to a finer spatial division of labour. Using georeferenced FDI data on cross-border investments distinguished by value chain function, we provide the first systematic mapping of functional specialization across European NUTS-2 regions over the period 2003–2018. We show that the most intangible-intensive functions at the upper ends of value chains are concentrated in a small number of advanced regions, while lower-income ones are largely and persistently engaged in production operations. We document the strong spatial persistence of functional specialization before and after the 2008 crisis and find that regions trapped in production functions are the least likely to upgrade towards more knowledge-intensive industries. By contrast, only the few regions which experienced functional upgrading trajectories have been able to diversify towards more innovative industries, revealing a close interdependence between functional and inter-sectoral upgrading. Accordingly, regional policies should aim at favouring functional upgrading of laggard regions as a key vehicle for economic and spatial convergence in Europe.

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1 Introduction

An expanding literature on Global Value Chains (GVCs) has highlighted that the international fragmentation of industries and the geographical dispersion of value-adding functions at global scale have fostered a new spatial division of labour (Fröbel et al. 1980; Massey 1995; Peck 2016; Giammetti et al. 2022). It is indeed widely acknowledged that economies tend to increasingly specialize in value-adding activities—from the conception of goods to their fabrication and commercialization—rather than in final products or services (Feenstra 1998; Grossman and Rossi-Hansberg 2008). The unequal capacity of economies to perform different GVC functions helps explain disparities in value capture and spatial development (Henderson et al. 2002; Coe et al. 2004, 2008; Hudson 2016; Capello et al. 2024). Accordingly, the growth opportunities of countries and regions have become largely dependent on their capability to experience "functional upgrading", i.e. to shift from low to higher value-adding activities along GVCs (Gereffi 1999; Blažek 2016; Coe and Yeung 2019).

In this regard, the GVC and evolutionary economic geography (EEG) literature have provided complementary insights into the determinants of regional development. On the one side, the GVC literature has extensively highlighted the risks and development opportunities associated with the international fragmentation of production and how this opened up prospects for different forms of economic upgrading (Humphrey and Schmitz 2002; Sturgeon and Gereffi 2009); on the other side, EEG has emphasized that a region's capacity to diversify into new economic activities is fundamentally conditioned by its pre-existing, place-specific capabilities (Boschma 2017). From both a conceptual and methodological viewpoint, however, EEG has mostly taken industries, products and technologies as fundamental units of analysis (Neffke et al. 2011; Kogler et al. 2017; Alonso and Martin 2019; Balland et al. 2019), while GVC-related categories, such as value-adding functions, economic upgrading and value capture, have often remained outside its analytical toolbox. The growing dialogue between these two research agendas has recently fostered increasing attention to the analysis of the "geography of functions" (Boschma 2022), namely to the investigation of the functional specialization patterns of regions and their consequences in terms of regional development.

Yet, one aspect which remains largely unexplored from an empirical point of view is the interdependency between sectoral and functional specialization. This is especially true when it comes to analysing development prospects at the subnational level, which largely reflect the combination of the characteristics of the local industrial base with the historical heritage of places in terms of the skills and abilities of local actors to perform specific tasks (Bellandi et al. 2019). From this perspective, sectoral specialization and upgrading patterns of places are most likely to be affected by their changing functional capabilities. In fact, regions engaging in new, more dynamic industries might not gain access to higher growth paths if they remain locked into low value-adding activities within industries. Conversely, one may assume that regions experiencing functional upgrading trajectories are more likely to acquire the know-how and financial assets which can be subsequently redeployed in

new industrial activities, therefore, favouring the diversification of regions towards more innovative sectors.

The main contributions of this paper are threefold. First, we use georeferenced data on cross-border investments distinguished by value chain function to provide the first systematic mapping of functional specialization across 266 European NUTS-2 regions over the period 2003–2018, moving beyond the sectoral dimension that has traditionally dominated in regional studies.

Second, we document the evolution and spatial persistence of functional specialization before and after the Great Financial Crisis, showing that regions locked into low value-adding production activities along GVCs exhibit the strongest functional inertia and the least capacity for structural change. We identify the few regions which have experienced functional upgrading—i.e. a shift towards specialization in functions with greater value capture potential—and the more numerous ones whose position in value chains has remained unchanged or deteriorated.

Third, and most importantly, we link the observed patterns of functional specialization with changes in sectoral specialization across the revised Pavitt Taxonomy (Pavitt 1984; Bogliacino and Pianta 2010) and provide novel evidence that functional upgrading trajectories are intertwined with inter-sectoral upgrading. Only those few regions climbing up the value ladder by moving towards the more knowledge-intensive functions at the upper ends of GVCs also diversified towards more innovative industries (i.e. inter-sectoral upgrading); conversely, regions trapped in production functions consolidated their specialization in supplier-dominated sectors.

The remainder of this work is organized as follows. Section 2 provides a conceptual framework concerning the interdependencies between functional and sectoral specialization patterns. Section 3 reviews the empirical literature on the geography of functions and extrapolates the research question we wish to address. Section 4 describes our data and methodology. Section 5 illustrates the functional trajectories of regions and their links with sectoral dynamics. Section 6 discusses the main findings, draws policy implications and outlines avenues for future research.

2 The links between functional and sectoral specialization: a conceptual framework

An extensive literature in evolutionary economic geography has pointed out that the economic development of regions is strongly linked to their ability to diversify into more dynamic and knowledge-intensive industries (Balland et al. 2019; Mewes and Broekel 2020; Content et al. 2022). This view ties in with a long-standing tradition of development studies emphasizing the structural change patterns triggered by industrialization and rising incomes (Chenery et al. 1986; Syrquin 1988). Moreover, the emphasis on the sectoral diversification of regions connects with the more recent attention to the role played by the diversification and complexity of countries' export baskets in determining their growth prospects (Hidalgo et al. 2007; Hausmann and Hidalgo 2011). However, the international fragmentation of production has led firms and regions to increasingly specialize in distinctive value chain functions rather than in final goods and services, implying the need to explore the links between the

patterns of industrial change and the value-adding activities being carried out within industries.

These links between the functional and sectoral diversification paths have been partially captured by recent empirical research at the country level, showing that the distribution of value-adding activities within industries—as measured by data on occupational categories of workers—is very different for high-income compared to low-income economies (Kruse et al. 2023). Notably, the latter countries tend to move across industries within occupational classes, whereas richer countries diversify towards different occupational classes within industries. It is also found that most countries follow patterns of moderate functional diversification over relatively long periods of time, but the ones deviating the most from their original functional profile exhibit the highest growth in GDP per capita. The authors suggest that their findings might reveal the existence of important complementarities between activities yielding important advantages to countries undertaking functional upgrading, but remain agnostic about the precise nature of such interdependencies (Kruse et al. 2023).

This evidence is consistent with the task-based view of technical change (Acemoglu and Autor 2011). Such a view also provides a natural bridge between functional specialization and labour market structure, insofar as value chain functions can be understood as bundles of tasks. From this perspective, functional upgrading entails changes in the composition of value-adding activities carried out locally, contributing to the accumulation of new capabilities and fostering a reorientation of the workforce towards more knowledge-intensive, non-routine jobs. This may also help to explain why shifts in the functional profile of an economy create greater growth opportunities than sectoral shifts alone.

