Functional specialization, R&D and upgrading 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 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 in 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 these value chain functions are the least likely to upgrade towards more knowledge-intensive industries. By contrast, only the few regions which experienced functional upgrading have been able to diversify towards more innovative industries. These findings suggest that the geographic concentration of intangible-intensive functions might well be among the key drivers of the rising inter-regional inequality 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 production has led economies to increasingly specialize in specific value-adding activities – from the conception of goods to their fabrication and commercialization (Feenstra, 1998; Sturgeon & Gereffi, 2009; Coe, 2014; Fernandez-Stark & Gereffi, 2019). This process has resulted in a major change in the economic geography of production and innovation at the international level, leading to a finer spatial division of labour across value chain functions, also called "tasks", rather than final products or services (Massey, 1984; Storper & Walker 1989; Grossman & Rossi-Hansberg, 2008; Mudambi, 2008).

However, extant empirical literature has devoted little attention to the analysis of the value chain functions performed by subnational regions. While some works have paved the way for a detailed study of the regional distribution of value-adding activities (Defever, 2012; Crescenzi et al., 2014; Crescenzi & Iammarino, 2017), there is still a lack of systematic analyses of the "geography of functions" (Boschma, 2022). What is largely missing is an analysis of the relative position of European regions in GVCs, which can best be captured by their functional specialization rather than considering the absolute volume of business activities they are involved in. Moreover, inter-temporal comparisons are mostly lacking, thus impeding to assess whether changes in specialization have occurred, especially after the great financial crisis. Finally, not enough attention has been paid to the links between changes in functional and sectoral specializations, thus limiting our understanding of regional upgrading patterns.

This work aims to take a step forward in filling these gaps by using data on Foreign Direct Investments (FDIs) at the regional, functional and sectoral levels.

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 first 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 trajectories – 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. We use the revised Pavitt Taxonomy (Pavitt, 1984; Bogliacino & Pianta, 2010) to offer suggestive albeit exploratory evidence on the relationship between the functional and inter-sectoral upgrading/downgrading trajectories of European regions.

Third**,** we combine the literature on the unequal distribution of value in GVCs (Durand & Milberg, 2020) with recent contributions on the role played by monopoly power in regional income disparities (Feldman et al., 2021) to provide new insights into the determinants of inter-regional inequality in Europe.

The remainder of this work is organized as follows. Section 2 reviews the emerging literature on the geography of functions and highlights the novelties of our approach. Section 3 describes our data and methodology. Section 4 maps the geography of functions, and illustrates the functional trajectories of regions and their links with sectoral dynamics. Section 5 discusses the "dark side" of the examined specialization patterns and Section 6 concludes.

2. GVCs and the spatial division of labour

2.1 From products to functions

Previous contributions have highlighted how the disintegration of industries and the consequent geographical dispersion of value-adding functions at global scale have fostered a new spatial division of labour (Massey, 1984; Hudson, 2016; Peck, 2016). On the one hand, the slicing up of GVCs has led firms in emerging economies to specialize in value-adding functions at the lower end of the value chain of products, namely production activities as fabrication and assembly operations. On the other hand, firms in developed economies have largely specialized in the most knowledge-intensive activities at the upper ends of the value chain, namely pre-production (such as headquarter, research, design and development activities) and post-production functions (like branding, marketing, sales and after-sales services). According to the well-known "smile curve" hypothesis, this division of labour reflects a spatial economic hierarchy in which the most developed economies capture "Schumpeterian rents" by performing functions featured by high barriers to entry, while less developed countries are likely to reap a much smaller share of value from production in GVCs (Mudambi, 2008; Shin et al., 2012).

