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- Andrea Coveri (Department of Economics, Society and Politics, University of Urbino)
- Elena Paglialunga (Department of Economics, Roma Tre University)
- Antonello Zanfei (Department of Economics, Society and Politics, University of Urbino)

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Functional specialization and upgrading in European regions: new insights from FDI data

Andrea Coveri
Department of Economics, Society and Politics, University of Urbino, Italy
Corresponding author; e-mail address: andrea.coveri@uniurb.it

Elena Paglialunga
Department of Economics, Roma Tre University, Italy
E-mail address: elena.paglialunga@uniroma3.it

Antonello Zanfei
Department of Economics, Society and Politics, University of Urbino, Italy
E-mail address: antonello.zanfei@uniurb.it

ABSTRACT

The geographic dispersion of production activities has led regions to increasingly specialize in specific value chain functions, giving rise to a finer spatial division of labour. In this work, we use georeferenced FDI data to investigate the geography of functions and the interdependencies between functional and sectoral specialization of European regions. We show that the most intangible-intensive functions at the upper ends of value chains are concentrated in few advanced regions, while lower-income ones are largely and persistently specialized in production operations. Moreover, we find that regions locked-into low value-adding 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. Accordingly, regional policies should aim at favouring functional upgrading of laggard regions as a key vehicle for economic and spatial convergence in Europe.

Keywords:
Geography of functions; Inter-regional inequality; Foreign direct investment; Global value chains; European regions

JEL codes:
F21; F23; L23

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, 1984; 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 & Rossi-Hansberg, 2008; Mudambi, 2008; Sturgeon & Gereffi, 2009; Coe, 2014). 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; Bair et al., 2021; 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; Humphrey & Schmitz, 2002; Blažek, 2016; Coe & Yeung, 2019).

Most notably, this shift has led scholars to disentangle sectoral specialization patterns from the evolving capacity of economies to perform specific GVC functions (Coveri & Zanfei, 2023). What remains largely unexplored, however, 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 favoring the diversification of regions towards more innovative sectors.

This paper aims to provide a systematic analysis of the "geography of functions" (Boschma, 2022) and shed light on the interdependencies between functional and sectoral specialization patterns of European regions over the period 2003-2018. To do so, a two-step empirical strategy will be undertaken.

First, we use georeferenced data on cross-border investments distinguished by business activity to map the "functional specialization in FDI" of 266 NUTS-2 European regions and trace its evolution before and after the Great Financial Crisis. Investigating changes in the functional specialization of regions allows us to offer novel systematic evidence on the spatial stickiness of functions and inertia in the positioning of European regions along GVCs. 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.

Second, we link the observed patterns of functional specialization with changes in sectoral specialization. More precisely, we use the revised Pavitt Taxonomy (Pavitt, 1984; Bogliacino & Pianta, 2010) to offer suggestive evidence on the relationship between the functional and inter-sectoral upgrading/downgrading trajectories of European regions. We find that regions climbing up the value ladder by moving towards the upper ends of GVCs have also been able to diversify towards more innovative industries (i.e., inter-sectoral upgrading).

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 and draws policy implications.

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 & Broekel, 2020). This view ties in with a long-standing tradition of development studies emphasising the structural change patterns triggered by industrialisation 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 & 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 within industries but remain agnostic about the precise nature of such interdependencies (Kruse et al., 2023). 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 reasons why the connections between functional and sectoral specialization should be explored further.

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 (like assembling and fabrication of standard components). While it may be true that specialising in micro-chips opens up higher learning and income growth opportunities than specialising 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 specialising in R&D, design and testing of micro-chips (Mudambi, 2008; Dedrick et al., 2010; Buckley et al., 2020; Durand & Milberg, 2020; Coveri & Zanfei, 2023).

