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Functional Specialisation in EU Value Chains:

Methods for Identifying EU Countries' Roles in International Production Networks

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Abstract

Geographically dispersed production networks have allowed countries to specialise in different functions of the value chain. By making use of two methodologies for quantifying the magnitude of functional specialisation – one based on trade flows and one based on FDI flows – detailed profiles of the functional specialisations of EU member states are identified. The analyses are conducted at the country, industry and regional level. In line with the existing literature, they reveal that EU-CEE countries are predominantly specialised in the fabrication stage, that is, they serve as 'factory economies', while the Western EU countries are mainly performing knowledge-intensive pre-fabrication activities – a characteristic of 'headquarter economies'. This dualism within the EU is confirmed by a cluster analysis. While functional specialisation patterns tend to be persistent, especially in the fabrication stage, there are also some signs of functional diversification in EU-CEE countries in more recent years. Still, these functional changes remain limited to a few industries. The dichotomy of factory and headquarter economies is also clearly discernible at the regional level. However, the fact that in most EU countries – mainly in the capital regions – there are some headquarter-type regions implies that a complete functional 'lock-in' in fabrication is less likely than suggested by the country-level patterns. Hence, while the results point towards major difficulties of functional diversification beyond the fabrication stage in the EU-CEE countries and regions, there are also several promising elements and trends discernible, in particular at the industry and the regional level.

Keywords: functional specialisation, global value chains, smile curve, factory economy, greenfield FDI

JEL classification: F15, F21, F23, F60

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APPENDIX

1. Introduction

The emergence of international production networks has given rise to an ever more granular international division of labour with new opportunities for specialisation. This paper focuses on the division of labour according to business functions – or value-chain functions[1] – which represent one of the new dimensions of specialisation that have accompanied the fragmentation of production processes across different locations (Jones and Kierzkowski, 1990, 2001). Such a fragmented mode of production implies that different 'blocks' of production (Jones and Kierzkowski, 1990) are linked with each other by services, such as transport, information and other business services. While this increasing specialisation in individual segments of the production processes can be seen as a direct application of Adam Smith's famous example of the pin factory, there is also a new element involved. Whereas in Smith's pin factory specialisation occurs in-house, in the current world of fragmented production the individual tasks that together make up the production process are geographically dispersed and extend beyond the boundary of the firm. Adjusting the zoom from micro to macro, thereby switching from the firm to a country perspective, one finds that internationally fragmented production and the resulting trade in tasks is qualitatively different from the traditional trade in goods (see Baldwin and Robert-Nicoud, 2014). Trade in goods gives rise to specialisation of countries by products and industries, while trade in tasks involves specialisation in different value-chain functions. In this context, it is important to note that functional specialisation does not replace specialisation of countries by industry. Rather, it adds another dimension to existing specialisation patterns.

Does this additional dimension of specialisation matter? This paper argues that it matters a lot, for at least two reasons. First, the technological asymmetry in specialisation by business function is likely to be even greater than in traditional product-based specialisation patterns (Baldwin, 2013; Baldwin and Lopez-Gonzalez, 2015), further increasing the risks of derailed convergence processes of catch-up economies or even 'growth traps' (Stöllinger, 2019). Second, and equally importantly, functional specialisation intensifies global competition in a way that is closer to individual workers. What we mean by that is that with trade in tasks it is not German steel competing against Indian steel, but it is Polish machine operators competing with Vietnamese machine operators. This is clearly a simplification, as the bankruptcy of a steel company would also lead to job losses. However, what we mean by this statement is that it is not individual jobs that are affected by trade in tasks, but that entire occupations are at stake in international competition. Suppose (in a rather realistic scenario) that customer support over the telephone can be provided at a lower cost in India. In a world of fragmented production it can then be assumed that this business function would be relocated to India not in one industry but across a wide range of industries. Hence, this would affect not only the jobs of struggling European steel companies, for example, but a full spectrum of call centre agents in Europe, including those in highly profitable and expanding firms. The consequences for the labour markets of high-income economies of this sort of competition can be seen in their unemployment statistics[2] of the past decades. Conversely, in the discussion of the labour markets of lower-income economies the

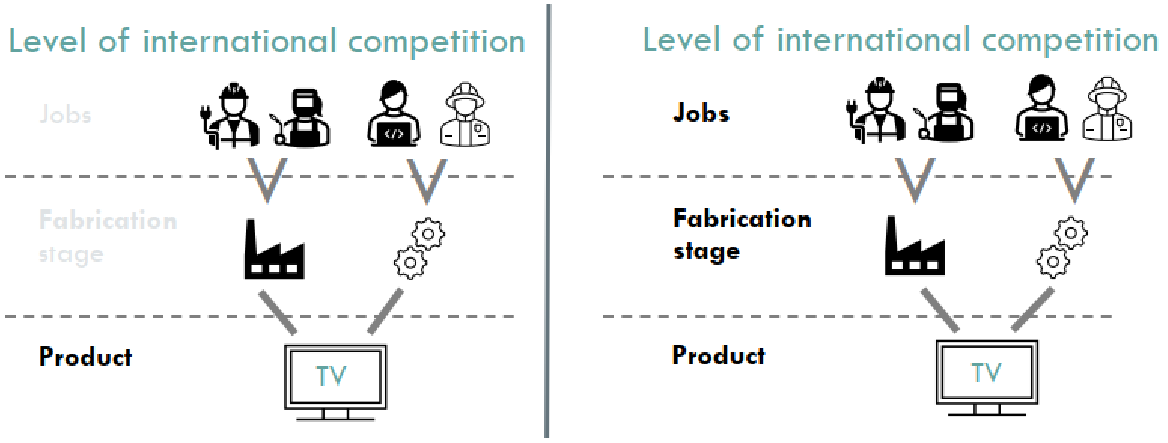
1 The terms business functions and value-chain functions will be used interchangeably throughout the text.

2 For this purpose, it is obviously long-term trends rather than business cycle-related fluctuations that have been considered. Or, if one believes in it, the natural rates of unemployment: these should have gone down much more than they actually did in view of the structural changes of labour markets, which for the most part took the form of liberalisations.

emphasis is on the wage 'advantage', bringing with it the risk of a race-to-the-bottom. In addition, there are also qualitative implications for the labour markets, which include the phenomenon of job polarisation (see Goos, Manning, Salomon, 2009; Goos, Manning, Salomon, 2014; Autor and Dorn, 2013), but also numerous other aspects of the work environment, such as work intensity and work extensity.

The distinction between trade in goods and trade in tasks can also be thought of as a distinction between international trade and international production. However, the fact remains that fragmented production intensifies competition and brings it closer to people's everyday life. When production is organised internationally, competition does not only take place at the product level. There is also more direct competition between the locations for fabrication activities (as well as other stages of the manufacturing process) and even between wider groups of jobs. It should be stressed again that the international production network does not bring an end to competition at the product level. Rather, it adds new layers of competition between countries in the form of attracting stages of production, which translates into direct competition among workers at the level of occupations. This is illustrated in Figure 1.

Figure 1 / Competition in the presence of international trade (left) and production (right)



Source: Authors' own work based on Baldwin (2013, Figure 1.9).

Before examining the topic in greater detail, it is necessary to lay the groundwork by establishing proper methodologies for measuring such functional specialisations. That is the core aim of this paper, along with the drawing of a descriptive picture of the functional specialisation profiles of EU countries and regions, which belong to the economically most integrated and hence most strongly affected economies in the world by this division of tasks.

The remainder of the paper is structured as follows. Section 2 gives more details on the conceptional features of functional specialisation. Starting from this conceptualisation, Section 3 illustrates how functional specialisation can be operationalised empirically, whereby two approaches are offered and compared. Section 4 provides an overview of stylised facts on functional specialisation patterns across EU countries, updating existing research in this field and presenting new evidence at the country and industry level. Section 5 contains a detailed analysis of functional clusters present in the EU. Section 6 adds another novel dimension by addressing functional specialisation patterns and inequalities therein at the regional level. The paper concludes with final remarks in Section 7.

2. Functional specialisation: A new dimension in a world of GVCs

The opening-up of the world economy since the 1980s has gone hand in hand with substantial reductions in coordination costs associated with doing business internationally as the technological revolution broke down the barriers to long-distance communication (Baldwin, 2016). At the turn of the century these developments paved the way for the dominance of the multinational corporation (MNC) in the global economy. For businesses, it represented a dismantling of borders on two counts: first, as firms were able to seize opportunities far beyond the boundaries of their home countries the practice of offshoring certain parts of the production process gained momentum. In addition, the practice of outsourcing non-core activities became the norm, breaking down the traditional concept of inter-firm boundaries as core firms took on the role of 'systems integrators' of a closely knitted network of suppliers (Nolan et al., 2008). The production process shifted from being a predominantly in-house operation with a clear country of origin to a complex web of business activities transcending individual firms and nations. International organisation such as the World Trade Organisation (WTO) and the Organisation for Economic Co-operation and Development (OECD) assigned this mode of production the label 'Made in the World'.[3]

Consequently, present-day production processes can be conceptualised most accurately through the lens of global value chains (GVCs). GVCs represent an interrelated chain of business activities that are needed for the full lifecycle of a given product or service and can thus extend across multiple countries and entities. Fabrication of a product represents only one section of the GVC sequence, alongside other functions such as research and development (R&D), marketing, logistics or support services.

As emphasised before, GVC-based production processes intensify competition at the global level. The ability to shift intermediate goods around and assemble them wherever the costs are lowest has induced a significant inflow of foreign direct investment (FDI) in emerging economies. In this way, the region of Central and Eastern Europe (CEE), in particular, was transformed following EU enlargement in 2004, as FDI – primarily in the automotive sector – flourished in the region (Grieveson et al., 2021). Consequently, these countries became known for their expanding automotive and electronics industries.

Yet, because in the world of GVCs only certain activities within the value chain actually take place in a given country, traditional product-based analyses of revealed comparative advantages (RCAs)[4] overlook important aspects of the present-day global division of labour. An RCA analysis of countries' exports would not show that EU members of the CEE region (EU-CEE), such as Slovakia or Hungary, have a comparative advantage in machinery and transport equipment, making them structurally relatively comparable to Germany, for example.[5] However, given today's unbundled production processes, looking at the structural characteristics of these countries solely based on export product categories

[3] See: https://www.wto.org/english/res_e/statis_e/miwi_e/flyer_miwi_e.pdf.

[4] See Balassa (1965).

[5] One can refer to UNCTADStat for RCA values of individual countries by product categories.

could result in misleading conclusions regarding the similarities and differences across countries. While countries such as Slovakia or Hungary are indeed large exporters of machinery and transport equipment, as is Germany, a distinction needs to be made whether countries merely have the capability of *fabricating* vehicles or whether they also possess the capability to *produce* them in the wider meaning of the word, including 'producing' the underlying technologies and the organisation of the value chain. This distinction is important, because locational determinants of GVCs are increasingly focused on the level of activities rather than sectors (Crescenzi et al., 2013), motivating the analysis of sectoral and functional agglomeration of activities (Defever, 2006).