What is apparent is that the sectoral composition of local economies does not per se reveal all the opportunities and constraints that may be associated with the functional profile of places. Indeed, to fully grasp the nature and developmental implications of international fragmentation of production, one needs to combine the sectoral dimension with an analysis of the value chain functions that regions mostly perform.

There are several theoretical mechanisms through which functional specialization may shape opportunities for inter-sectoral upgrading.

First, sectoral diversification may have completely different implications in terms of economic development depending on the activities undertaken within sectors. A shift from low to higher technology-intensive industries is likely to yield very little economic benefits to economies that are locked into low value-adding activities (such as assembling and fabrication of standard components). While it may be true that specializing in micro-chips opens up higher learning and income growth opportunities than specializing in potato chips (Dosi et al. 2021), it is also likely that pure assembling of micro-chips will not yield the same value capture and growth opportunities as specializing in R&D, design and testing of micro-chips (Mudambi 2008; Dedrick et al. 2010; Buckley et al. 2020; Durand and Milberg 2020).

Second, there is no guarantee that entering new more dynamic sectors, or increasing specialization therein, will bring along higher capacities to undertake higher value-adding activities, either upstream (e.g. R&D) or downstream (e.g. marketing and after-sales services). Access to these functions can be hampered by inertial

factors and barriers to entry created by players (e.g. lead firms in GVCs) controlling the intangible assets necessary to operate in those value chain segments and to capture economic value from them (Davis et al. 2018; Gereffi 2019; Kaplinsky 2019). Indeed, entry in high-tech sectors may imply a greater exposure to larger and more dynamic markets which might stimulate innovation and favour the accumulation of novel knowledge and competencies. However, these are likely to be gradual, contested as well as time and resource consuming processes that might be out of reach for new entrants, especially small enterprises located in laggard regions (Pavlínek and Ženka 2011; Plank and Staritz 2015; Bernhardt and Pollak 2016; Pavlínek 2022).

Third, functional upgrading is instead likely to open sectoral upgrading opportunities, i.e. greater possibilities to enter new and more innovative industries. In fact, and consistently with the task-based view of technical change (Acemoglu and Autor 2011), the shift towards more intangible-intensive activities entails the accumulation of task- (rather than industry-) specific knowledge, skills and organizational capabilities that can be redeployed beyond the industries in which they were originally developed. Accordingly, functional upgrading can provide regions with the capacity to generate, or gain access to, valuable knowledge and assets that can be applied to different sectoral contexts, making it a particularly promising—albeit challenging—strategy to pursue (Humphrey and Schmitz 2002; Kaplinsky et al. 2002; Lee and Gereffi 2015; Capello et al. 2024).

Not all assets generated and accessed via functional upgrading can be easily applied across sectors. This will largely depend on how general and abstract knowledge assets are (Arora and Gambardella 1994), and hence on the costs of de-contextualizing knowledge generated through specific learning experiences. Nevertheless, firms' investment in specific intangible-intensive activities, e.g. R&D functions, is generally associated with the accumulation of valuable capacities to absorb knowledge from external parties, including suppliers, users and competitors, which might enable them to innovate and compete also in different sectors (Cohen and Levinthal 1989). This is particularly the case of basic research, which is even more likely to enable firms to plug into knowledge circuits and application contexts that may be (technologically and organizationally) distant from the sectors and technological classes they originate from (Rosenberg 1990). Consistently, the concept of absorptive capacity has been extended to the analysis of innovation dynamics and economic performance from the firm level up to the sectoral (Malerba 2005), country (Criscuolo and Narula 2008) and regional (Asheim and Gertler 2005) levels.

From a GVC perspective, it follows that the control of the most intangible-intensive functions at the upper ends of the value chain can be associated to substantial economies of scope and learning (Teece 1986, 1998; Pagano 2014), hence providing the financial and knowledge resources to favour the diversification of economies towards more innovative industries.

Accordingly, one may expect that economies experiencing functional upgrading trajectories are also more prone to follow inter-sectoral upgrading paths. Conversely, economies being locked into low value-adding activities (e.g. fabrication and assembly operations), or experiencing functional downgrading trajectories, can

be expected to either be stuck in low-tech sectors, or shift towards less innovative industries.[1]

The line of argument just sketched is general enough to be applied to different spatial scales, including the regional one. Nevertheless, as we shall see in the next section, the lack of empirical studies combining the functional and sectoral specialization patterns of regions is especially apparent, mainly due to the paucity of data on value chain functions at the subnational level.

3 Empirical literature on regional specialization

Empirical studies at country and subnational level have long focused on the sectoral specialization patterns of countries (Leamer 1984; Dosi et al. 1990; Archibugi and Pianta 1994; Neffke et al. 2011; Boschma et al. 2013; Content et al. 2022). Conversely, research on functional specialization patterns have long been hindered by the lack of detailed data on GVC activities, which are dramatically less available than information on products and sectors. Besides case studies (e.g. Dedrick et al. 2010), this scarcity of data has been partially overcome at the national and macro-regional level by using trade statistics based on input–output data combined with information on the occupational categories of workers employed in exporting sectors (Timmer et al. 2019) or detailed FDI data reporting information on value chain activities (Stöllinger 2021; Coveri and Zanfei 2023).

Data limitations are even more binding when it comes to regional level analyses. In fact, input–output tables and occupational wage and employment data are generally not available with a high level of geographical disaggregation, hence limiting the possibility to replicate the approach developed by Timmer et al. (2019) for subnational regions.[2] Relatively few studies have examined the regional distribution of value-adding activities using the richness of FDI data on value chain functions. Crescenzi and Iammarino (2017) used data on FDIs attracted and promoted by European regions as a proxy for their international networking and offered evidence on the changing functional composition of investments as the total amount of FDIs attracted and promoted by regions changes. Focusing on Southern and Eastern Ireland, Scotland and Wales, Iammarino (2018) observed patterns of inward and outward FDIs in different functions to and from these regions, and draw insights on how the differentiated exposure to foreign capital, knowledge and skills shapes regional development trajectories. Comotti et al. (2020) pooled FDI flows from 2003 to 2017 to analyse the involvement of European regions in different value chain

[1] Humphrey and Schmitz (2002) distinguish between process, product, functional and inter-sectoral (or chain) upgrading. Our analysis focuses on the relationship between functional and inter-sectoral upgrading, where the latter involves the exploitation of accumulated capabilities related to selected value-adding functions to enter more innovative sectors. Although we do not directly examine process and product upgrading, our use of Pavitt's taxonomy (Pavitt 1984) provides some insights into regions' propensity to also undertake these forms of upgrading (see Sect. 4).

[2] Accordingly, indicators based on this approach have been mainly used in country-level analyses (de Vries et al. 2019; Pleticha 2021; Kordalska and Olczyk 2022).

functions and its link with country-level indicators of trade in GVCs. In a similar vein, Crescenzi and Harman (2022) provided evidence on the amount of FDIs across GVC stages accruing to and from Chinese provinces over the 2003–2017 period, and the association between GDP per capita and the share of inward FDI in knowledge-intensive functions for a number of Asian countries.