GVCs have been largely regarded as an important ladder for development by allowing peripheral economies to join the capitalist space without establishing new industries or the whole supply chain of a product from scratch (Cattaneo et al., 2010; Taglioni & Winkler, 2016). By participating in GVCs, firms located in less developed countries can also benefit from knowledge and technological transfers due to interactions with lead firms and from incentives to conform to the quality standards imposed by global buyers and transnational producers (Morrison et al., 2008; Nadvi, 2008; Saliola & Zanfei, 2009; Rigo, 2021). In this context, economic development has been largely redefined in terms of "upgrading" in GVCs, namely the process by which laggard countries and regions improve their productive capabilities to climb up the value ladder (Humphrey & Schmitz, 2002; Gereffi et al., 2005).

However, systematic evidence on the spatial division of labour and upgrading trajectories is still largely missing, especially at the subnational level.

Besides case studies (Linden et al., 2009), new quantitative approaches to functional specialization have recently emerged, including the one developed by Timmer et al. (2019). These authors computed an indicator of Revealed Comparative Advantage (Balassa, 1965) based on the amount of value-added embodied in exports (derived from international input-output tables) that can be traced back to workers employed in different occupations. While this analytical effort sheds useful light on the geography of functions, it comes with two shortcomings. First, it is based on mapping occupational (ISCO-88)

categories to business activities; however, the classifications of workers' occupations do not show a direct connection with the internal (functional) organization of firms nor with specific value generation stages (Brown, 2008). Second, and most importantly, the combined lack of input-output tables and occupational wage and employment data with a high level of geographical disaggregation largely limits the possibility to replicate the approach of Timmer et al. (2019) for subnational regions. Consistently, this indicator has been used mainly in country-level analyses (de Vries et al., 2019; Pleticha, 2021; Kordalska & Olczyk, 2022).

2.2 FDIs and the geography of functions

Other works have examined the geography of functions using detailed FDI data by region and business activity, thus partially overcoming the shortcomings of trade-based analyses we have just highlighted.

A first stream of literature exploited data on the functional distribution of FDIs to explore regions' involvement in global production and innovation networks. 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.

A second stream of literature has 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 in 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" with greater producer service connectivity.

While these works offered seminal evidence on the functional distribution of cross-border investments, they do not fully account for the geography of functions in Europe and its evolution over time. First, they are based on the absolute size (or number) of investment projects across subnational areas, disregarding their specialization patterns and failing to assess their relative position in GVCs. Second, the analyses reviewed largely fail to detect functional upgrading, downgrading and lock-in phenomena at specific stages of the value chain and their implications in terms of uneven economic development (Phelps et al., 2018). Third, previous contributions overlook the links between regional patterns of functional and sectoral specialization. This substantially limits our understanding of regional economic development, which 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 & Schmitz, 2002). This work aims to take a step forward along these three dimensions of analysis.

3. Data and methodology

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.[1] A distinctive feature of the fDi Markets database is that 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.[2]

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; Fernandez-Stark & Gereffi, 2019). This classification has been adopted in previous conceptual and empirical analyses to investigate the value capture opportunities and

[1] 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.

[2] 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.

development prospects of economies according to their functional positioning along GVCs (Shin et al., 2012; Crescenzi et al., 2014; Baldwin & Evenett, 2015; 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;

(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 (Stollinger, 2019, 2021; Zanfei et al., 2019; Coveri & Zanfei, 2022a), 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 year (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 Stollinger (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:

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

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 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.

4. Measuring the geography of functions and its evolution

Recent contributions have mapped the geography of functions and the functional specialization of economies at macro scale, but there is less systematic evidence on how subnational regions are involved in GVCs. This has prevented to detect the within-country heterogeneity in GVC positioning and how this is related to uneven economic development in space. In what follows, we exploit georeferenced FDI data to map the geography of functions for 266 NUTS-2 regions in the EU27 and the UK from 2003 to 2018.

4.1 Mapping the geography of functions at the subnational level

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.

[FIGURE 1 ABOUT HERE]

Three important findings emerge from Figure 1. 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.[3] 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, regions hosting capital districts and large metropolitan areas exhibit the lowest values of the RFS index, i.e., they are the least specialized in production activities.[4] This finding is corroborated by 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, Bruxelles 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 Bruxelles 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.