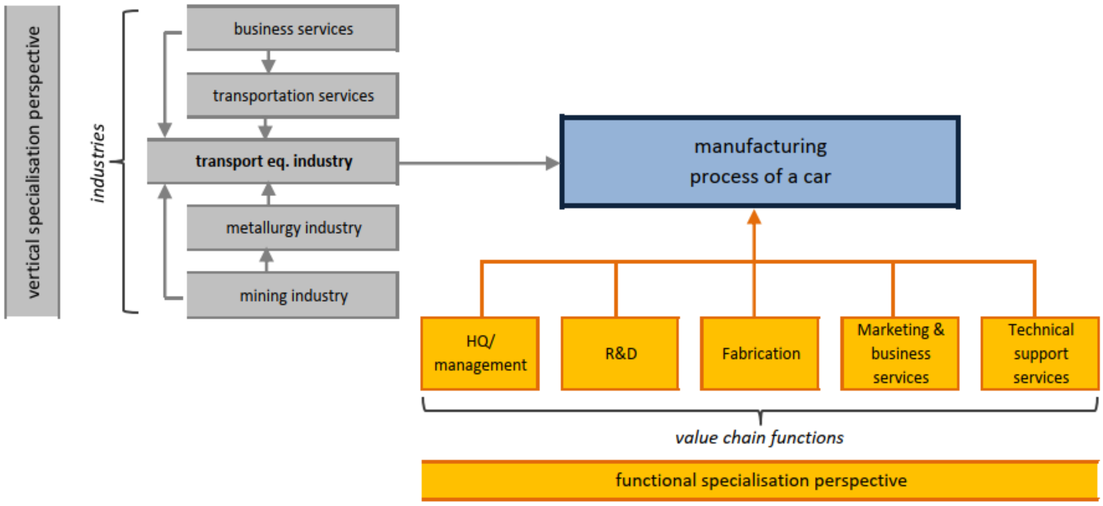
The functional dimension to specialisation can have notable implications for economic development. As one might expect, value added is not equally distributed along the value chain (Gereffi and Fernandez-Stark, 2019). Shih's (1996) concept of the smile curve summarises this in a clear and simple manner: these days the fabrication stage of the production process has become the least value-intensive activity within a GVC.[6] In this sense, shifts in orientation towards the outer edges of the smile curve, which imply changes in the functional specialisation of an economy, may present a pathway to structural upgrading (Humphrey and Schmitz, 2002). Yet it is worth noting that in this paper the conceptual framework of the smile curve, which considers primarily the product level, is transposed to the industry level. The question to be asked is therefore whether the main hypothesis of the smile curve concept – that is, the varying potential for capturing value added across different activities of the value chain – can also be identified at the industry level and in the aggregate economy. Admittedly, this transition to the industry level comes at some cost. In particular, the sequencing of activities is less clear at the industry level. While making use of the terminology of pre-fabrication and post-fabrication segments of the value chain, this reality is fully acknowledged by the authors.

To better understand the orientation of economies in terms of specific activities carried out, a measure that would differentiate between various tradeable tasks within the value chain is needed. Functional specialisation aims to do precisely that, by considering countries' extent of participation in different stages of the production process. This is motivated by the recognition that present-day global competition tends to take place at the level of activities (or *functions*), which are independent of single industries or products (Timmer et al., 2019). When we refer to functions, what we mean here are the different aforementioned tasks involved in the overall business process, including management, R&D, fabrication, marketing, sales and logistics, as well as other auxiliary services such as technical support, training or customer support (see Figure 2).

With this approach it is possible to uncover labour division dynamics present in the contemporary global economy. Indeed, earlier papers on the subject have found a distinct functional division between 'factory' economies – generally developing economies dominating the fabrication stage – and 'headquarter' economies – generally developed economies dominating the stages that tend to precede and succeed fabrication, or those activities that oversee the whole production process. This dichotomy, coined by Baldwin and Lopez-Gonzalez (2015) and empirically identified by Stöllinger (2019; 2021) and Timmer et al. (2019), among others, points to important technological asymmetries present between the two groups. However, given possibly different development trajectories over time as well as cross-country nuances and increased discussions of middle-income traps in parts of the world, including the EU-CEE region, an examination of specialisation patterns in the EU beyond this dichotomy is still called for.

6 See Stöllinger (2021) for a deeper discussion of the smile curve concept.

Figure 2 / Functional and vertical perspectives of production



Note: HQ=headquarter functions.
Source: Adapted from Stöllinger (2019).

At the same time it remains an open question whether comparable patterns can also be discerned at the subnational level. Hence, this paper also turns to the examination of the regional dimension of functional specialisation. In a similar manner He and Xiao (2011) consider the geographical dispersion of MNCs operating in China based on business functions. As anticipated, they find that first-tier cities within the Chinese urban hierarchy tend to agglomerate higher value-added activities such as headquarter or R&D. In this regard, investigating functional specialisations at the subnational level in EU countries is deemed highly relevant, as it can shed light on distributional drivers within an economy and inform regional and cohesion policy making.

3. Empirical methods

The analysis presented in this report uses two methodologies for identifying functional specialisation patterns, namely the trade-based approach and the FDI-based approach.

3.1. MEASURING FUNCTIONAL SPECIALISATION IN TRADE

The trade-based approach to functional specialisation relies on the methodology proposed by Timmer et al. (2019), which focuses on value-chain activities by considering the occupation of the workers who carry out these activities. This approach provides a new and more detailed way of decomposing gross export flows and enables to identify domestic value added (DVA) embodied in a country's gross exports with particular reference to value-chain functions presented in Figure 3. The methodology combines the concept of DVA with information that comes from the labour market side.

Occupations that allow workers to perform specific tasks are assigned to four separate sub-groups, where each sub-group of occupations corresponds to a business function. Using information about occupations from the International Standard Classification of Occupations (ISCO88), occupations are mapped into four business functions, namely: *(i)* research and development activities (R&D), *(ii)* management services (MGT), *(iii)* pure fabrication (FAB), and *(iv)* marketing services (MAR).[7] The assignment of detailed occupations to particular business functions is presented in Appendix 1. All of this constitutes an initial step, but at the same time a very crucial step, in the construction of weights for the gross exports decomposition.

Measuring functional specialisation in trade requires two types of data. The first source of data provided by Buckley et al. (2020) combines occupations information as described above with information on wages that come from the Structure of Earnings Survey to arrive at income shares by business functions at the country-industry level.[8] This database determines the weights that allow us to decompose DVA into DVA created by the four business functions mentioned above in the second step.[9]

The second source of data that is needed are international input-output tables. In order to identify DVA in trade in each value-chain function we use the World Input-Output Database (WIOD) release 2016 (Timmer et al. 2015), which contains information about input-output flows, final demand, gross value

7 The number of business functions in functional specialisation in trade approach differs slightly from the number of functions presented in Figure 2. The trade-based approach takes the number of functions directly from Timmer et al. (2019). A direct translation between the general division of functions (Figure 2) and the trade-based approach is in the case of R&D and fabrication function. Management function is understood as HQ activities, whereas marketing function is closely linked to marketing and business functions.

8 In our analyses, this database uses NACE rev.2 classification of industries and covers the period 2000-2014. A general form of the occupational database is included in Appendix 1. Income shares by business functions sum up to 1.

9 Total income in the economy is split into labour income and capital income, thus the Timmer et al. (2019) methodology allows to identify not only DVA related to labour income (that is a point of interest in this Report) but also DVA related to capital income.The columns of matrix W do not sum up to one, the remaining part belongs to shares of capital incomes in total incomes.

added and gross output for 43 countries and the rest of the world, and for 56 industries according to the NACE rev.2 classification. We are limited to the period of 2000-2014 due to the availability of the occupational database that is constructed for the WIOD database only.

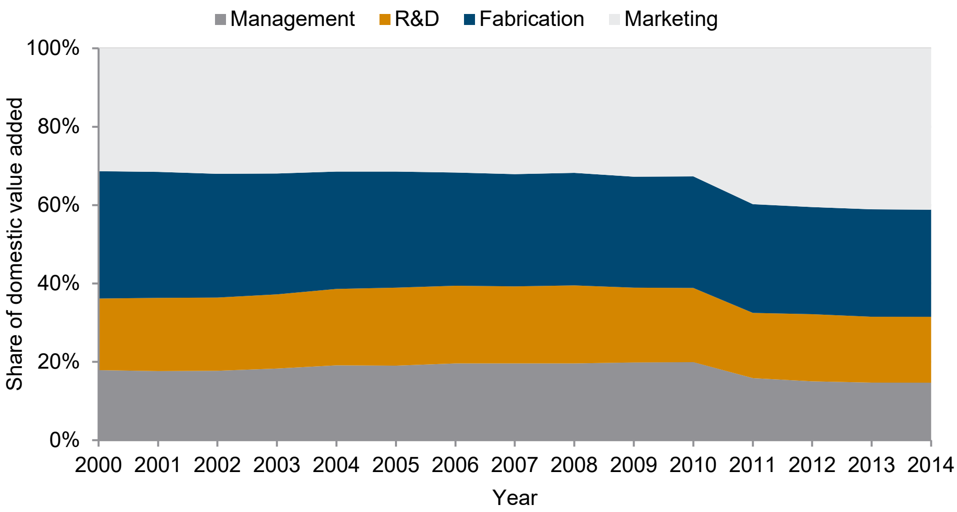
Next, combining both sources, an equation for N=44 countries and G=56 industries that allows the domestic value added by function k in country *i*'s and industry *j*'s total exports to be tracked takes the following form:

(1) $$\mathbf{f} = \mathbf{W}\,\mathbf{V}\,(\mathbf{I} - \mathbf{A}^{\mathrm{D}})^{-1}\mathbf{e},$$

where **W** is a K×GN matrix with K=4, which portray the income of all workers who carry out function k in country *i* and industry *j*, as a share of the value added generated by country *i* and industry *j*. **V** is a GN×GN matrix of value-added shares of gross output on the diagonal and zeroes otherwise, $\mathbf{A}^{\mathrm{D}}$ is a GN×GN block-diagonal matrix with G×G matrices on the diagonal containing domestic intermediate input coefficients and zeroes otherwise. **I** is a GN×GN identity matrix. **e** refers to a GN×GN matrix of each reporting country's global gross exports on the diagonal and zeroes off diagonally. Finally, matrix **f** of dimension K×GN represents the $f_{i,j}^{k}$ – the domestic value added by function *k* in country *i*'s and industry *j*'s exports.

Using the methodology described above, an identification of domestic value added by business function that is embodied in gross exports is made for all 43 countries and the rest of the world, and for 56 NACE rev.2 industries. For the purposes of this project, we focus on 27 EU countries along with the United Kingdom due to the time range of trade-based data, i.e. 2000-2014. This approach allows for country and country-industry analyses, but in contrast to the FDI-based methodology described next in Section 3.2 it does not allow for a regional examination of functional specialisation patterns.