Other studies investigated the determinants of the locational choices of cross-border investments by multinational corporations (MNCs) in different value chain functions. Defever (2012) used data on the location choices of MNCs in 224 European NUTS-2 regions between 1997 and 2002 to analyse the spatial co-location of different stages of their value chain (production, headquarters, R&D, logistics and sales). Crescenzi et al. (2014) found considerable heterogeneity in the determinants of inward investment of EU regions in the most knowledge-intensive functions compared to other value chain stages over the period 2003–2008. Belderbos et al. (2016) explored the "push" and "pull" factors shaping outward and inward FDIs in upstream functions (especially knowledge-intensive activities such as research, design and development) at the city-level using data on greenfield cross-border investments over the period 2003–2011. They showed that the technological strength of local universities and the international connectivity of the city, along with standard cost factors (e.g. wages, corporate taxes and fiscal R&D incentives), are key drivers of FDIs in knowledge-intensive activities. Castellani et al. (2016) used data on 146 European NUTS-2 regions over the 2005–2008 period to study the determinants of FDIs in business services. They found that regions whose manufacturing industries exhibit a higher propensity to use business services attract more FDI in this function than other regions. Krisztin and Piribauer (2021) analysed the spatial determinants of bilateral FDI flows between European NUTS-2 regions from 2003 to 2014, focusing on origin, destination and third-region effects and distinguishing FDI flows across different value chain stages. They found that FDIs in production functions tend to locate in smaller regions near urban agglomerations, whereas those in upstream and downstream activities concentrate within major urban areas, driven by the availability of human capital. They also show that regional knowledge capital is a key determinant of FDI outflows. Finally, using data on greenfield FDIs received by the US Metropolitan Statistical Areas from 2009 to 2014, Castellani et al. (2022a) showed that the areas connected to the global economy by international networks of inventors are particularly attractive for R&D activities. Conversely, inward FDIs in production and logistics functions are concentrated in locations with greater infrastructural connectivity for the mobility of goods and people; while MNCs' investment in downstream functions such as sales and marketing activities are more likely to occur in "global cities" exhibiting greater worldwide connectivity.

While these works offered seminal evidence on the functional distribution of cross-border investments, the links between the functional and sectoral specialization trajectories of regions remain largely unexplored. This lack of attention to the connections between the functional and sectoral profile at the subnational level substantially limits our understanding of regional economic development. Indeed, as argued above, the development of regions most likely depends on both dimensions of upgrading, i.e. the ability of regions to move towards higher value-adding

functions and to develop the capabilities to enter more innovative sectors (Humphrey and Schmitz 2002).

The discussion above leads us to formulate our main research question as follows: how are the functional specialization trajectories of regions associated with their opportunities for inter-sectoral upgrading?

4 Data and methodology

To measure the functional specialization of European regions, we use FDI data provided by fDi Markets, a deal-based database maintained by fDi Intelligence (a specialist division of Financial Times Ltd) collecting information on cross-border greenfield investments covering all sectors and countries worldwide from 2003 onwards.[3] A distinctive feature of the fDi Markets database is that, together with the sectoral detail, it reports the main business activity—i.e. the value chain function such as headquarter services, R&D, manufacturing, logistics, sales, marketing and support, etc.—each FDI project is aimed to carry out. This represents the crucial information that we exploit to compute our indicators of functional specialization, together with city-level details on the origin and destination of FDIs.[4]

Differently from trade-based indicators derived from international input–output tables combined with labour statistics (Timmer et al. 2019), FDI data by value chain function are available at the subnational level for a relatively long time span, thus providing a valuable opportunity to explore the geography of functions and its evolution over time. Subsequently, we use fDi Markets to collect georeferenced FDI data for 266 NUTS-2 regions in the EU27 and in the UK from 2003 to 2018.[5]

We first classify inward FDIs according to the value chain functions they are related to and adopt the canonical "smile curve" classification by grouping the value-adding activities into three GVC stages: upstream, production and downstream (Mudambi 2008). This classification has been adopted in previous conceptual and empirical analyses to investigate the value capture opportunities and development prospects of economies according to their functional positioning along GVCs (Crescenzi et al. 2014; Baldwin and Evenett 2015; Krisztin and Piribauer 2021; Crescenzi and Harman 2022; Coveri and Zanfei 2023). Accordingly, we group the business activities reported by fDi Markets as follows:

[3] We have access to fDi Markets data from 2003 to 2018; hence, our empirical analysis cannot account for the outbreak of the COVID-19 pandemic.

[4] Consistently with several previous works (Castellani et al. 2013, 2016; Crescenzi et al. 2014, 2015; Ramasamy et al. 2012; Krisztin and Piribauer 2021), we consider the number of FDI projects rather than the value of capital involved because the monetary values of the capital investment are almost exclusively estimated, and estimation criteria are not explicit. In addition, as noted by Crescenzi et al. (2015, p. 33), the number of investment decisions is likely to be a more proper unit of analysis than the value of the project insofar as such decisions have been demonstrated to be broadly independent from the amount of capital invested.

[5] Detailed descriptive statistics on the distribution of FDI projects included in the fDi Markets database are reported in Appendix A of the Online Supplementary Material.

(i) *Upstream functions*: headquarters activities, R&D, design, development & testing, education & training and ICT & Internet Infrastructure activities;
(ii) *Production functions*: fabrication, assembly, recycling and extraction activities;
(iii) *Downstream functions*: activities related to marketing, advertising, sales and after-sale services, logistics, distribution and transportation.

Then, following previous works that used inward FDI data to measure Functional Specialization (FS) at the country level (Stöllinger 2021; Coveri and Zanfei 2023), we compute Balassa's (1965) index to measure the *revealed comparative advantage of regions in a given* GVC *stage* as follows:

$$FS_i^a = \frac{\frac{FDI_i^a}{\sum_a FDI_i^a}}{\frac{\sum_i FDI_i^a}{\sum_i \sum_a FDI_i^a}} \quad (1)$$

where the share of inward FDIs related to the *a*-th GVC stage over total inward FDIs received by the *i*-th region in a given period (the numerator) is normalized with the share of inward FDIs in the same GVC stage over total inward FDIs for the world as a whole (the denominator). The indicator takes a value greater than one when the region reports a relative specialization in (attracting FDIs into) a given GVC stage.

We also compute an indicator of *relative functional specialization of regions* (RFS)—first used by Stöllinger (2021) at the country-industry level—which provides a synthetic index of the functional specialization of a region in production functions with respect to its functional specialization in the most knowledge-intensive stages. Formally, the RFS index of the *i*-th *region* is calculated as follows:

$$RFS_{i,t} = \frac{FS_{i,t}^{production}}{FS_{i,t}^{upstream} + FS_{i,t}^{downstream}} \quad (2)$$

Next, by exploiting the variation across time of the FS indicator, we group together regions experiencing similar functional trajectories during the two periods considered. More specifically, we compute a transition matrix based on the functional specialization in FDI of NUTS-2 regions between 2003–2008 and 2013–2018.[6] To compute the transition matrix, we first calculate the FS index for each region, each time period and each GVC stage. Given that regions can be specialized in one or two GVC stages at the same time, we select the GVC stage in which each region is mainly specialized in each time period. Accordingly, each region is assigned to only one of the three GVC stages (upstream, production and

[6] Observe that we compute the FS (and RFS) indicators based on the cumulative number of inwards FDIs in each region during the two time periods. This implies that, even in the absence of information on disinvestment decisions (which is not available but would be required to fully reconstruct the stock of FDI in each region), our indicators are the closest available proxy for the stock of international investment in the examined period.

downstream), that is the one in which the region reports the highest value of the FS index in one time period. Then, we group together all regions that, being specialized in a given function in 2003–2008: i) remained specialized in that same function also in the following period (main diagonal of the transition matrix) and ii) recorded a different specialization in the following period (off-diagonal elements of the matrix). This allows us to track regions that remained persistently specialized in the same functions in both time periods and those which experienced either functional downgrading (i.e. the shift from specialization in upstream or downstream stages in the pre-crisis period to production stages in the post-crisis period) or functional upgrading trajectories (i.e. from production to upstream or downstream functions).[7]

Finally, we investigate how the functional specialization patterns of regions are associated with changes in specialization at the industry level, also dubbed "intersectoral upgrading" (Humphrey and Schmitz 2002). To this aim, we use the classification of European regions according to their functional trajectories (e.g. upgrading, persistency and downgrading) and examine how each group of regions has been specializing across industries. Sectoral specialization is measured by means of an inward FDI-based Balassa index calculated for industries classified according to the revised Pavitt's taxonomy (Pavitt 1984; Bogliacino and Pianta 2010).