[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

[3] 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).

[4] 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.

of patents than regions with higher RFS index (i.e., higher FS in production functions).[5] 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.[6]

[TABLE 2 ABOUT HERE]

4.2 The spatial stickiness of functions

The previous section offered a static picture of the function specialization of European regions, showing that less developed ones mostly specialized in low value-adding activities, while few advanced regions specialized in upstream and downstream functions. However, a major challenge faced by less advanced regions concerns their ability of climbing up the value ladder by moving towards the most knowledge-intensive functions at the upper ends of the value chain. In this section we therefore adopt a dynamic perspective and provide first evidence on the functional trajectories experienced by European regions over the considered period.

To this aim, Table 3 reports a transition matrix based on the functional specialization in FDI of NUTS-2 regions before and after the crisis, i.e., in the periods 2003-2008 and 2013-2018.[7] By looking at the main diagonal of the matrix, the first striking result is 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%) resulted 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 resulted 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.[8]

[5] 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.

[6] The cross-sectional correlation between regions' specialization across GVC stages and their level of GVA per capita (controlling for the level of technological development, country and year fixed effects) confirms 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). See Table A.1 in Appendix.

[7] To compute the transition matrix, we first select for each region and each time period the GVC stage in which a given region reports the highest value of the FS index. Then we count the number of 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).

[8] 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.

A second finding from Table 3 is that functional downgrading trajectories (i.e., the shift from specialization in upstream or downstream stages in the pre-crisis period to production stages in the post-crisis period) appear almost as frequent as functional upgrading trajectories (from production to upstream or downstream functions).[9] While the analysis conducted here does not permit to assess whether nor 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 3 ABOUT HERE]

4.3 Functional specialization and inter-sectoral upgrading of European regions

To better illustrate regional development prospects in Europe, we now 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). An extensive literature in evolutionary economic geography has pointed out that the economic performance of regions is strongly linked to their ability to diversify into industries with higher levels of technological sophistication and more complex production output (Balland et al., 2019; Mewes & Broekel, 2020). However, analyses based only on the sectoral composition of local economies do not consider the opportunities and constraints that may be associated with the functional profile of places. The geographically dispersed organisation of industries requires indeed to combine the sectoral dimension with an analysis of the value chain functions in which regions are active in order to assess their upgrading potential.

To this aim, in Table 4 we classify the European regions according to their functional trajectories shown in Table 3 (e.g., upgrading, persistency, downgrading) and examine how each group of regions have 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

[9] Table 3 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).

the region's potential to experience forms of process and product upgrading (Humphrey & Schmitz, 2002).[10]

Table 4 shows 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).[11]

[TABLE 4 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).

5. Discussion: the "dark side" of the geography of functions

The evidence offered in this work has highlighted important spatial asymmetries, which can be summarised in three "stylized facts". First, functions at the upper ends of the value

[10] 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 Appendix.

[11] 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.

chain are concentrated in few high-income regions (often hosting capital cities).[12] A much larger number of regions, marked by lower economic development, is mainly specialized in production functions, namely the GVC segment in which global competition has increased the most in recent decades. Second, we detected a remarkably high spatial stickiness in the geography of functions in Europe. 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. Third, by linking the functional trajectories of European regions to their evolving FDI-based sectoral specialization, we found that the latter is also uneven and selective. In fact, low-income regions locked-into the production stages of the value chain were the least prone to sectoral upgrading, while only the few regions which experienced forms of functional upgrading have been able to diversify towards more innovative industries.

These findings are suggestive of some key drivers behind the increasing inter-regional inequality that has been observed in Europe in the last decades (Heidenreich & Wunder, 2008; Iammarino et al., 2019).