Figure 3 / Structure of domestic value added by business functions, EU, 2000-2014

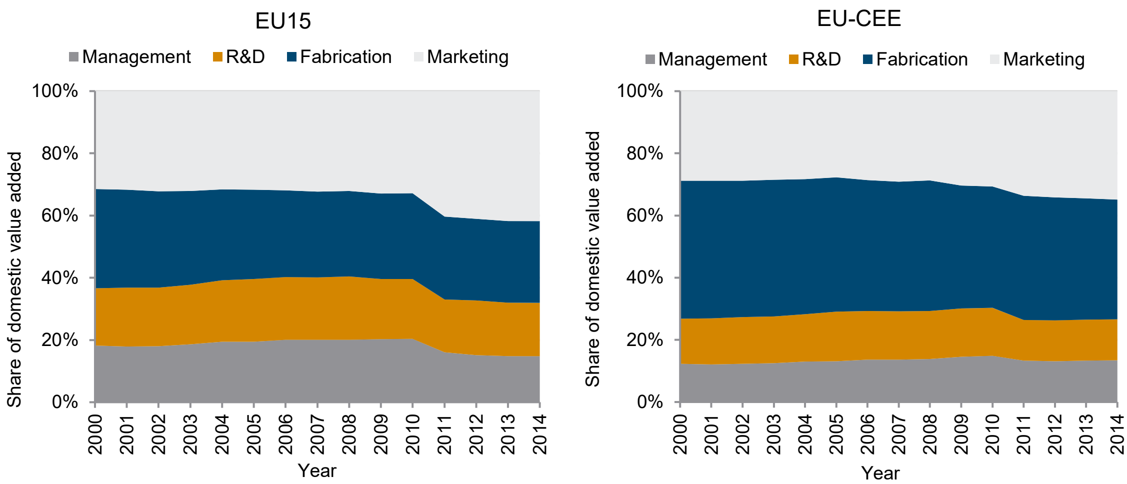


Note: For the details of the 'activities' included in each of the value chain functions see Appendix 1. Figure includes the UK.
Source: WIOD 2016, authors' own calculations.

Looking at the structure of domestic value added in exports by four value-chain functions, one can see that at the beginning of the period analysed the fabrication function was of the greatest importance (33%) and comparable in its scale to the marketing function (31%) (Figure 3). Over the sample period, however, the significance of the pre-fabrication activities, i.e. management and R&D, as well as of the fabrication function faded slightly in favour of the marketing function, the share of which accounted for 41% in 2014.[10]

The differences between business functions are more visible if we look at the EU15 and the EU-CEE separately (Figure 4). The greatest discrepancies are observed in the fabrication function. The share of this function in the EU15 fluctuates between 26% and 32%, whereas for the EU-CEE it ranges between 39% and 44% over the period analysed. Similar to the general pattern, R&D services in both groups of countries drop in their importance, and this drop is to a similar extent (~ 1 percentage point). As one might expect, management activities gain significance in the EU15, but the positive change is also observed for the rest of the economies.

Figure 4 / Structure of domestic value added by business functions, EU15 vs. EU-CEE, 2000-2014



Note: For details of the 'activities' included in each of the value-chain functions see Appendix 1. Figures include the UK. EU-CEE including Malta and Cyprus.
Source: WIOD 2016, authors' own calculations.

Domestic value added in exports by the four value-chain functions examined above serves as the main information source for the construction of functional specialisation indices. Here, the revealed comparative advantages index proposed by Balassa (1965) is adapted for the calculation of country *i*'s relative functional specialisation (RFS) in trade in industry *j* for each business function separately:

(2) $$RFS_{i,j}^{k} = \frac{f_{i,j}^{k} / \sum_{k} f_{i,j}^{k}}{\sum_{i} f_{i,j}^{k} / \sum_{i} \sum_{k} f_{i,j}^{k}} \; .$$

10 A visible change in 2011 compared to 2010 in management, R&D and fabrication functions is linked to the change of occupations classification used in the European Union Labour Force Survey (LFS). ISCO88 was used until 2010, and since 2011 the LFS uses the ISCO08 classification. Buckley et al. (2020), the authors of the occupational database for the period 2000-2014, use the crosswalks for the years 2011-2014 to harmonise this period with the preceding years. The movement between 2010 and 2011 does not influence functional specialisation measures in any significant way.

This index reflects the relationship between the share of function *k* in the overall income in the country's exports and the income share of function *k* for all countries in their total exports.

Finally, in line with the approach taken by Laursen (2015) in relation to revealed comparative advantage measures, we normalise RFS indices and present them in the following form:

(3) $$normRFS_{i,j}^{k} = \frac{RFS_{i,j}^{k}-1}{RFS_{i,j}^{k}+1}$$

This conversion makes functional specialisation indices symmetric and allow us to specify them in the range of -1 to 1. Index values above 0 indicate functional specialisation – or revealed comparative advantages – in the respective function. Negative values indicate a lack of functional specialisation, that is, a revealed comparative disadvantage.

3.2. MEASURING FUNCTIONAL SPECIALISATION IN FDI

The methodology for measuring FDI-based functional specialisation is rather simple and intuitive. It focuses on business activities offshored by firms via FDI to determine the specialisation patterns of a given location. This is possible based on the information obtained from the cross-border investment monitor fDi Markets, maintained by the Financial Times Ltd.[11] The underlying database compiles individual greenfield FDI projects and major extensions from 2003 onwards.[12] Since the database is composed of single greenfield FDI projects, a large number of characteristics of the individual greenfield FDI is available, including the investor company, the name of the subsidiary established, the origin and destination locations of the project, as well as the industry affiliation. Most importantly for our research, the database also contains information on the purposes of the established subsidiary services. The purposes, which are labelled 'activities' in the database, largely correspond to business functions that can be used directly for the categorisation of projects by functions. This way, greenfield FDI projects are assigned to one of the following five groups of value-chain functions: *(i) headquarter services*, *(ii) R&D*, *(iii) fabrication,*[13] *(iv) sales and distribution services* (including marketing, sales, logistics, marketing, business services), and *(v) technical support services and training.*[14]

These value-chain functions will form the core of the FDI-based approach to pinpoint countries' functional specialisation patterns. However, other characteristics of the fDi Markets database are also exploited. First, instead of counting the sheer number of projects, we also consider the scale of each project by basing the functional specialisation measure on the number of jobs created by the respective greenfield FDI project. Second, we make use of the information on the industries to which the projects

[11] See: http://www.ftspecialist.com/fdi_markets.html.

[12] The database only records new investment projects referred to as greenfield investments as well as major extensions of existing projects. The records reflect the announcement of new investments. Hence, it may well be that some of the projects do not materialise. According to the Financial Times Ltd. the database is regularly updated and cleaned from unrealised projects. In order to minimise the number of projects which in the end do not materialise, the sample period is limited to 2015, despite the fact that more recent data have become available.

[13] We use the term 'fabrication' when referring to the actual production stage of the (much wider) manufacturing process. This choice of terminology is that fabrication, though less common in English, makes it clear that it does not mean the entire production process in a generic sense but the specific production stage (or one of the production stages).

[14] The details of the mapping of the activities according to the fDi Markets database, along with three respectively five-pronged groupings, are provided in Appendix 1.

are assigned. A slight inconvenience is the fact that the classification of sectors used in the fDi Markets database does not correspond to the NACE classification of economic activities or any other standard classification of industries. However, with the help of the sub-sectors it is possible to establish a correspondence between the sectors in the fDi Markets database and NACE Rev.2 industries.[15] Since the geographical division of fabrication and non-fabrication activities is at the core of our study, the industry-level analysis is limited to manufacturing industries as well as selected business-related services industries that are directly linked to manufacturing. Third, the database also provides information on the destination of the project, that is, the location of the newly established subsidiary. Importantly, this information on the location of the projects is not limited to the country, but in the overwhelming majority of cases it also specifies the destination ‘state’ or ‘province’ and the destination city. The latter information, in particular, allows us to establish the NUTS 3-level regional codes (2016 vintage) for almost 90% of all observations realised in EU member states and thus conduct the analysis at the regional level.

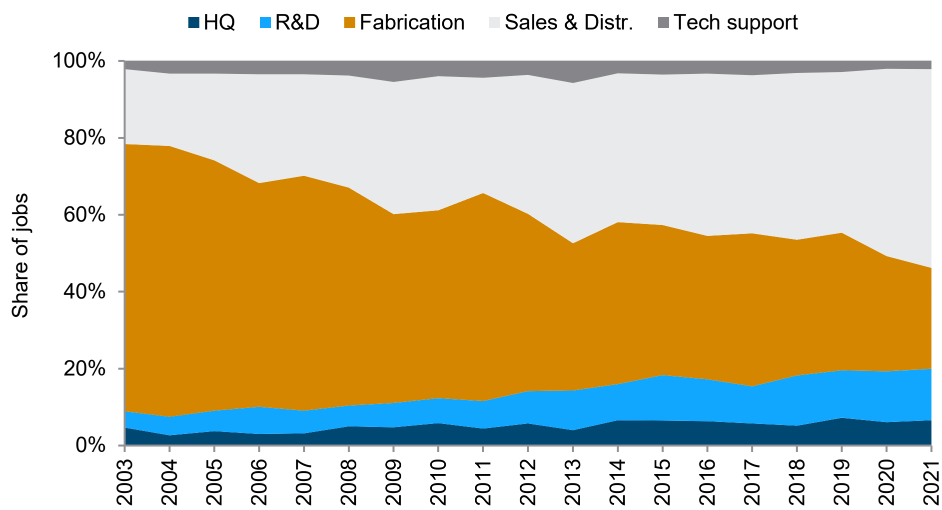
Overall, the sample of cross-border greenfield projects comprises 157.297 observations[16] over the period 2003-2021, of which 59.265 have been realised or announced to be realised in EU member states (including the UK over the entire period covered). The projects stem predominantly from manufacturing industries (NACE 10 to 32) enriched with some projects in closely related services industries, such as land transport (49), warehousing (52), legal and accounting activities, telecommunications services (61), computer programming (62), activities of head offices (69), architectural and engineering activities (70), scientific research and development (71), and advertising and market research (72).

Figure 5 presents the functional break-up of the number of greenfield FDI projects undertaken throughout the EU27 (and the UK) over the sample period. The value-chain function fabrication is the largest of the five categories throughout much of the observation period. At the same time, the dominance of fabrication-related investments is particularly pronounced in the EU-CEE, which is consistent with the trade-based data (Figure 6). Over time, however, R&D services as well as the two post-fabrication activities are rising in importance in both regions, as business process outsourcing becomes increasingly exploited by multinational enterprises (MNEs). A closer look at the structure of FDI greenfield investments shows that the growth rate in R&D services and in sales and distribution services in CEE countries exceeds that of the EU15. Over the period analysed the EU-CEE economies are perceived as one of the most attractive regions globally in terms of FDI and jobs (EY, 2010; EY, 2019). Combining high-skilled workers and relatively low fixed capital per employee attracts international companies to locate more complex processes in the CEE economies and makes significant changes in long-run trends in FDI investments in these countries (Skanska, 2021). This trend is visible in the growing importance of knowledge-intensive services, especially business services, and thus in the growing demand for white-collar workers compared with the demand for blue-collar ones, both in services and in services-oriented manufacturing (Skanska, 2021).