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 (Tokatli, 2013; 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 & Ženka, 2011; Plank & Staritz, 2015; Bernhardt & Pollak, 2016; Blažek, 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, the shift towards higher intangible-intensive activities can provide regions with the capacity to generate, or gain access to, valuable knowledge and assets that can be applied to different sectoral contexts. This is consistent with the general view that technical change is largely task-specific (Acemoglu & Autor, 2011) and that functional upgrading is particularly promising albeit a difficult strategy to be pursued (Humphrey & Schmitz, 2002; Kaplinsky et al., 2002; Lee & Gereffi, 2015; Morris & Staritz, 2019; 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 & Gambardella, 1994), and hence on the costs of de-contextualising knowledge generated through specific learning experiences. Nevertheless, firms' investment in specific intangible-intensive activities, e.g., R&D functions, are 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 & 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 organisationally) 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 & Narula, 2008), and regional (Asheim & 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.

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 & Pianta, 1994; Neffke et al., 2011; Boschma et al., 2013). 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 & 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.[1]

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

Relatively few studies have examined the regional distribution of value-adding activities using the richness of FDI data on value chain functions. Crescenzi & 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 functions and its link with country-level indicators of trade in GVCs. In a similar vein, Crescenzi & 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 MNCs' cross-border investments 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 analyze 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 like 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. 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 of regions substantially limits our understanding of

regional economic development. In fact, we suggest that the development of regions is most likely to depend 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 & Schmitz, 2002).

The discussion above leads us to formulate our main research question as follows: how does the functional specialization trajectories of regions affect 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.[2] 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 like 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.[3]

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.

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 & Evenett, 2015; Coveri & Zanfei, 2023; Crescenzi & Harman, 2022). Accordingly, we group the business activities reported by fDi Markets as follows:

(i) *upstream functions*: headquarters activities, R&D, design, development & testing, education & training, ICT & Internet Infrastructure activities;

[2] 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.

[3] Consistently with several previous works (Castellani et al., 2013, 2016; Crescenzi et al., 2014, 2015; Ramasamy et al., 2012), 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.

(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 & 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.[4] 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 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); 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

[4] 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.

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).[5]

Finally, we investigate how the functional specialization patterns of regions are associated with changes in specialization at the industry level, also dubbed "inter-sectoral upgrading" (Humphrey & Schmitz, 2002). To this aim, we use the classification of European regions according to their functional trajectories (e.g., upgrading, persistency, 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 & Pianta, 2010). 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 organisational characteristics and market potential of industries than classifications (e.g., OECD taxonomy) based only on R&D intensity (Galindo-Rueda & 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 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 & Schmitz, 2002).[6]

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 focused on greenfield FDIs only. 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.

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 characterised by the equity participation of

[5] 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.

[6] The revised Pavitt Taxonomy proposed by Bogliacino and Pianta (2010) extends the original Pavitt taxonomy to include both manufacturing and service industries.

MNCs in the different locations where they operate. These are indeed only a fraction of GVCs which have proliferated over the past decades, i.e., those largely marked by a hierarchical type of governance (Gereffi et al., 2005). By contrast, our indicators might be less able to measure the participation of regions in GVCs not necessarily governed by MNCs, that involve firms with different degrees of internationalisation, and that mainly rely on inter-firm trade and on collaborative alliances (UNCTAD, 2011; Bernard & Fort, 2015).

Yet, MNCs do play a key role in orchestrating GVCs (Iammarino & 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 & 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 organisation of cross-border production and innovation networks (Castellani et al., 2022b). It should also be emphasised 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 defined by available technologies and factor endowments (Nachum et al., 2000; Hausmann & Rodrik, 2003; Waldkirch, 2011). Hence, one might fairly assume that our inward FDI-based indicators of functional specialization largely reflect the actual involvement of regions in GVC stages.

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 employment data. 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.[7]

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.[8] Three main patterns emerge from this figure.

[7] Detailed results are available upon request.

[8] Evidence on the specialization patterns of European regions across the three GVC stages is available upon request from the authors. As expected, a relatively large number of regions are specialized in production functions, while fewer are specialized in the upstream and downstream GVC stages.