The first driver has to do with the different capability of places to capture value in GVCs according to their specialization in different segments of GVCs. A growing literature has shown that the most upstream and downstream functions largely rely on intangible assets, hence allowing firms, countries and regions controlling them to seize huge monopoly rents (Buckley et al., 2020; Durand & Milberg, 2020; Rikap & Flacher, 2020; Chen et al., 2021; Buckley et al., 2022).[13] The high intangible-intensity of functions at the upper ends of GVCs is key to understanding the spatially uneven distribution of rents and the path dependent nature of specialization patterns. In fact, intangibles can provide nearly infinite returns to scale once the initial investment is made (Durand & Milberg, 2020). Moreover, they are associated to substantial economies of scope (due to the fungibility of knowledge assets) and learning (due to increasing use of intangibles), while the accumulation of the resulting monopoly rents is favoured by effective appropriability regimes (Teece, 1998; Villalonga, 2004). The protection of intellectual property (e.g., patents, designs and copyrights, brands, trademarks and marketing strategies) has been greatly enhanced by the TRIPS agreements, enabling those who control and deploy these assets to gain access to large shares of intellectual rents (Teece, 1986, 1998; Pagano, 2014; Buckley et al., 2022). From this perspective, the evidence provided on the geographical concentration of the most knowledge-intensive functions (and related innovation capabilities) in few prosperous regions, as well as its remarkable spatial stickiness, is consistent with the view that value capture dynamics tend to be geographically circumscribed and persistent (Feldman et al., 2021; Pinheiro et al., 2022).

The second potential driver of regional inequality has to do with agglomeration economies, which largely arise from the spatial concentration of the most upstream and

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

[13] While typical forms of tangible assets are represented by land, machinery and equipment, and production plants, intangibles are made by headquarter services, patents, copyrights, trademarks, databases and software, as well as branding, and marketing functions (Corrado et al., 2009).

downstream functions in high-income regions. These offer indeed the most proper environment (e.g., ICT infrastructures, skilled workforce, rule of law, and often low corporate tax rates) to protect, manage and profit from the control of these value chain stages (McCann & Acs, 2011). By reducing the cost of knowledge transmission within advanced regions and centres of excellence, agglomeration economies can thus allow these places to benefit from cumulative process of technological and organizational innovation (Cooke & Morgan, 1994; Duranton & Puga, 2001; Storper & Venables, 2004; Asheim & Gertler, 2005), and to attract the most qualified workforce in search of higher wages and promising career opportunities. This "brain drain" can contribute to widening a talent divide between wealthy and lower-income regions, and likely hinders the economic development prospects of less advanced areas (Iammarino et al., 2019; Kenney & Zysman, 2020; Feldman et al., 2021). Finally, the value captured by high-income regions due to rents from intangibles can make these places increasingly attractive to financial investors seeking higher and more secure returns, diverting financial resources from lagging to more advanced regions (Zeller, 2007; Feldman et al., 2021). Accordingly, our findings can be interpreted as suggestive of the self-reinforcing interaction between agglomeration economies in regions specialized in the most intangible-intensive GVC functions and the massive (static and dynamic) economies of scale that intangible assets are able to trigger due to their high scalability and appropriability.

A third potential driver of unequal spatial development is given by the increasing competition in fabrication and assembly activities triggered by the international fragmentation of production. Fiercer competition in fabrication stages may in fact reduce the value captured by regions specializing in such GVC functions. As known, a key driver of the geographical dispersion of value chain activities towards laggard regions lies in the strategies of wage arbitrage and search for cheap intermediate inputs pursued by MNCs (Baldwin & Evenett, 2015). On the one hand, this might have increased market opportunities for producers of standard components and commodities based in lower-income regions (e.g., in Central and Eastern European countries). On the other hand, international outsourcing practices expose local producers to higher competitive pressure from foreign suppliers, thus drastically reducing their margins. Moreover, to the extent that local firms gain access to valuable technology transferred by global buyers and transnational producers, this could result in decreasing value capture opportunities for lower-income regions. In fact, the availability of better technology might well allow local suppliers to carry out manufacturing operations more efficiently (resulting in forms of process upgrading). However, the resulting increase in productivity – combined with strong competitive pressures – may induce a race to the bottom in prices, which might reduce the overall value of exports even in the presence of increasing production volumes (an application of the Prebisch-Singer hypothesis in a GVC framework; see Prebisch, 1949; Singer, 1950). Therefore, the amount of value that local suppliers in laggard regions can garner is bound to shrink, while most productivity gains are capitalized elsewhere, especially in core cities and regions hosting headquarters of lead firms (Kaplinsky, 2000; Kaplinsky et al., 2002; Dünhaupt & Herr, 2021). This entails a drain of value at the expense of lagging behind regions to the benefit of wealthiest regions. Overall, this points to the risk that laggard regions in Europe involved in fabrication functions may be