In analytical terms, to measure sectoral Pavitt-based Specialization (PS), we compute a Balassa (1965) index of revealed comparative advantage in each Pavitt class k for region i as follows:

$$\mathrm{PS}_i^k = \frac{\frac{\mathrm{FDI}_i^k}{\sum_k \mathrm{FDI}_i^k}}{\frac{\sum_i \mathrm{FDI}_i^k}{\sum_i \sum_k \mathrm{FDI}_i^k}} \tag{3}$$

where the numerator is the share of inward FDIs in Pavitt class k out of total inward FDIs received by region i, and the denominator is the share of inward FDIs in Pavitt class k out of total aggregate inward FDIs. As with the functional specialization index in Eq. (1), values greater than one indicate a revealed comparative advantage of region i in attracting FDI flows in Pavitt class k.

Pavitt's taxonomy seems particularly suitable for exploring patterns of upgrading in GVCs (other than functional ones) for at least two reasons. First, by classifying industries according to market structure and the nature, sources and appropriability of innovation, it is more informative of the technological and organizational characteristics and market potential of industries than classifications (e.g. OECD taxonomy) based only on R&D intensity (Galindo-Rueda and Verger 2016). Second, Pavitt's taxonomy also provides insights into the propensity of industries to introduce new processes and products (e.g. the former are supposed to be more frequent in Supplier-Dominated and Scale-Intensive industries). Accordingly, the sectoral

[7] In a robustness exercise, we disregard the selection criterion based on the highest value of the FS index (i.e. we assign regions to all the GVC stages in which their associated FS index is larger than (1) and replicate the transition matrix (observe that in this case, the row sums of the matrix are, by construction, different from 100%). Our results remain qualitatively unchanged and are available upon request.

specialization of regions in a specific Pavitt class is at least partially informative about the region's potential to experience forms of process and product upgrading (Humphrey and Schmitz 2002).[8]

Some important limitations of our indicators need to be acknowledged and discussed to further justify their use. First, fDi Markets does not include information on mergers and acquisitions (M&As). However, no data are available on the functional nature of brownfield investments, reason why previous contributions focusing on the value chain functions pursued by cross-border investments (reviewed in the previous section) also relied exclusively on greenfield FDIs. Moreover, while the spatial distribution of greenfield investments is mainly driven by the structural economic conditions of destination regions, M&As are strongly affected by the existence and characteristics of target firms or pure financial motivations (Castellani et al. 2016). Accordingly, data on greenfield FDI should be better suited for tracing the functional profile of regions. Yet, excluding M&As introduces a potential bias whose direction is worth considering. Cross-border M&As in Europe include a significant share of transactions involving firms performing upstream knowledge-intensive activities—such as technology acquisitions and takeovers of R&D-intensive companies. To the extent that this is the case, our indicators may understate the upstream functional specialization of regions that host attractive acquisition targets, which tend to be more technologically advanced. Conversely, M&As targeting manufacturing plants—which are more likely to occur in production-intensive regions—would reinforce rather than contradict our characterization of peripheral regions as production-specialized. While these conjectures cannot be fully tested with currently available data, they suggest that the qualitative direction of our main findings is unlikely to be reversed once M&As are taken into account.

Second, and most importantly, the FS and RFS indices we have described can identify a substantial but non-exhaustive part of the phenomenon of interest, i.e. the regional specialization across GVC functions. Given that they reflect the geographical distribution of value-adding activities associated with cross-border investments, our indicators mainly capture the involvement of regions in GVCs characterized by the equity participation of MNCs in the different locations where they operate. Within the GVC governance typologies proposed by Gereffi et al. (2005), these correspond primarily to value chains marked by hierarchical forms of governance, where lead firms coordinate geographically dispersed activities through ownership-based relationships. Since governance structures shape firms' learning opportunities and upgrading prospects, our analysis is particularly informative about the geography of functions within these types of GVCs. By contrast, our indicators are less suited to capture functional specialization emerging from value chains that rely predominantly on arm's-length transactions or collaborative inter-firm relationships, such as market, modular or relational governance structures.

[8] The revised Pavitt taxonomy proposed by Bogliacino and Pianta (2010) extends the original Pavitt taxonomy to include both manufacturing and service industries. See Table A.2 in the Online Supplementary Material.

A related concern is that the activities of domestic firms are not captured by greenfield FDI data. To the extent that domestic firms also perform a range of value chain functions (including upstream activities such as R&D and design), our indicators may understate the true functional capabilities of certain regions, particularly those with a strong base of innovative small and medium enterprises that are not embedded in MNC networks.

Yet, the likely extent of these biases is mitigated by two considerations. MNCs do play a key role in orchestrating GVCs (Iammarino and McCann 2013; UNCTAD 2013; Cadestin et al. 2019; Bohn et al. 2021) and are themselves responsible for the development of knowledge and production flows both within and across firms, hence involving internal and external networks in all contexts in which they set up their activities (Castellani and Zanfei 2006; Meyer et al. 2011; Alcácer et al. 2016). Therefore, data on the functional distribution of FDIs do capture a key albeit non-exhaustive part of the worldwide organization of cross-border production and innovation networks (Castellani et al. 2022b). It should also be emphasized that, by comparing the *relative* ability of regions to attract foreign capital in specific functions, functional specialization in FDI is likely to reflect more generally the current comparative advantages of places as actively shaped by MNCs' investment decisions as well as domestically available technologies and knowledge sources (Nachum et al. 2000; Waldkirch 2011; Neffke et al. 2018; Elekes et al. 2019). Hence, one might fairly assume that our inward FDI-based indicators of functional specialization largely reflect the actual involvement of regions in GVC stages.

Moreover, the reliability of our indicators has been also assessed by comparing FDI-based specialization indices by Pavitt macro-sectors with the same indices computed using Eurostat data on domestic employment. This validation exercise allows to measure the extent to which our indicator accurately proxies the specialization of the regions' domestic economic activity. We find that, over the first (second) period considered, the FDI-based specialization index predicts the same outcome of the employment-based index in 60% (68%) of the cases.[9]

Finally, since our empirical strategy compares functional and sectoral specialization across groups of regions between two periods only, we acknowledge that our analysis should be interpreted as correlational rather than causal. In other terms, our empirical findings should be interpreted as documenting systematic associations between functional and sectoral upgrading trajectories that are consistent with, but do not definitively establish, the proposed mechanisms linking the two aspects.