[15] For the details on all included NACE Rev. 2 industries see Appendix 1.

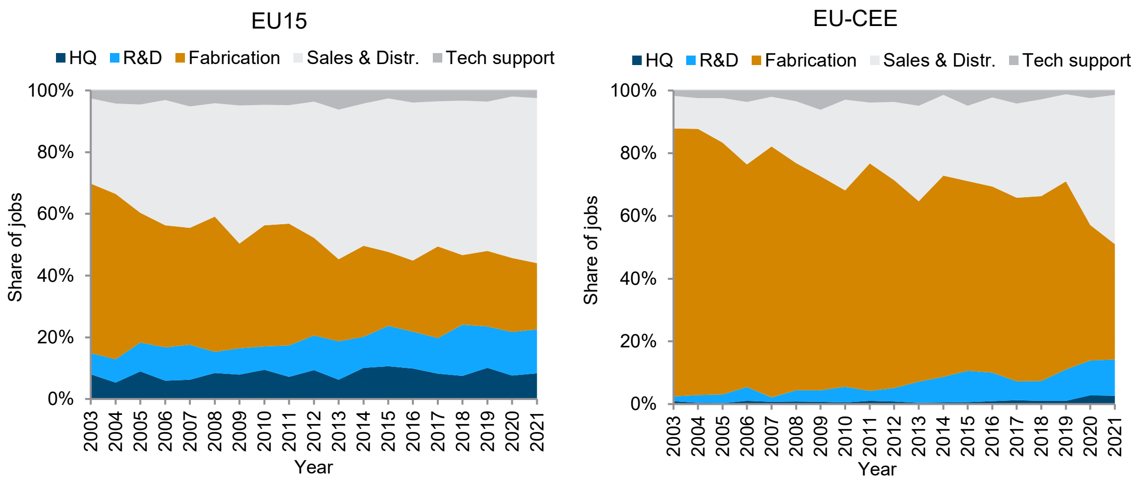
[16] For the regional- and industry-level analysis the number of observations is somewhat lower as a part of the sample is lost.

Figure 5 / Share of EU-wide FDI greenfield investments by value-chain function, 2003-2021



Note: Sales & Distr. = Sales and distribution. Tech support = technical support. For the details of the 'activities' included in each of the value-chain functions see Appendix 1. All data refer to inward greenfield FDI, that is, jobs created by projects realised in the EU. Figures include the UK.
Source: fDi Markets; authors' own calculations.

Figure 6 / Structure of FDI greenfield investments by value chain functions, EU15 vs. EU-CEE, 2003-2021



Note: Sales & Distr. = Sales and distribution. Tech support = technical support. For the details of the 'activities' included in each of the value-chain functions see Appendix 1. All data refer to inward greenfield FDI, that is, jobs created by projects realised in the EU. Figures include the UK. EU-CEE including Malta and Cyprus.
Source: fDi Markets, authors' own calculations.

Based on the information on the projects, and in particular the value-chain functions they serve, the relative functional specialisation (*RFS)* in FDI (*FDI-based RFS* for short) can be derived. The FDI-based RFS measure can be calculated at the country or the regional level, in both cases for the economy as a whole (aggregate level) or for individual industries *j*. To facilitate the notation but keeping these different dimensions in mind, we omit the time subscript in the formal definition of the FDI-based RFS measure and refer to the possible destinations as ‘locations’. Denoting value-chain functions by *f*, the *RFS* measure of any location ℓ[17] in value-chain function *k* is defined as:

(4) $$RFS_{\ell,j}^{k} = \frac{J_{\ell,j}^{k} / \sum_{k} J_{\ell,j}^{k}}{\sum_{\ell} J_{\ell,j}^{k} / \sum_{\ell} \sum_{k} J_{\ell,j}^{k}},$$

where J_{ℓ}^{f} is the number of jobs created by greenfield FDI projects serving function *f* in location ℓ. Likewise, $\sum_{k} J_{\ell,j}^{k}$ is the total number of jobs created by greenfield FDI projects in country ℓ across all value-chain functions. Analogous definitions apply for the number of jobs in the denominator, where jobs are also summed up over locations to yield the EU-wide number of jobs created by greenfield FDI.

As can be seen, the FDI-based RFS also corresponds methodologically to revealed comparative advantages (RCAs), popular in the trade literature for measuring product or industry specialisations (Balassa, 1965). The twist given to these RCAs is that in the case of the FDI-based RFS trade flows are replaced by the number of jobs created by inward FDI projects and that the unit of analysis is not industries but value-chain functions. In this context it is also interesting to note that the economic geography literature interprets the RCA as a locational concentration measure, which is called location quotient (LQ) and mathematically equivalent to the RCA (Hoen and Oosterhaven, 2006).

Consistent with the trade-based approach, we follow the analysis by Laursen (2015) and report the RFS in a normalised form, so that the values range from -1 (no projects attracted) to +1. The normalised RFS, *normRFS*, is symmetric around 0 and is defined as:

(5) $$\text{norm}RFS_{\ell,j}^{k} = \frac{RFS_{\ell,j}^{k} - 1}{RFS_{\ell,j}^{k} + 1}.$$

3.3. COMMONALITIES, COMPLEMENTARITIES AND DIFFERENCES OF THE TWO APPROACHES

While both methods for calculating functional specialisation pursue the same objective of quantifying the functional specialisation profiles of different locations, it should be clear from the previous sections that they approach the issue from different viewpoints. Applying both methods in the analysis therefore allows comparing and checking the robustness of the presented results. At the same time each method has its own unique benefits and shortcomings, which can be balanced out by relying on both measures. For instance, the advantage of the FDI-based approach lies in the longer time frame covered by the dataset. As the fDi Markets database is updated on a regular basis, the data on greenfield FDI projects are available with only a minor reporting lag (although the most recent years are preliminary). The results based on this up-to-date FDI-based approach can also be deemed useful for an early indication of certain emerging trends or patterns, because the data capture greenfield FDI projects at the moment they are announced. On the other hand, the trade-based approach benefits from a complete dataset both at the country and the industry level, which is not the case in the FDI-based approach. The latter is more sensitive in this regard, as the number of greenfield FDI projects realised over a given period can sometimes be limited, particularly if one pursues greater levels of granularity, such as annual, regional or

[17] In the context of FDI-based RFS we refer to locations ℓ instead of countries *i*, because the indicators can be calculated at the regional level as well. In the further equations, at the country and country-industry level we assume that $i=\ell$ in order to use more concise subscripts.

industry-level breakdowns. In turn, the trade-based approach can be criticised for its fixed occupation classification (ISCO88), which is unable to catch new occupations currently appearing on the labour market that may be particularly relevant for new technologies, such as artificial intelligence, additive manufacturing, machine learning or simply new communication technologies. However, having value-chain functions broadly defined as in Timmer et al. (2019), this is not critical in the context of our examination. Notwithstanding some limitations of both approaches, the results presented in the next section show that there is a common narrative emerging, which is by and large consistent across the trade-based and the FDI-based approach to functional specialisation.

4. Stylised facts on functional specialisations in EU countries – reconciling FDI- and trade-based data

4.1. COUNTRY-LEVEL ANALYSES OF FUNCTIONAL SPECIALISATION PATTERNS

Previous research (Stöllinger, 2019; 2021) has shown that FDI-based functional specialisation patterns are quite pronounced within the EU. This conclusion was also reached by Kordalska and Olczyk (2021; 2022) using trade-based data. Both approaches reveal that at the country level one can easily identify a group of countries, mainly in the EU-CEE region, that specialise strongly in fabrication. Examples include Czechia, Hungary, Poland or Romania. These CEE members of the EU stand out as being functionally distinct from their 'Western' counterparts, i.e. those that joined the EU before 2004, and the extent of specialisation in EU-CEE often runs deeper than in other EU countries (see Appendix 2).

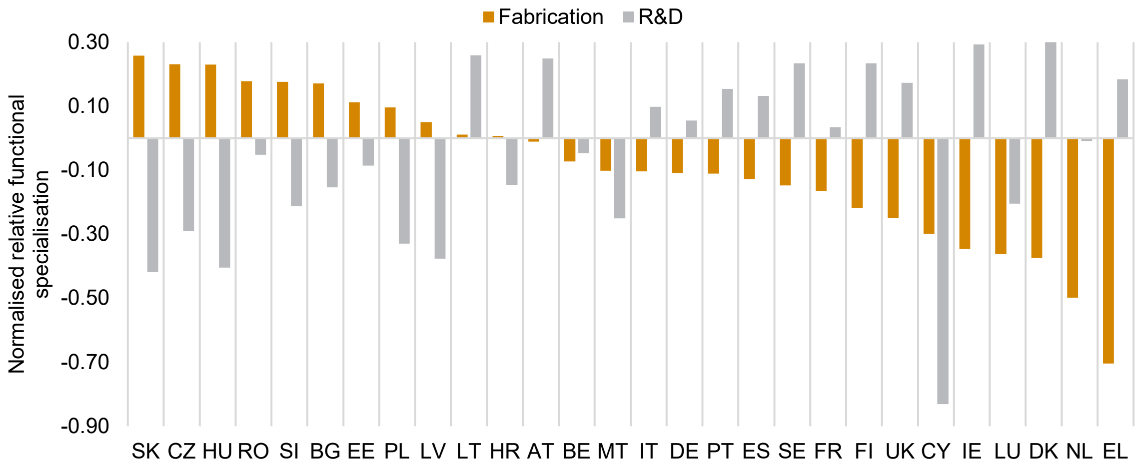
EU15 countries, which are characterised by comparatively high income levels, tend to display relative specialisation in pre-fabrication activities, namely headquarter services (or management when using the trade-based distinction) and R&D. Germany, Austria and the UK but also France and Italy (for R&D) belong to this group. The pattern for post-fabrication activities (sales and distribution services and technical support in the case of the FDI-based approach, or marketing in the case of the trade-based approach) tends to be more mixed, but more often than not countries with positive RFS values in pre-fabrication activities also have positive RFS in the post-fabrication segment.

Focusing on two of the value-chain functions, fabrication and R&D activities, can help to illustrate this complementarity in specialisation patterns observable across the EU. Sorting countries by RFS values in fabrication shows that particularly those countries that are strongly specialised in fabrication have comparatively low FDI-based RFS scores in R&D activities (Figure 7). Hence, countries to the left in Figure 7 would fall into the category of 'factory economies', as Baldwin and Lopez-Gonzalez (2015) have dubbed them. And while the FDI-based RFS in R&D are not monotonically increasing, it is obvious that high scores in this function are found predominantly on the right-hand side of the figure. Good examples include the Netherlands or Denmark, but also the UK and Germany.

Looking at fabrication activities and R&D services from the trade-based functional specialisation perspective (Figure 8) leads to analogous conclusions. The dominance of the fabrication function in EU-CEE countries pushes these countries to the left-hand side of the graph (forming the 'factory economies' group), while the above-mentioned 'Western' countries, i.e. Germany, the UK, France, the Netherlands or Denmark, reveal strong specialisations in R&D combined with low values in their fabrication function indices.