Figure 1. RFS index at the NUTS-2 level for Europe, pre- and post-crisis period

[FIGURE 1 ABOUT HERE]

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 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 Figure 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.[9] 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 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).[10] 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 includes the largest non-capital city in the EU) are among the most specialized in downstream functions.[11]

[9] 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).

[10] These findings are broadly consistent with the seminal work carried out by Duranton & 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.

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

Table 1. Top 5 and bottom 5 NUTS-2 regions by functional specialization in *upstream*, *production* and *downstream* functions, 2003-2018

[TABLE 1 ABOUT HERE]

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 Figure 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).[12] 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 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). 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.[13]

Table 2. Economic and technological characteristics of regions by RFS index value ranges

[TABLE 2 ABOUT HERE]

Table 3. Cross-sectional correlation between Functional specialization in FDI and the economic and technological development of regions

[TABLE 3 ABOUT HERE]

[12] 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.
[13] We obtain consistent findings also when measuring the indicators of (relative) functional specialization of regions at the end year (results are available upon request).

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), 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.[14]

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).[15] While the analysis conducted here does not permit to assess whether or to what extent crisis-related factors 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.

Table 4. Transition matrix

[TABLE 4 ABOUT HERE]

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, downgrading) shown in Table 4, we examine the sectoral specialization of each group of regions (Table 5).

[14] 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.

[15] Table 4 shows that 15 regions experienced forms of functional downgrading (7 from upstream and 8 from downstream), while 19 regions experienced forms of functional upgrading (11 from production towards upstream and 8 from production towards downstream stages).

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 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).[16]

Table 5. Sectoral trajectories

[TABLE 5 ABOUT HERE]

We conducted two main robustness checks. First, 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. Second, 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).

6. Conclusions

This work has emphasised 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 specialising into more dynamic industries, characterised by a higher technological content, may not significantly improve their growth opportunities if they remain locked-into low value-adding functions within such

[16] 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.

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 & 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 have 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 specialising 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.

Overall, our findings 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 last decades (Iammarino et al., 2019). In this regard, our investigation suggests that policy interventions aimed at reducing existing spatial disparities should focus not only on the industrial structure of regions, but also and especially on the value chain functions performed by regions along GVCs. This is at least partially in line with recent EU policy initiatives that stress the importance of "Strengthening Strategic Value Chains for a future-ready EU Industry", putting emphasis on "the whole ecosystem of strategic value chains, covering the whole spectrum from research and development to manufacturing and related services" (European Commission, 2019, p. 15). However, this approach has not translated yet into a coherent EU Cohesion Policy and Smart Specialization Strategy (Comotti et al., 2020; Casadei et al., 2023). Our findings suggest that any smart specialization policy should be "scaled down" at the functional level, implying a careful consideration of the participation and positioning of regions along sectoral value chains: mapping what activities regions are able to perform in which industries and exploring their capacity to increase the value captured along GVCs is a necessary condition to evaluate growth prospects and investment needs. This should allow to better detect the specific profile of regions and tailor EU industrial policy interventions accordingly in terms of fund allocation, infrastructure provision and instruments for investment attraction. A more detailed analysis and understanding of the functional specialization of regions should thus inform

placed-based policy initiatives aimed at achieving economic convergence across EU regions.

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7. Tables in the main text

Table 1. Top 5 and bottom 5 NUTS-2 regions by functional specialization in *upstream*, *production* and *downstream* functions, 2003-2018

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

Source: authors' elaboration based on fDi Markets data.

Table 2. Economic and technological characteristics of regions by RFS index value ranges

	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

Source: authors' elaboration based on fDi Markets, OECD and Eurostat data.

Table 3. Cross-sectional correlation between Functional specialization in FDI and the economic and technological development of regions

	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

Note: Pooled OLS with country and time fixed effects. Robust standards errors clustered by NUTS-2 region in parentheses. *** p<0.01, ** p<0.05, * p<0.1. 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).
Source: authors' elaboration based on fDi Markets, OECD and Eurostat data.