[9] Detailed results are reported by Table B.1 in the Online Supplementary Material.

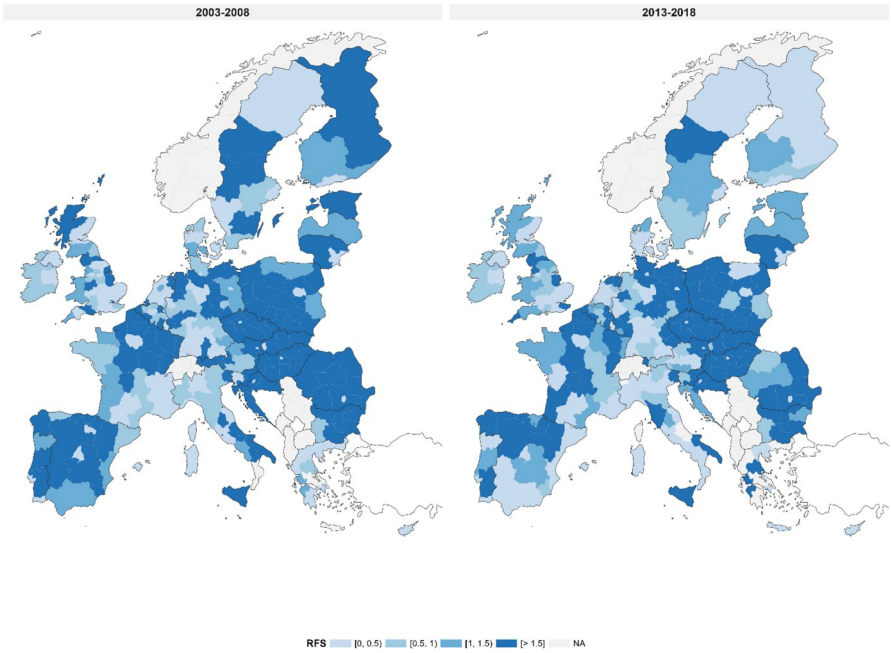


Fig. 1 Relative Functional Specialization (RFS) at the NUTS-2 level for Europe, pre- and post-crisis period. *Note* NA stands for "not available" and includes regions which did not receive FDIs over the periods (e.g. a few Italian and Greek regions) as well as non-EU27 countries (i.e. Albania, Bosnia and Herzegovina, Kosovo, Montenegro, North Macedonia, Norway, Serbia and Switzerland). *Source* authors' elaboration based on fDi Markets data

5 Patterns of functional specialization of regions and industrial change

5.1 Mapping the geography of functions and its evolution in European regions

As a preliminary step to analysing the links between functional and sectoral specialization, this section offers novel evidence on the geography of functions in Europe and its evolution over time. Figure 1 maps our synthetic indicator of Relative Functional Specialization (RFS) at the NUTS-2 level in the 6 years before and after the Great Financial Crisis, i.e. 2003–2008 and 2013–2018.[10] Three main patterns emerge from this figure.

First, we detect a high cross-sectional heterogeneity in the functional specialization of European regions. It is worth reminding that the RFS index is given by the ratio between the FS in production functions over the FS in upstream and

[10] Figure A.3 in the Online Supplementary Material shows the specialization patterns of European regions across the three GVC stages. As expected, a relatively large number of regions are specialized in production functions, while fewer are specialized in the upstream and downstream GVC stages.

Table 1 Top 5 and bottom 5 NUTS-2 regions by functional specialization in *upstream*, *production* and *downstream* functions, 2003–2018. *Source* authors' elaboration based on fDi Markets data

NUTS 2	Region	Upstream FS	NUTS 2	Region	Production FS	NUTS 2	Region	Downstream FS
SE33	Upper Norrland	4,23	AT34	Vorarlberg	6,40	MT00	Malta	1,44
UKI5	Outer London (East/North East)	3,63	PL92	Mazovia Province	6,40	ES53	Balearic Islands	1,42
BE35	Namur Province	3,11	BG31	Northwest Planning Region	5,82	CY00	Cyprus	1,39
UKI7	Outer London (West/North West)	2,72	HU31	Northern Hungary	5,60	BE10	Bruxelles (Capital region)	1,32
NL23	Flevoland	2,72	HU22	Western Transdanubia	5,53	DE60	Hamburg	1,31
–	–	–	–	–	–	–	–	–
HU33	Southern Great Plain	0,21	SE11	Stockholm	0,10	BE35	Prov. Namur	0,22
CZ05	Severovýchod	0,20	DE30	Berlin	0,09	HR02	Principality of Pannonian Croatia	0,19
PL82	Subcarpathian Voivodeship	0,19	NL32	North Holland	0,08	BG31	Northwest Planning Region	0,14
BG42	South-Central Planning Region	0,18	BE10	Bruxelles (Capital region)	0,05	HU22	Western Transdanubia	0,14
CZ04	Northwestern region	0,15	UKI3	Inner London (West)	0,01	HU31	Northern Hungary	0,09

Table 2 Economic and technological characteristics of regions by RFS index value ranges. *Source* authors' elaboration based on fDi Markets, OECD and Eurostat data

	No. of regions		Average GVA p.c		Average no. of patents	
	2003–2008	2013–2018	2003–2008	2013–2018	2003–2008	2013–2018
RFS index						
0–0.5	94	70	41,102	47,177	0.255	0.335
0.5–1.0	35	58	32,340	35,619	0.095	0.109
1.0–1.5	34	33	28,374	31,023	0.053	0.086
> 1.5	103	105	23,538	27,467	0.022	0.039

downstream stages, hence the larger the RFS value, the stronger the specialization in the least promising GVC stages in terms of value capture. Notably, darker shades are much more numerous than lighter ones in Fig. 1, suggesting that, at the European NUTS-2 level, functional specialization in production stages (FS > 1) is relatively more frequent than in upstream or downstream activities.[11] Regions with the highest relative specialization in production activities spread across Europe, they are more frequently observed in the Southern and Eastern countries, but they are largely present in the core economies of Central and Northern Europe as well.

Second, we confirm previous findings emerged in the literature, i.e. regions hosting capital districts and large metropolitan are mostly involved in the most knowledge-intensive functions, while being the least specialized in production activities (these areas exhibit the lowest values of the RFS index).[12] This is illustrated in Table 1, which shows the top 5 and bottom 5 regions sorted according to their level of functional specialization in upstream, production and downstream stages. In fact, capital cities appear among the bottom 5 regions in terms of specialization in production stages: Regions with the lowest specialization in production activities are indeed capital metropolitan areas such as Stockholm, Berlin, Brussels and Inner London, plus North Holland which includes the capital city in the Groot-Amsterdam subregion (NL329). Quite symmetrically, capital cities and metropolitan areas have a substantial presence among the top 5 regions specialized in upstream and downstream GVC stages, e.g. Outer London regions are among the most specialized in upstream functions; the Brussels region as well as the Hamburg region (which

[11] About 60% of the regions are specialized in production activities. It should also be noted that the value of the FS index is heterogeneous across functions and regions: While regions specializing in downstream (upstream) activities report a specialization in these activities below 2 (below 4), regions specializing in production functions report an FS index in these activities above 6 (see Table 1).