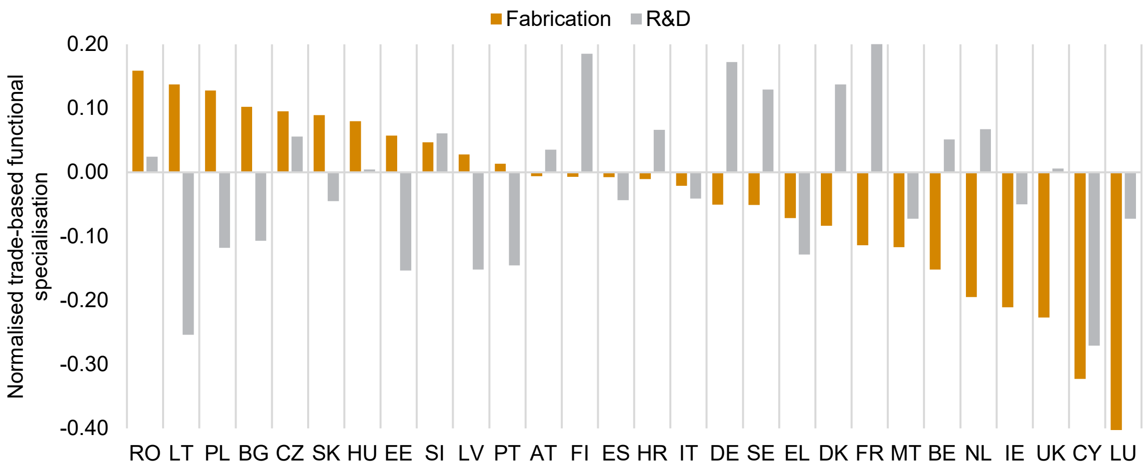
The rankings presented in Figure 7 and Figure 8 also offer an opportunity to sound a note of caution regarding the interpretation of RFS measures in general. The RFS per se is solely a specialisation measure. As such, it says nothing about the *absolute* strength a country possesses in the respective function. Hence, a country's locational capabilities and macroeconomic fundamentals cannot be directly inferred from the RFS. Greece is a case in point. It has very low FDI-based RFS in fabrication but scores highly in terms of R&D. From this we simply learn that Greece is relatively more attractive for greenfield FDI investments in R&D labs than for production sites.

Figure 7 / FDI-based relative functional specialisation in the EU, 2003-2021



Source: fDi Markets; authors' own calculations.

Figure 8 / Trade-based relative functional specialisation in the EU, 2000-2014



Source: WIOD2016; authors' own calculations.

Abstracting from individual country results, these patterns for the distribution of functional specialisation measures obtained with the aid of both methods can be illustrated more systematically by the (pairwise) correlations between functional specialisation values across all countries (Table 1). These correlations confirm the conclusion from eyeballing the country-level functional specialisations of member states. In particular, there is a strong positive correlation between headquarter services and R&D activities as well as between headquarter services and sales and distribution services in FDI-based data, and a positive and significant correlation between R&D activities and marketing services in trade-based data. In contrast, and regardless of the approach we use, fabrication is negatively correlated with all other value-chain functions. This means that countries which are specialised in fabrication are typically not specialised in other value-chain functions. This is an important finding and points to the marked difference between fabrication and all other value-chain functions.

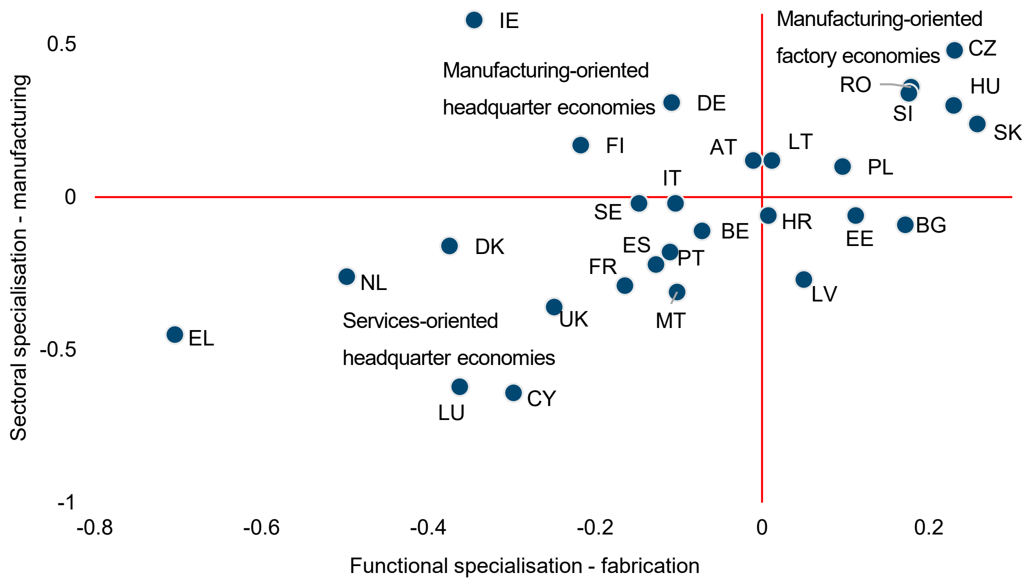
Table 1 / Correlation between the normalised RFS of value-chain functions, country level

	FDI-based relative functional specialisation (2003-2021)				
	Headquarter	**R&D**	**Fabrication**	**Sales and distribution**	**Technical support**
Headquarter	1				
R&D	0.6231*	1			
Fabrication	-0.6640*	-0.5926*	1		
Business services	0.5710*	0.5274*	-0.8438*	1	
Technical support	0.4280*	0.3200*	-0.2574*	0.1323*	1

	Trade-based relative functional specialisation (2000-2014)			
	Management	**R&D**	**Fabrication**	**Marketing**
Management	1			
R&D	0.0430	1		
Fabrication	-0.5002*	-0.3364*	1	
Marketing	-0.0421	0.1285*	-0.7453*	1

Note: Pairwise correlations. * indicates statistical significance at the 5% level.
Source: fDi Markets, WIOD2016; authors' own calculations.

Figure 9 / Sectoral and FDI-based functional specialisation in the EU, 2003-2021



Note: Sectoral specialisation in manufacturing is the ratio of each country's value-added share of manufacturing relative to that of the EU minus 1. A value of 0 indicates a manufacturing share equal to that of the EU over the period 2003-2020. Functional specialisations in fabrication are normalised values.
Source: fDi Markets; authors' own calculations.

Figure 9 zooms in on the FDI-based RFS in fabrication (horizontal axis) and adds another dimension of specialisation, which is the sectoral specialisation in manufacturing (vertical axis). In this representation it is easy to identify the countries of the 'Central European manufacturing core' discussed in Stöllinger (2016); Stehrer and Stöllinger (2015) and the IMF (2013), which have as one of their characteristics an above-average value-added share in manufacturing. Notably, there are numerous countries with a high manufacturing share and a high FDI-based functional specialisation in fabrication. At the same time, there are also countries, including Germany and Austria, which have a sectoral specialisation in manufacturing but are *not* functionally specialised in fabrication. Rather, manufacturing firms in these countries focus predominantly on other value-chain functions. This overlap in sectoral specialisation in combination with markedly distinct functional specialisations is likely to have supported the competitiveness of the members of the Central European manufacturing core.[18] Moreover, Figure 9 also reveals that countries which are sectorally quite different – say Germany, the manufacturing powerhouse of the EU, and France, a services-oriented economy – have similarly low levels of specialisation in fabrication, that is, they are functionally similar, with the characteristics of headquarter economies.

Another interesting aspect to investigate is the stability of functional specialisations across countries over time. To this end we run the tests suggested in Laursen (2015) and Dalum et al. (1998) for revealed comparative advantages (which are methodologically equivalent to the RFS, as established earlier). This test consists of regressing the normalised RFS in period *t* on that of the previous period *t-1*. The regressions are run separately for each function *k* across all EU countries ℓ and across periods,[19] formally:

(6) $$normRFS_{t,\ell}^{k} = \alpha + \beta^{k} \times normRFS_{t-1,\ell}^{k} + \varepsilon_{t,\ell}^{k}$$

If β^k is statistically significant and equal to 1, the functional specialisations are stable. In contrast, if β^k is smaller than 1, the functional specialisations in function *f* tend to decrease. Conversely, in the case where β^k is greater than 1, the functional specialisations intensify.

The results in Table 2 suggest the relative persistence of existing functional specialisations across EU countries. This implies path dependencies in functional specialisation patterns, which in turn are related to countries' capabilities to perform different value-chain functions. In the case of the FDI-based analysis, all β coefficients are highly statistically significant (at the 1% level). They are also significantly different from 1, and in all cases smaller than 1. This is an indication of β-convergence, meaning that the absolute values of the RFS decline over time. In other words, there is some functional convergence. Nonetheless, the fabrication function displays the highest β coefficient, suggesting that a specialisation in the fabrication stage of the value chain appears to be the stickiest over time. This particular stability in the fabrication function is echoed by the results using trade-based data, whereby the β coefficient for fabrication is not only the highest among all functions, but it also cannot be rejected that it is equal to 1.

18 Stehrer and Stöllinger (2015) and Stöllinger (2016) define the Central European manufacturing core to comprise Germany, Austria, Hungary, Czechia, Slovakia, Poland and Slovenia. While it is clear that Germany is at the centre of this country group, the exact membership of this group is not precisely defined. For example, at present it is more than plausible to include Romania.

19 In the case of the FDI-based approach, the data are broken down into five periods: (i) 2003-2007; (ii)2008-2011; (iii) 2012-2015; (iv) 2016-2019; and (v) 2020-2021. In the case of the trade-based approach, the data are broken down into four periods: (i) 2000-2002; (ii) 2003-2007; (iii) 2008-2011; and (iv) 2012-2014.

At the same time the trade-based functional specialisations also exhibits a notably greater stability over time across all other value-chain functions, with β values falling just barely below 1.

Table 2 / Stability tests for normalised RFS of value chain functions, country-level

	FDI-based relative functional specialisation (2003-2021)				
	Headquarter	R&D	Fabrication	Sales and distribution	Technical support
β	0.6225	0.4292	0.74478	0.6248	0.5495
t-test (β=1)					
p-value	0.0000	0.0000	0.0000	0.0000	0.0005
σ	0.6573	0.4788	0.7238	0.6998	0.4868
β / σ	0.9471	0.8964	1.0289	0.8928	1.1288
Observations	88	103	109	112	93
R-squared	0.4320	0.2293	0.5240	0.4897	0.2370

	Trade-based relative functional specialisation (2000-2014)			
	Management	R&D	Fabrication	Marketing
β	0.8542	0.9320	1.0199	0.9068
t-test (β=1)				
p-value	0.0132	0.0708	0.448	0.0075
σ	0.8109	0.9292	0.9705	0.9397
β / σ	1.0534	1.003	1.0509	0.9649
Observations	84	84	84	84
R-squared	0.6575	0.8634	0.9419	0.8831

Note: β = estimated coefficient; σ = regression correlation coefficient. *β*-coefficients indicate *β*-convergence. *β/σ* indicates the sigma-convergence.
Source: Regressions based on Laursen (2015), Dalum et al. (1998), fDi Markets; WIOD2016; authors' own calculations.