Table 4. Transition matrix

		2013-2018			
		Upstream	***Production***	***Downstream***	*Tot.*
2003-2008	***Upstream***	*Persistently upstream* **73%** **(41)**	*Downgrading* 13% (7)	*From upstream to downstream* 14% (8)	100% (56)
	Production	*Upgrading* 7% (11)	*Persistently production* **88%** **(135)**	*Upgrading* 5% (8)	100% (154)
	Downstream	*From downstream to upstream* 16% (9)	*Downgrading* 14% (8)	*Persistently downstream* **70%** **(39)**	100% (56)

Source: authors' elaboration based on fDi Markets data.

Table 5. Sectoral trajectories

(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*

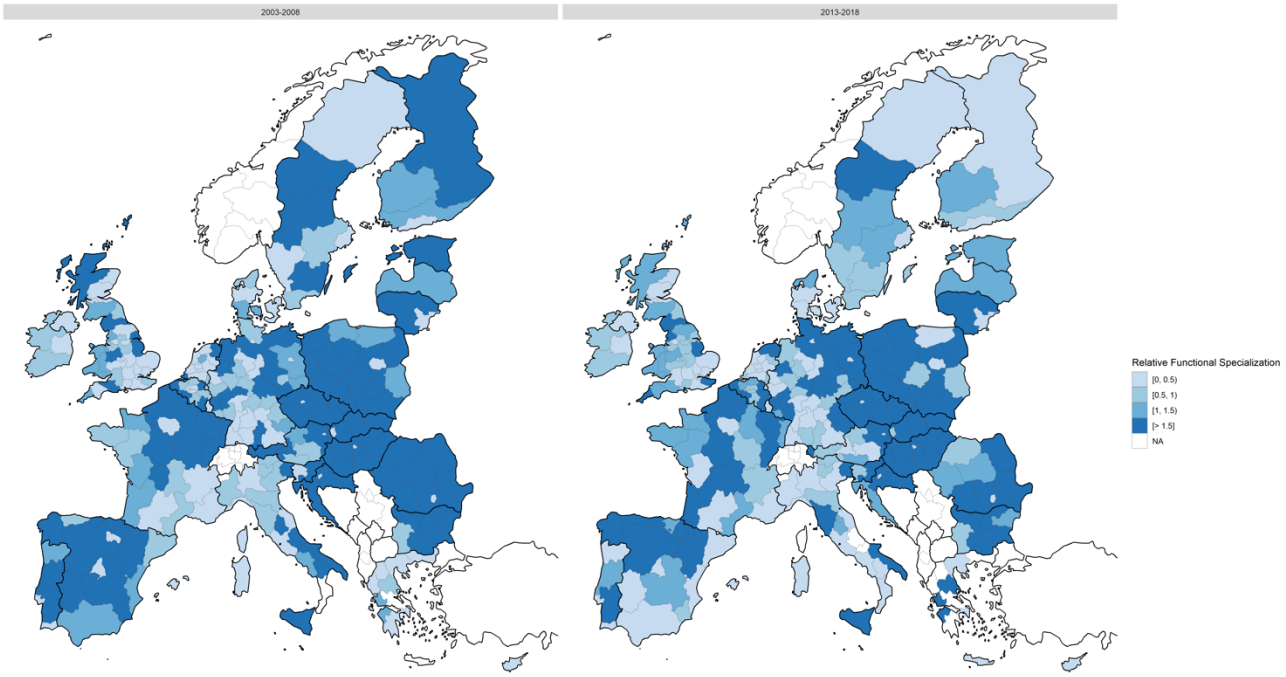
(C) Regions experiencing functional downgrading

	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*

Note: 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.
Source: authors' elaboration based on fDi Markets data.

8. Figure in the main text

Figure 1. RFS index 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.