[12] These findings are broadly consistent with the seminal work carried out by Duranton and Puga (2005), who showed that larger cities in the US in the 1970-1990s specialized in headquarter and business service activities, while fabrication and assembly functions concentrated in smaller ones. This led them to conclude that "cities are increasingly distinguished by their functional specialization (i.e. in management and services versus production) rather than by their sectoral specialization (i.e. in one particular sector of activity versus another one)" (pp. 343–344). Adopting the same methodology, Bade et al. (2004) found similar results by using German data over the period 1976–2002.

Table 3 Cross-sectional correlation between functional specialization in FDI and the economic and technological development of regions. *Source* authors' elaboration based on fDi Markets, OECD and Eurostat data

	Upstream FS	Production FS	Downstream FS	RFS index
GVA p.c. (log)	0.2045*	− 1.6215***	0.5348***	− 1.1338***
	(0.1231)	(0.2385)	(0.0744)	(0.2035)
Patents (log)	1.2311**	− 1.6207***	0.7072***	− 1.4917***
	(0.4808)	(0.5102)	(0.1565)	(0.5382)
Urban areas	0.1627**	− 0.3252***	0.1250***	− 0.4358***
	(0.0709)	(0.1145)	(0.0389)	(0.1027)
N. obs	4256	4256	4256	4256
Year FE	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes
Std. errors	by NUTS 2	by NUTS 2	by NUTS 2	by NUTS 2

Pooled OLS with country and time fixed effects. Robust standards errors clustered by NUTS-2 region in parentheses.

The variable "Urban areas" is computed as a dummy variable equal to 1 if the region is predominantly urban and is characterized by the presence of at least one Metropolitan area (i.e. agglomerations of at least 250 000 inhabitants)

***$p<0.01$, **$p<0.05$, *$p<0.1$

includes the largest non-capital city in the EU) are among the most specialized in downstream functions.[13]

Third, peripheral and less advanced regions show a higher RFS index, e.g. Southern regions of Italy, the regions of Eastern Germany, of North UK, and most of the Eastern periphery of the European Union, which are largely marked by darker shades in Fig. 1. This is broadly consistent with the evidence reported in Table 2, which suggests that (in both periods) regions featuring lower values of the RFS index (i.e. higher FS in upstream and downstream GVC stages) are marked by higher GVA per capita and higher number of patents than regions with higher RFS index (i.e. higher FS in production functions).[14]Previous research at the country level has found a strong negative (positive) relationship between the GDP per capita of economies and their specialization in fabrication (R&D) activities (Timmer et al. 2019). Our results confirm that these relationships hold true also at the subnational level.

This evidence is also corroborated by the econometric exercise reported in Table 3, which confirms our expectations about the cross-sectional correlation between the regions' specialization across GVC stages and potential determinants of regional specialization. In particular, controlling for the regional level of technological development (patent per capita), for the presence of urban areas and for

[13] This is also consistent with previous evidence on the concentration of higher production and knowledge complexity in high-income cities (Balland et al. 2020).

[14] Data on regional population and Gross Value Added (Million USD, constant prices, constant PPP, base year 2015) are taken from the OECD, while data on (high-tech) patents are drawn from Eurostat.

Table 4 Transition matrix. *Source* authors' elaboration based on fDi Markets data

		2013–2018			
		Upstream	Production	Downstream	Tot
2003–2008	Upstream	**73%** **(41)**	13% (7)	14% (8)	100% (56)
	Production	7% (11)	**88%** **(135)**	5% (8)	100% (154)
	Downstream	16% (9)	14% (8)	**70%** **(39)**	100% (56)

Each cell reports the share of regions (%) and the number of regions (in parentheses) that transition from the functional specialization of the row period (2003–2008) to that of the column period (2013–2018). Row percentages sum to 100%. The main diagonal (bold) reports the share of regions that maintain the same dominant functional specialization across both periods (i.e. *persistently specialized* regions). Off-diagonal cells indicate functional transitions: *Upgrading* refers to a shift away from production (from either upstream or downstream) reflecting a move towards higher value-adding functions and *downgrading* refers to a shift towards production activities (from either upstream or downstream functions); the remaining off-diagonal cells capture switches between upstream and downstream specializations

country and year fixed effects, our results confirm that when comparing all regions of a given country in a given year, regions with higher levels of GVA per capita feature a higher (lower) FS in upstream and downstream (production) GVC stages, and a lower RFS value (all coefficients are statistically significant).[15] Furthermore, in regions predominantly urban and characterized by the presence of at least one Metropolitan area, the level of functional specialization in the most knowledge-intensive GVC stages (i.e. upstream and downstream functions) is relatively higher.

The results reported in Table 3 are robust to alternative treatments of spatial dependence. Because regional functional specialization may be affected by geographically correlated shocks and cross-regional spillovers, we re-estimate all specifications using Conley (1999) spatial HAC standard errors under alternative distance cut-offs (1500 km and 2000 km). The results remain fully consistent with the baseline estimates. Coefficient signs and magnitudes are virtually unchanged, while the statistical significance of the estimates is unaffected or slightly strengthened under the Conley correction.[16]

5.2 Functional specialization and inter-sectoral upgrading of European regions

Table 4 reports the transition matrix that, based on the functional specialization in FDI of NUTS-2 regions in the two considered periods (2003–2008 and 2013–2018),

[15] We obtain consistent findings also when measuring the indicators of (relative) functional specialization of regions at the end year (results are available upon request).

[16] Full results are shown by Table D.1 in Appendix D of the Online Supplementary Material. We also estimated spatial autoregressive panel models as an additional robustness check. The results are qualitatively consistent with the baseline specifications and do not alter the substantive conclusions of the analysis. For brevity, these estimates are not reported but are available upon request.

allows us to detect the trajectories of functional upgrading and downgrading of European regions. Two main findings emerge this table.

First, the main diagonal of the matrix suggests a very strong spatial inertia of the functional specialization of European regions, especially for regions specialized in the low value-adding GVC segment. Out of 56 regions specialized in upstream stages before the crisis, 41 (73%) were specialized in the same stages in 2013–2018. Similarly, out of 56 regions specialized in downstream stages in the pre-crisis period, 39 (70%) turned out specialized in the same functions in the post-crisis period. The persistence is even higher when it comes to regions specialized in production activities: 154 out of 266 regions specialized in production stages in the pre-crisis period, and 135 of such regions (88%) were still specialized in production functions in the post-crisis period.[17]

Second, Table 4 shows that functional downgrading trajectories (i.e. the shift from specialization in upstream or downstream to production stages) appear almost as frequent as functional upgrading trajectories (from production to upstream or downstream functions).[18] While the analysis conducted here does not permit to assess whether or to what extent crisis-related factors (see, e.g. Marino et al. 2025) are responsible for the (high) persistence and (circumscribed) changes observed in patterns of functional specialization, this result further illustrates the slow pace of regional economic development in Europe at times of crisis.

Overall, the trajectories of functional upgrading and downgrading of European regions confirm our expectations concerning the functional division of labour in Europe and the challenges for regions to experience functional upgrading trajectories, i.e. moving from production stages to the upper ends of GVCs.

Building on this, we now assess whether the functional specialization patterns of regions are related to their capability to develop new specializations towards more innovative sectors. To this aim, based on the classification of the European regions according to their functional trajectories (e.g. upgrading, persistency and downgrading) shown in Table 4, we examine the sectoral specialization of each group of regions (Table 5).