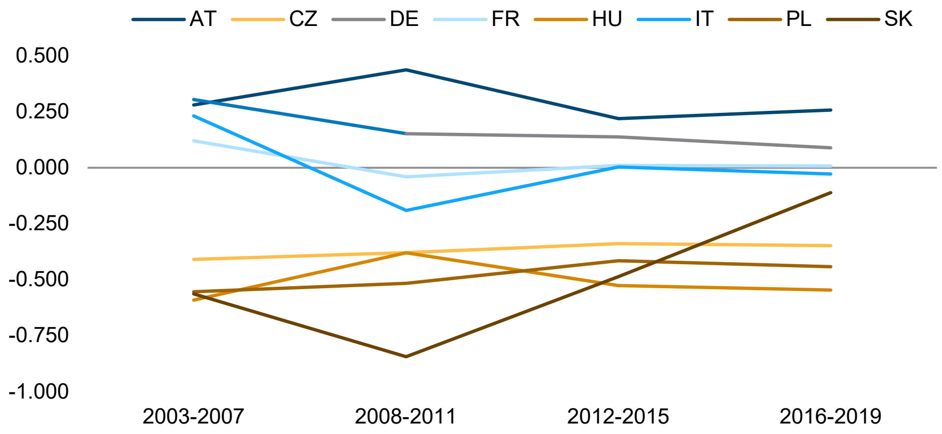
Similar to the growth literature, one can also consider the concept of σ-convergence. The latter implies that the dispersions of the functional specialisations across countries decline.[20] Looking at σ-convergence in FDI-based functional specialisation shows that there is a mild decrease in the cross-country dispersions in headquarter services, R&D and sales and distribution services, but not in fabrication and technical support services. Here too, the trade-based functional specialisations prove more stable, with only the marketing function exhibiting a very limited decrease in the cross-country dispersions.

Figure 10 illustrates the tendency towards declining functional specialisations over time using FDI data for the aggregated pre- and post-fabrication functions for a subset of countries, especially those of the Central European manufacturing core. For this set of countries, the β-convergence is most clearly visible in the pre-fabrication activities. This example, however, also shows that the dynamics are due to a few countries, mainly Slovakia and to a lesser extent Germany. Other countries, such as Czechia or Hungary, have a relatively stable RFS. Therefore, it seems that the FDI-based relative functional specialisation patterns are also fairly persistent, even though they are not entirely stable. Rather, the β-convergence that is observable is limited to specific countries in specific value-chain functions. Taking this into account, the industry-level analysis presented in the next section considers a country-specific analysis of functional stability.

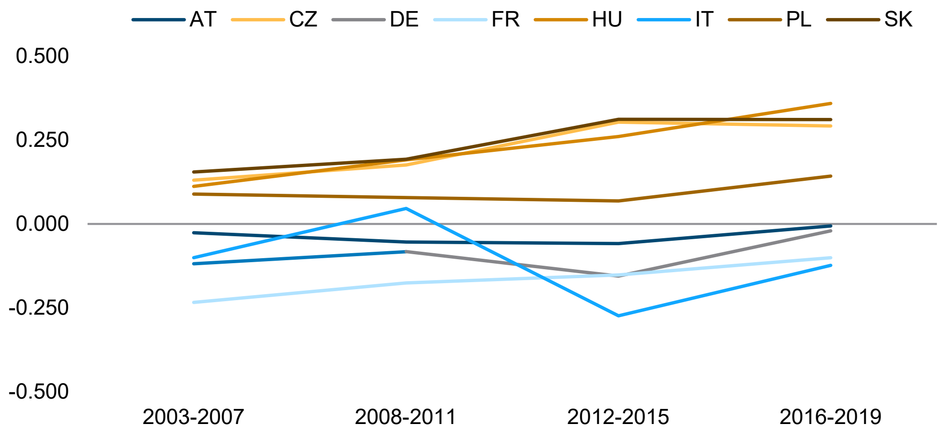
20 β-convergence does not necessarily imply σ-convergence.

Figure 10 / FDI-based relative functional specialisation over time, selected countries

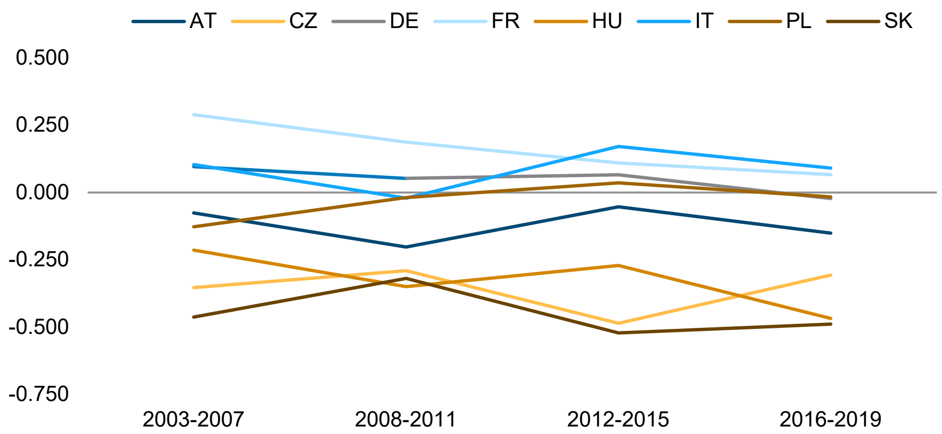
(a) Pre-fabrication



(b) Fabrication



(c) Post-fabrication



Note: Pre-fabrication includes R&D and headquarter activities; post-fabrication includes business services and technical support.
Source: fDi Markets; authors' own calculations.

4.2. HETEROGENEITY IN FUNCTIONAL SPECIALISATIONS ACROSS INDUSTRIES

A major advantage of both the trade-based and the FDI-based methodology for calculating the functional specialisation measures is that value-chain functions are defined independent of industries, which contrasts with most other approaches in the literature. Therefore, the analysis of functional specialisation patterns can be undertaken not only at the economy level but also at the level of individual industries.

The focus of the analysis is primarily on five selected industries: chemicals, electrical equipment, machinery, pharmaceuticals and vehicles. These are chosen because they cover various subsets of the economy that are relevant for GVC integration.

Zooming into the industry level, we find that the 'headquarter' vs. 'factory' economy distinction that could be inferred from the country-level analysis does not necessarily feature so prominently across all sectors. At the same time, differences between industry-level RFS and country-level RFS values appear to be most pronounced in the EU-CEE countries. This can be seen in Table 3, where the industry deviations from economy-wide FDI-based RFS values are the largest in countries such as Bulgaria, Czechia or Croatia.[21] Similarly, relatively large deviations can also be found in selected sectors in other Visegrád and Baltic states. A closer look at industry-level trade data leads to similar conclusions (Appendix 2). Among the top10 economies with the highest average variance seven belong to the EU-CEE group (the Baltic states, Hungary and Slovakia, but also Cyprus and Malta). This is indicative of some functional diversification present in certain industries. In other instances, however, the industry deviations may simply reflect an augmentation of economy-wide patterns, echoing more intensely the functional divisions in manufacturing industries that are characteristic of the Central European manufacturing core.

In contrast, industries in Western European countries such as Germany or France show only small variations from economy-wide functional specialisation patterns, irrespective of whether FDI-based or trade-based indicators are considered. This suggests that more developed economies tend to have quite stable functional specialisations across sectors and have functionally upgraded their economy in such a way that they maintain their 'headquarter' status across industries. Finland stands out as a visible exception in Table 3, with a different pattern of functional specialisation in the vehicles industry. Here, investments in the headquarter function become particularly prominent and dominate over the R&D specialisation that characterises the whole economy. Yet even in this case, the relative specialisation in the pre-production functions remains unchanged.

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21 In the case of Croatia there were only 409 jobs created in the electrical equipment industry throughout the observation period, hence one should interpret this deviation with a degree of reservation.

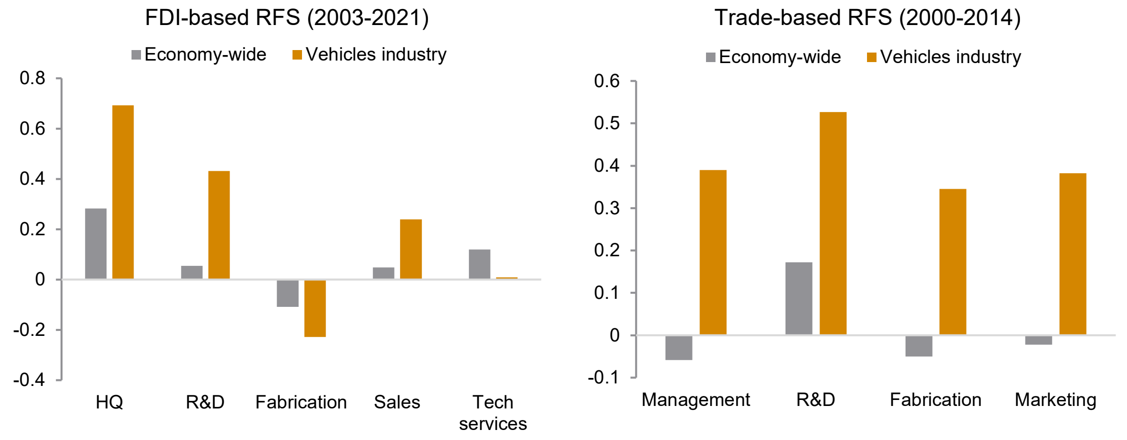
Table 3 / Deviations of industry-level FDI-based RFS from economy-wide specialisations (2003-2021)

	Chemicals	Electrical equipment	Machinery	Pharmaceuticals	Vehicles
AT	0.31	0.84	0.37	0.33	0.03
BE	1.11	0.68	0.29	0.11	0.01
BG	1.13	0.28	1.89	1.28	0.33
CY	0.92	0.94	0.83	0.94	0.94
CZ	1.49	0.13	0.17	1.66	0.12
DE	0.07	0.14	0.16	0.20	0.36
DK	0.34	0.52	0.21	1.32	0.51
ES	0.57	0.40	0.02	0.27	0.23
EE	0.67	0.68	0.37	0.64	0.58
FI	0.39	0.61	0.37	0.16	1.94
FR	0.34	0.45	0.15	0.32	0.11
UK	0.29	0.59	0.17	0.04	0.15
EL	0.22	0.44	1.18	0.45	1.37
HR	0.55	3.76	0.53	0.63	0.94
HU	0.78	0.11	1.02	0.25	0.13
IE	0.49	0.26	0.36	1.14	0.83
IT	0.24	0.10	0.68	0.59	0.35
LT	0.92	0.91	0.64	1.61	0.95
LU	0.79	0.39	0.63	0.25	1.66
LV	1.05	0.65	0.64	1.02	0.99
MT	0.67	0.70	0.74	0.88	0.89
NL	0.61	0.86	0.21	0.30	0.31
PL	0.12	0.12	0.17	1.29	0.05
PT	0.60	0.54	0.36	0.74	1.13
RO	0.32	0.52	1.03	0.95	0.29
SK	1.44	0.29	0.62	1.31	0.34
SI	0.19	1.21	0.45	0.31	0.98
SE	1.05	1.00	0.55	0.28	0.29

Note: Deviations calculated as sums of squared differences between industry-level and country-level RFS values of each value-chain function. The darker the colour of the field, the greater the deviation of industry-level results from the country-level values.
Source: fDi Markets; authors' own calculations.