exposed to a process of immiserizing economic specialization (Bhagwati, 1958; Gimet et al., 2010; Milberg & Winkler, 2013).

6. Conclusions

Our analysis has shed new light on the functional specialization of European regions. These functional patterns of specialization appear to persist over time and across different sectors and are associated with differences in income levels and innovation capacities. Therefore, the range of functions wherein regions are specialized cannot be disregarded when evaluating their development prospects. One may thus venture saying that the potential for value capture of countries and regions can no longer be adequately illustrated only by the product composition of their exports. A key role is played by the specific functions they perform along the GVC of those products.

From this perspective, our work has emphasised the need to jointly consider the horizonal (namely sectoral or inter-chain) and vertical (namely functional or intra-chain) dimensions when investigating the growth opportunities of regions. In fact, expanding the product variety combined with an increasing specialization in only one or a few value chain functions might result in a "fictious" diversification (Coveri & Zanfei, 2023). Similarly, performing the simplest and low knowledge-intensive functions (e.g., assembly operations) in the production of highly sophisticated goods (e.g., smartphones or aircrafts) cannot be taken as a signal of economic or technological strength of a region.

The importance of combining the sectoral and functional levels of analysis is accentuated by a set of dynamic factors we have highlighted. In fact, GVC stages are characterized by different knowledge intensities, require specific skills and are featured by heterogeneous degrees of market competition, which in turn significantly contribute to determine the share of value that actors along the chain are able to capture (Durand & Milberg, 2020; Rikap & Flacher, 2020; Rikap, 2022). Furthermore, GVC functions show a different propensity to be outsourced and spatially dispersed (Alcácer & Delgado, 2016; Mudambi et al., 2018; Coveri & Zanfei, 2022b), making the study of the interaction between the nature of GVC functions and their geographical concentration or dispersion across regions of major relevance to understand the mechanisms that shape the uneven economic development of places.

These remarks are likely to be even more important when considering the "dark side" of the geography of functions (Hudson, 2016; Peck, 2016; Phelps et al., 2018; Werner, 2019). Accordingly, a careful and detailed examination of the geography of functions is a necessary condition to predict which regions will forge ahead or lag behind in the race for value capture. Future research could explore how intra-regional capabilities and inter-regional GVC linkages support or hinder the functional upgrading of firms and regions, and how this combines with larger opportunities for economic and social upgrading (Zhu et al., 2017; Yeung, 2021). The evidence and reflections provided on the link between the functional specialization of regions and their capability to develop new specializations at the industry level represents a starting point for more refined research in this direction.