Results in Table 5 highlight that regions which succeeded in following a functional upgrading trajectory (panel A) also succeed in diversifying their specialization towards more knowledge-intensive industries. While in the pre-crisis period. these regions were specialized in Supplier-Dominated (SD) (1.28) and Scale-Intensive industries (SI) (1.08), after the crisis, they turn out being strongly specialized in Science-Based (SB) industries (1.42), while maintaining a specialization in SD industries (1.29). This is suggestive of a sectoral upgrading path. Regions persistently specialized in production stages of GVCs (panel B) did not experience any

[17] As a robustness check, we calculated the transition matrix at a much finer level, i.e. for Balassa index intervals of 0.2 amplitude. Results confirm that the vast majority of regions are distributed along the main diagonal, indicating that even at a finer-grained level, the functional specialization of regions shows strong spatial inertia. These results are available upon request from the authors.

[18] Table 4 shows that 15 regions experienced forms of functional downgrading (seven from upstream and eight from downstream), while 19 regions experienced forms of functional upgrading (11 from production towards upstream and eight from production towards downstream stages).

Table 5 Sectoral trajectories. *Source* authors' elaboration based on fDi Markets data

(A) Regions experiencing functional upgrading			
	2003-2008	2013-2018	*Avg.*
Science-Based	0.94	**1.42**	*1.18*
Supplier Dominated	**1.28**	1.29	***1.28***
Scale Intensive	1.08	0.72	*0.90*
Specialised Supplier	0.67	0.64	*0.66*
(B) Regions persistently specialized in production functions			
	2003-2008	2013-2018	*Avg.*
Science-Based	0.90	0.86	*0.88*
Supplier Dominated	**1.16**	**1.28**	***1.22***
Scale Intensive	1.15	1.05	*1.10*
Specialised Supplier	0.73	0.80	*0.76*
(C) Regions experiencing functional downgrading			
	2003-2008	2013-2018	*Avg.*
Science-Based	0.87	0.75	*0.81*
Supplier Dominated	**1.28**	**1.49**	***1.39***
Scale Intensive	1.13	0.96	*1.04*
Specialised Supplier	0.67	0.85	*0.76*

Boxes in the matrix are shaded in grey when values are greater than 1 (indicating sectoral specialization), while the highest sectoral specialization value for each time period is shown in bold

form of sectoral upgrading. Conversely, they consolidated their specialization in the less innovative industries (a specialization index of 1.16 and 1.28 in SD sectors before and after the crisis) while reducing their specialization in the SI class of industries (from 1.15 to 1.05). Finally, regions experiencing a functional downgrading trajectory (panel C) decreased their specialization in SI industries (from 1.13 to 0.96), while increased their specialization in SD industries (from 1.28 to 1.49).[19]

The evidence presented in Table 5 is corroborated by a set of additional statistical analyses reported in Online Appendix E. Chi-squared tests reject the null hypothesis of independence between functional trajectory groups and sectoral specialization patterns, indicating that the two dimensions are systematically associated. Moreover, comparisons across trajectory groups reveal significant differences in changes in specialization in Science-Based industries. Regions following a functional upgrading trajectory exhibit the strongest gains, whereas regions experiencing functional downgrading and, to a lesser extent, those persistently specialized in production

[19] We also found that regions persistently specialized in upstream functions have consolidated their specialization in the most innovative sectors, i.e. the SB class of industries. Regions persistently specialized in downstream functions have maintained their specialization in Specialized Supplier (SS) sectors, while also increasing their specialization in the SD class of industries. Results are available upon request from the authors.

functions display weaker performance. These patterns remain robust across alternative statistical specifications and controls for initial specialization levels. Taken together, the findings suggest that functional upgrading in GVC and inter-sectoral upgrading towards more knowledge-intensive activities tend to co-evolve within regions, although the empirical framework does not allow the temporal ordering of the two processes to be identified.

Finally, we carried out four further robustness checks.

First, we assessed the sensitivity of our results to alternative definitions of the period boundaries around the crisis years. In particular, we replicated the analysis using different temporal splits and complemented the transition analysis with annual RFS measures and rolling moving averages (3-year and 5-year windows). Overall, the results confirm that the transition patterns reported in Table 4 are highly stable across specifications, while rolling averages display persistence coefficients much closer to those implied by our baseline discrete-period approach. This suggests that our baseline specification effectively captures medium-term structural dynamics rather than short-run fluctuations.[20]

Second, we replicated the entire analysis by calculating Balassa's specialization index (Eq. 1) using as denominator the share of inward FDIs in a specific GVC stage out of the total FDI in Europe (instead of the world), i.e. the European (instead of the world) average. This enabled us to compute a measure of relative attractiveness of European regions in each GVC stage with respect to a more homogeneous spatial sample, especially in terms of the frequency of greenfield-type inward FDI projects. All previous findings concerning the geography of functions in Europe, the persistence of functional specialization and the trajectories of inter-sectoral upgrading of regions are qualitatively unchanged (results are available upon request).

Third, we replicated the overall analysis on a restricted sample, excluding regions which attracted a very low number of FDIs over the investigated periods (i.e. those that on average did not receive at least 1 inward FDI per year in the two 6-year periods). Also in this case, all our previous findings are largely confirmed (results are also available upon request).

Fourth, we replicated the analyses using an alternative classification of value chains functions into GVC stages, in which "Business Services" activities are assigned to the upstream stage rather than to the downstream stage. This is because this function accounts for a substantial share of observed FDI projects and, more importantly, because its position along GVCs is conceptually less clear-cut than that of other functions. In fact, Business Services often encompass support activities for the entire value chain, including legal and financial services (Sturgeon 2008; Crescenzi and Harman 2022). Accordingly, this value chain function has been classified as a pre-production (upstream) activity in some previous studies using the same FDI data source (e.g. Crescenzi et al. 2014; Krisztin and Piribauer 2021). Notably, the results remain qualitatively unchanged, confirming the strong association between functional specialization and regional development patterns, the persistence of functional trajectories over time and the positive relationship between functional

[20] Detailed results and discussion are reported in Appendix C of the Online Supplementary Material.

upgrading and inter-sectoral upgrading towards more Science-Based industries (also in this case, results are available upon request).

6 Conclusions

6.1 Discussion of the main findings

This work has emphasized the need to jointly consider the sectoral (or inter-chain) and functional (or intra-chain) dimensions when investigating the growth opportunities of regions. We proposed that regions specializing into more dynamic industries, characterized by a higher technological content, may not significantly improve their growth opportunities if they remain locked into low value-adding functions within such industries. By contrast, regions undergoing functional upgrading patterns gain larger opportunities to access new knowledge and financial resources, which can, in turn, be redirected into more innovative and dynamic productions.

On the empirical ground, we shed new light on the patterns of functional specialization of European regions and how these correlate with changes in their sectoral profiles over time.

First, we showed that functions at the upper ends of the value chain are concentrated in few high-income regions, often hosting capital cities (Duranton and Puga 2005; Balland et al. 2020; Gervais et al. 2021). Functional upgrading trajectories are indeed limited and highly selective: Only a few regions have managed to move from production to the upstream and downstream functions, and roughly, the same number of regions has experienced a downgrading trajectory. Overall, this evidence highlighted that the patterns of functional specialization of regions persist over time and across different sectors, and that are associated with differences in income levels, innovation capacities and the presence of urban agglomerations.