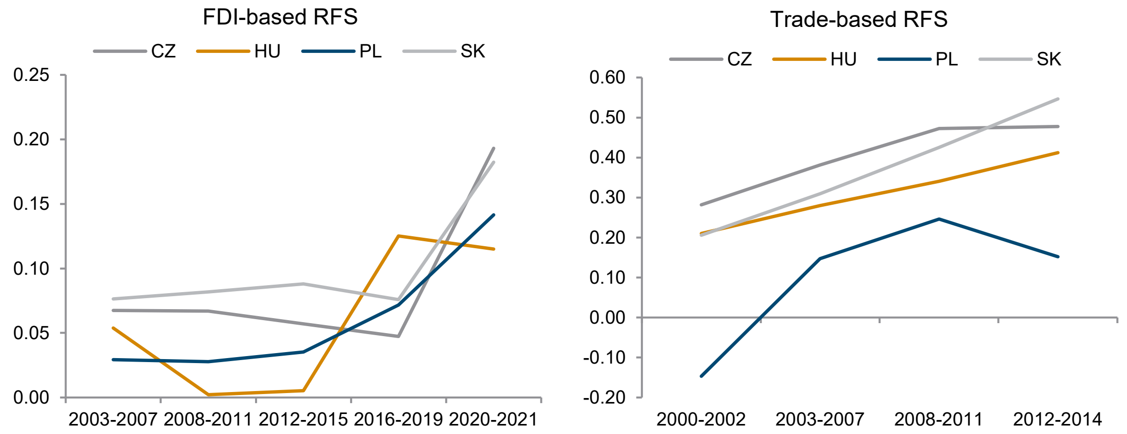
Turning one's focus to the vehicles industry, which is of crucial importance to the Central European manufacturing core, one can see that this sector does indeed emphasise and drive country-wide functional specialisation patterns (see the case of Germany, and especially its R&D pre-fabrication function in Figure 11). What is more, the developments presented in Figure 12 show that regardless of the measuring approach, the relative specialisations of the Visegrád economies in the fabrication stage remain significant for the entire period. Between 2003 and the mid-2010s the orientation of this business function was generally steady, but it appears to have been on an upward trend in recent years. This is again suggestive of the difficulty of moving beyond existing divisions of functional specialisations and the stickiness of being a 'factory economy'.

Figure 11 / Economy-wide and vehicles industry functional profiles of Germany



Source: fDi Markets, WIOD2016; authors' own calculations.

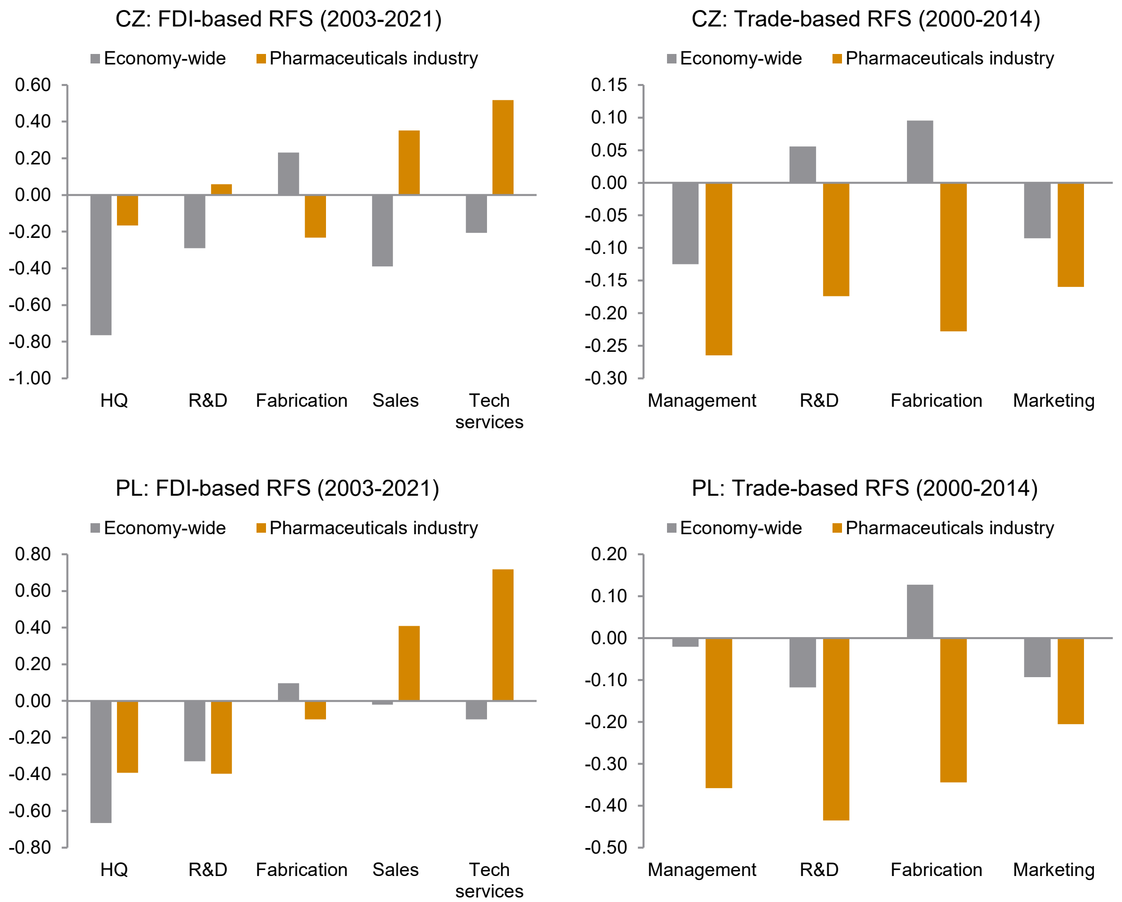
Figure 12 / Fabrication function in the vehicles industry (Visegrád economies)



Source: fDi Markets, WIOD2016; authors' own calculations.

By contrast, functional specialisations in the pharmaceuticals industry stand out as the most characteristically different among the EU-CEE economies. Here, the countries do not entirely fit the 'factory' economy label, as depicted by the example of Czechia and Poland in Figure 13. Instead, the EU-CEE region tends to specialise in the post-fabrication service functions of the pharmaceutical industry value chain (sales and technical support in FDI data), and even display relative de-specialisation in fabrication.

Figure 13 / Economy-wide and pharmaceuticals industry functional profiles of selected EU-CEE countries

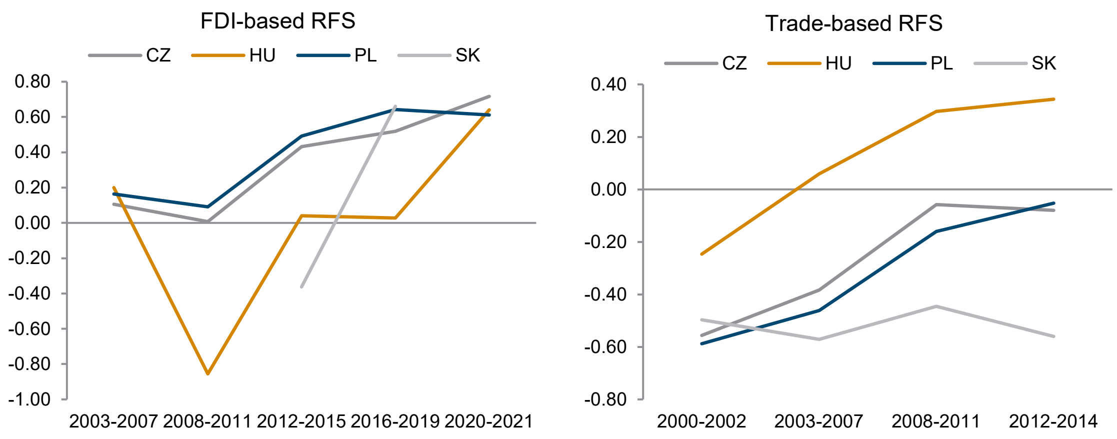


Source: fDi Markets; authors' own calculations.

Although the importance of post-fabrication function is not displayed in trade (Figure 13) this relative specialisation in the post-fabrication stage has been strengthening over time (Figure 14). At present the number of jobs created in EU-CEE countries by this industry generally accounts for roughly 1% of all jobs created by incoming greenfield FDI projects over the sample period, and similarly, domestic value added in exports from the pharmaceutical industry accounts for just about 1% of all EU-CEE countries' DVA. Hence, the overall effect on the countries' functional profiles is naturally limited. However, the upward trend coincides with the aforementioned growth witnessed in the number of FDI projects related to support services and may in the future present an opportunity for the region to functionally diversify beyond the fabrication stage.

However, the diversity observed in the functional profiles of countries at the industry level may also relate to varying degrees of complexity involved in fabricating different products. More specifically, it may be the case that taking on the fabrication function in different industries requires different levels of capabilities, technological endowments and know-how. This, in turn, could be driving the varying functional specialisation patterns across industries, and therefore it does not necessarily follow that a move away from the fabrication stage equates to a functional upgrading of the economy. Despite this possibility, it is nevertheless a promising finding for the EU-CEE countries that their functional specialisations are not exclusively in fabrication activities.

Figure 14 / Post-fabrication function in the pharmaceutical industry (Visegrád economies)



Source: fDi Markets, WIOD2016; authors' own calculations.

The industry-level data also allow us to expand the stability tests suggested by Laursen (2015) and Dalum et al. (1998). Specifically, the greater number of observations makes it possible to examine country-by-country dynamics and test whether the functional specialisation patterns of individual EU countries are stable over time, as the aggregated EU results presented in Table 2. To this end, in order to address the shortcoming of missing values in the FDI-based approach discussed above, the data on greenfield FDI projects are converted into a 'stock'-style measure, whereby the cumulative number of projects is considered as the basis for the RFS calculation. In turn, this stability analysis consists of regressing the normalised 'stock'-style RFS in year *t* on its three-year lagged value (*t-3*). For trade-based data we use, as before, the normalised RFS based on (2) and (3) and regress it on its three-year lagged values. In this specification the regressions are run separately for each EU country ℓ, across all functions k, industries j, and years t, formally:

(7) $$normRFS_{t,k,j}^{\ell} = \alpha + \beta^{\ell} \times normRFS_{t-3,k,j}^{\ell} + \varepsilon_{t,k,j}^{\ell}.$$

In this case, if β^{ℓ} is statistically significant and equal to 1, the functional profile of the given location is stable over time. If β^{ℓ} exceeds 1, a country is becoming more specialised in the value-chain function in which it already had a high RFS value, while even more de-specialising in other functions (β-specialisation, as coined by Dalum et al. (1998)). Analogously, if β^{ℓ} is below 1, the function in which a country was initially relatively specialised is weakening over time, while another function with a lower initial value is increasing (β-de-specialisation).