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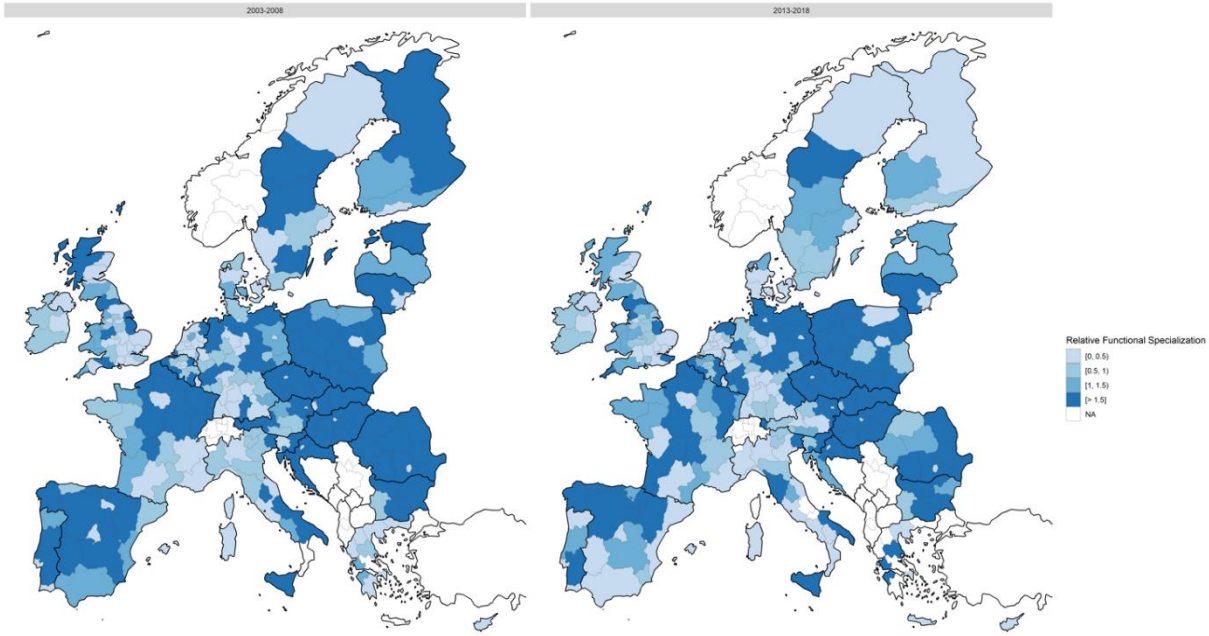
Figure 1. RFS index at the NUTS-2 level for Europe, pre- and post-crisis period



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.

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. 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 4. 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.

Appendix

Table A.1 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)	0.2865**	-1.7853***	0.5978***	-1.3533***
	(0.1174)	(0.2457)	(0.0756)	(0.2217)
Patents (log)	1.3921***	-1.9425***	0.8309***	-1.9228***
	(0.5107)	(0.5433)	(0.1703)	(0.5983)
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.

Table A.2 The Revised Pavitt Taxonomy

RPC	Description	Industry examples (NACE Rev. 2 code)
Science-Based industries (SB)	Sectors where innovation is based on advances in science and R&D (such as the pharmaceuticals, electronics, computer services) where research laboratories are important, leading to intense product innovation and a high propensity to patent.	Chemical (C20); pharmaceutial (C21); electronics (C26); computer programming (J62-J63)
Specialised Supplier industries (SS)	Sectors producing machinery and equipment; their products are new processes for other industries. R&D is present but an important innovative input comes from tacit knowledge and design skills embodied in the labour force. Average firm size is small and innovation is carried out in close relation with customers.	Electrical equipment (C27); machinery and equipment (C28); legal and accounting activities (M69-M70); architectural and engineering activities (M71)
Scale and Information Intensive industries (SI)	Sectors (such as the automotive sector and financial services) characterized by large economies of scale and oligopolistic markets where technological change is usually incremental. New processes (often related to information technology) shape the organisation of production and coexist with new product development.	Basic metals (C24); Motor vehicles (C29); publishing activities (J58); Financial services (K64)
Supplier Dominated industries (SD)	Sectors (such as food, textile, retail services) where internal innovative activities are less relevant, small firms are prevalent and technological change is mainly introduced through the inputs and machinery provided by suppliers from other industries. Firms in this group do not carry out much R&D or other innovative activities.	Food (C10-C12); textile (C13-C15); wholesale trade (G46); accomodation (I)

Note: RPC stands for Revised Pavitt Classification.
Source: authors' elaboration based on Bogliacino and Pianta (2010, pp. 801, 807).