Second, and most importantly, we highlighted that the few regions which experienced functional upgrading resulted more prone to engage in more dynamic industries, as identified by Pavitt's Science-Based sectors. By contrast, we found that regions which followed functional downgrading trajectories or were persistently specializing in low value-adding functions (such as assembling and fabrication) are the least prone to inter-sectoral upgrading and consolidate their specialization in supplied dominated sectors.

These results envisage a rather dismal scenario of persisting asymmetries and diverging regional development patterns, which are broadly consistent with the increasing inter-regional inequality that has been observed in Europe in the past decades (Iammarino et al. 2019). However, our findings should not be interpreted as the automatic outcome of pre-existing regional comparative advantages. Rather, they also reflect the strategic decisions of MNCs regarding the geographical allocation and reorganization of value chain functions, which contribute to reinforcing or reshaping the functional and sectoral trajectories of regions over time. This interpretation is consistent with the emerging literature on the agents of structural change, which emphasizes that regional economic development—or its absence—is driven not only by domestic economic and institutional conditions, but also by the

strategies of different (local and) non-local actors that reshape regional production structures by introducing novel activities and knowledge sources into regions (Neffke et al. 2018; Bellandi and Storai 2025).

In particular, MNCs may foster structural change by leveraging knowledge and resources available through their global intra-corporate networks to establish activities that would, otherwise, be difficult to sustain on the basis of local capabilities alone (Elekes et al. 2019). At the same time, MNCs' organization and investment decisions can contribute to reinforcing existing patterns of regional specialization by concentrating knowledge-intensive functions in a limited number of high-income metropolitan areas, accentuating the centripetal effects induced by agglomeration economies (Phelps et al. 2018; Feldman et al. 2021). In this sense, the strong persistence of functional specialization we documented is likely to be consistent with the tendency of lead firms to retain control over the most intangible-intensive GVC stages, thereby limiting opportunities for economic upgrading, especially in regions specialized in fabrication and assembly operations. This is also closely connected to the governance type of GVCs established by lead firms, which deeply affects the extent to which local actors can acquire new capabilities and move towards higher value-adding functions (Gereffi et al. 2005; Davis et al. 2018; Kaplinsky 2019). From this perspective, MNEs can act both as catalysts of structural transformation and as agents reinforcing existing spatial hierarchies, depending on how different value-adding activities are geographically organized and embedded within regional economies.

Although our analysis has not directly investigated firm-level agency, the specialization patterns captured by our FDI-based indicators can be interpreted as the aggregate territorial outcome of MNCs' strategic investment decisions and their interaction with other place-specific factors (e.g. local knowledge assets, skill composition, urban scale and agglomeration advantages) that jointly shape regional development paths.

6.2 Policy implications

Taken together, the contributions of this work point to a broader conclusion: moving beyond the sectoral lens that has traditionally dominated empirical and policy analyses of regional development is not merely an analytical refinement, but a necessary step to understand the developmental implications of GVC participation. The evidence presented here shows that functional and inter-sectoral upgrading are closely intertwined, and that policies targeting only the sectoral composition of regions risk missing the value chain dimension that ultimately determines where economic rents are captured. In this regard, our findings carry specific implications for the design of regional and cohesion policies in Europe. Based on the trajectories identified in our transition matrix, we can detect three types of regions that warrant differentiated policy attention.

First, the small group of regions that achieved functional upgrading offers instructive evidence on what institutional conditions appear favourable for this transition: Our data show that these regions predominantly include metropolitan areas

and capital city regions with strong human capital bases. This suggests that functional upgrading is not simply a matter of investment attraction but requires prior investments in absorptive capacity–education, R&D infrastructure and institutional quality–that enable regions to move up the value chain.

Second, the large group of regions persistently locked into production functions represents a first pressing policy challenge. For these regions, attracting additional FDIs in manufacturing without addressing the functional composition of such investments is unlikely to improve their development trajectories. Instead, policy should explicitly foster the attraction and steer the development of knowledge-intensive activities–particularly R&D, design and testing activities–through instruments such as R&D tax credits linked to the establishment of innovation centres, co-investment schemes between MNCs and local universities and skills upgrading programmes targeting technical and required capabilities. Smart Specialization Strategies (S3) for these regions should be assessed not only in terms of the sectors they target but also in terms of the value chain activities they seek to develop within those sectors.

Third, regions experiencing functional downgrading face the most urgent policy challenge, as they appear to be losing ground not only in sectoral but also functional terms. For these regions, stabilization of existing high value-adding activities through place-based support schemes–including retention incentives for knowledge-intensive MNC subsidiaries–may be a necessary precondition before any upgrading strategy can be pursued.

Overall, our findings support the view that EU Cohesion Policy and S3 frameworks should incorporate explicit indicators of functional specialization alongside the sectoral indicators currently used (Comotti et al. 2020; Casadei et al. 2023). Mapping what functions regions perform within which industries—and tracking how these evolve over time–should become a standard component of regional development diagnostics.

6.3 Limitations and avenues for future research

It is worth stressing that our analysis is subject to some limitations that point to promising avenues for future research.

First, our analysis relies exclusively on greenfield FDI, as no comparable data are currently available on the functional nature of cross-border M&As. Although greenfield investments are generally better suited to capture the functional profile of regions, extending the analysis to include M&As—should suitable data become available—would allow a more comprehensive assessment of regions' involvement and upgrading trajectories in GVCs.

Second, our indicators capture the functional and sectoral specialization based on inward FDI flows and, therefore, do not directly account for value chain activities undertaken by domestic firms. Although MNCs' investment decisions contribute to shape regional production structures and our validation exercise reassures us that our FDI-based measures broadly reflect the actual specialization of regions, our indicators may in some cases understate their true functional capabilities (e.g. regions hosting innovative enterprises that are nevertheless poorly integrated in MNC

networks). Accordingly, future research could combine FDI-based measures with occupational or wage data on domestic firms—where available at the subnational level—to more accurately characterize the evolving functional profile of regions.

Third, although our results consistently point to a strong and systematic association between functional trajectories and inter-sectoral upgrading, they cannot be interpreted as evidence of a causal relationship. Rather, our findings suggest that these two processes tend to co-evolve. This limitation is also related to the period-based nature of our empirical strategy, which compares two pooled 6-year windows (2003–2008 and 2013–2018) separated by the Great Financial Crisis interval. It follows that, while the robustness checks provided confirm that our main findings are not driven by the specific periodization adopted, future research could exploit higher-frequency data (where available) to identify the causal mechanisms linking functional and inter-sectoral trajectories at the subnational level.

Finally, our analysis is conducted at the NUTS-2 level and, therefore, abstracts from potentially important within-region heterogeneity across administrative units. In this regard, our findings show that regions including at least one large metropolitan area display higher specialization in upstream and downstream functions. Nonetheless, these NUTS-2 regions often also encompass surrounding rural and peri-urban territories, meaning that the concentration of knowledge-intensive functions in urban cores is likely to be partly diluted in our measures. This suggests that the spatial polarization in terms of functional specialization might be even more pronounced than our results indicate. Future research using finer spatial units (where data availability permits) could provide a more granular understanding of the geography of value chain activities and shed further light on the role of urban agglomeration economies in shaping regional functional and inter-sectoral trajectories.

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Data availability This work is largely based on proprietary data, which are not made available but can be provided upon motivated request.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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