All countries presented above exhibited some degree of β-de-specialisation in the time frame under consideration (Table 4). Still, the countries' functional profiles appear relatively persistent over time, and the trade-based perspective again reveals more stability than the FDI approach. While the trade data show no significant discrepancies between individual countries, the β coefficients of EU-CEE countries appear to be systematically higher than in their 'Western' counterparts when measured by the FDI approach. Therefore, the EU-CEE countries seem to have particularly robust functional specialisation patterns. This echoes the findings presented earlier when looking at the stability of individual functions, whereby relative (de-)specialisation in the fabrication function was found to be the stickiest over time. Hence, it stands to reason that EU-CEE economies highly specialised in this part of the value chain would also display the most stable specialisation patterns.

Table 4 / Stability tests for relative functional specialisation profiles of countries, industry level

FDI-based relative functional specialisation (2003-2021)

Selected EU15 countries	AT	DE	ES	FR	IT
β	0.6438	0.5539	0.5488	0.4456	0.5735
t-test (β=1)					
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	724	788	773	770	712
R-squared	0.5644	0.4697	0.4564	0.3714	0.4691

Trade-based relative functional specialisation (2000-2014)

Selected EU15 countries	AT	DE	ES	FR	IT
β	0.9591	0.9322	0.8783	0.9683	0.9474
t-test (β=1)					
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	2,688	2,688	2,688	2,688	2,688
R-squared	0.8973	0.9141	0.8153	0.9329	0.8821

FDI-based relative functional specialisation (2003-2021)

Selected EU-CEE countries	CZ	HU	PL	RO	SK
β	0.7765	0.7664	0.7431	0.7615	0.7888
t-test (β=1)					
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	693	625	732	606	555
R-squared	0.7334	0.6758	0.6829	0.6853	0.7583

Trade-based relative functional specialisation (2000-2014)

Selected EU-CEE countries	CZ	HU	PL	RO	SK
β	0.9485	0.9427	0.9278	0.9086	0.9026
t-test (β=1)					
p-value	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	2,688	2,688	2,688	2,688	2,688
R-squared	0.8636	0.8884	0.8505	0.8644	0.8081

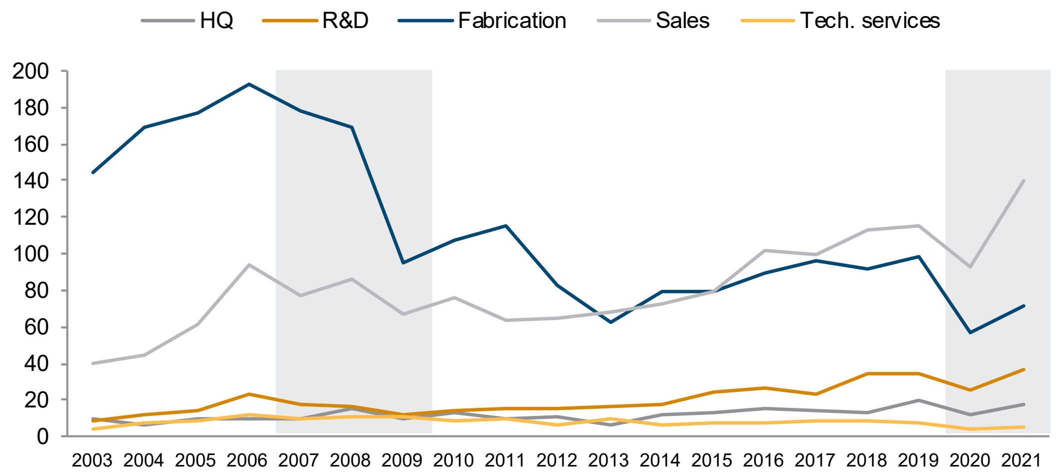
Note: Normalised RFS values based on cumulated greenfield FDI data are used; β = estimated coefficient
Source: Regressions based on Laursen (2015), Dalum et al. (1998), fDi Markets, WIOD2016; authors' own calculations.

BOX 1 / ASSESSING THE IMPACT OF THE COVID-19 CRISIS FROM THE PERSPECTIVE OF FDI-BASED FUNCTIONAL SPECIALISATIONS

The data on greenfield investment projects used in the FDI-based approach span the pandemic years. This makes it possible to explore possible changes in FDI project announcements and resultant shifts in functional patterns over this crisis period. While the available data for 2020 and 2021 are preliminary, there are already some visible distinctions from previous periods.

Unsurprisingly, the number of jobs created by FDI projects declined across all business functions in 2020 in response to the COVID-19 crisis. Glancing at Figure B 1, one can see that in absolute terms the sharpest drop by far is observed in the fabrication function. Furthermore, a notable drop in fabrication-oriented FDI was also observable during the previous crises. The Great Recession years (highlighted in blue) as well as the years surrounding the European sovereign debt crisis show even sharper declines in the job-creating capacity of the fabrication function.

Figure B 1 / Number of new jobs created from greenfield FDI projects by value chain function (in thousand)



Note: Estimated number of jobs created by greenfield FDI projects in EU28. The years of the Great Recession and the COVID-19 crisis are highlighted in blue.
Source: fDi Markets; authors' own calculations.

The pandemic-induced declines in FDI activity were generally followed by a strong rebound that exceeded the previous five-year average in 2021. However, this does not hold true in the case of the two functions which experienced the greatest relative shrinkages in 2020, namely fabrication and technical services (Figure B 2). New jobs created by these two value-chain functions remained significantly below the average 2015-2019 levels even in 2021. This is likely to have been driven by the reluctance of producers to expand capacity and instead to withhold investments until the period of uncertainty had passed.

With global value chains experiencing a notable supply shock since the onset of the pandemic, firms continue to remain conservative in their appetite to commit to new productive assets in offshore destinations (UNCTAD, 2022). Conversely, in response to the changes in doing business brought on by the pandemic, the strong recovery in pre-fabrication activities could be interpreted as investments required to adapt to new operating conditions, for example, the need to rapidly digitalise business processes in response to lockdowns.

Figure B 2 / Change in the number of new jobs created from greenfield FDI projects by value-chain function (in % against the 2015-2019 average)

Note: Estimated number of jobs created by greenfield FDI projects in EU28.
Source: fDi Markets; authors' own calculations.

In the EU context, this development has unique implications for the EU-CEE economies, which, as illustrated earlier, occupy predominantly the fabrication function. It would then follow that it is these economies which would struggle the most to attract new productive investments into their countries in times of rising uncertainty. This also fits into the overall narrative regarding the uneven post-pandemic recovery in FDI discussed by UNCTAD (2022), whereby developed nations accounted for the bulk of the rebound in 2021 and greenfield investment and FDI into emerging markets remained at relatively low levels.

Figure B 3 / Change in the number of new jobs created by fabrication FDI (in % against the 2015-2019 average)

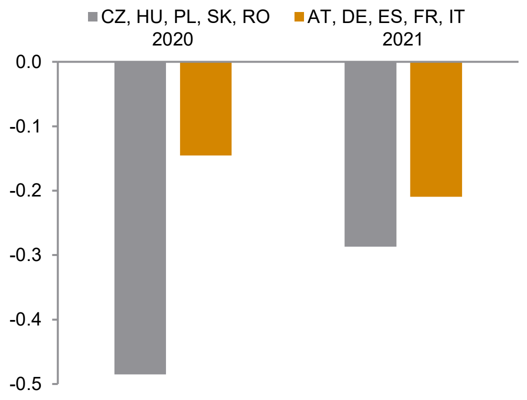
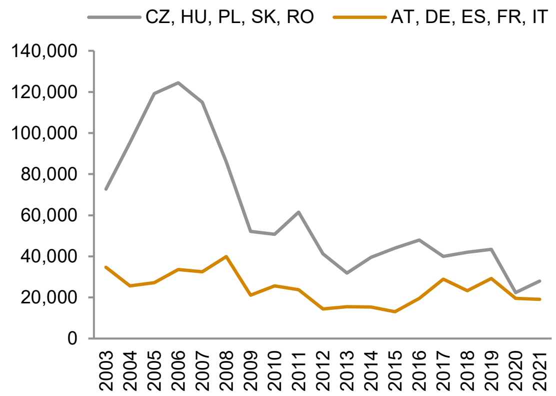


Figure B 4 / Number of new jobs created by fabrication FDI (in thousand)

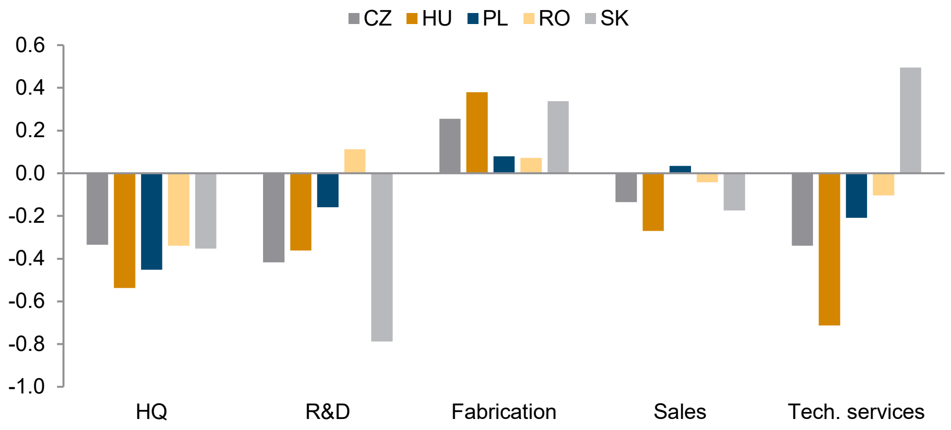


Source: fDi Markets; authors' own calculations.

Indeed, most of the decline in the number of new fabrication jobs in 2020 took place in the EU-CEE (Figure B 3). At the same time, the crises appear to have only augmented the larger downward trend that had started in the mid-2000s (Figure B 4). This trend is in line with the claim that the expansion of international value chains had come to an end around 2012 (e.g. World Bank, 2020).

Still, preliminary results of the FDI-based RFS for 2020 and 2021 do not display significant deviations from the labour division patterns in the EU presented in the previous sections. The RFS values do not yet reveal stronger functional convergence in the COVID-19 period as a result of the slowdown in fabrication-related investments. Rather, the EU-CEE region remained almost entirely specialised in the fabrication function (Figure B 5). This is indicative of the fact that the sharp decline in fabrication-related investments in EU-CEE countries was not offset by the milder declines in other functions. In absolute terms, the number of new jobs created by the fabrication function continued to dominate in the region, albeit at a lower overall level. In other words, given the relative nature of the RFS measure at hand, even when the fabrication part of the value chain struggles most prominently in crises settings, this does not automatically lead to immediate changes in the specialisations of individual economies.

Figure B 5 / FDI-based normalised RFS in EU-CEE countries (2020-2021)



Source: fDi Markets; authors' own calculations.

5. Emerging patterns of functional specialisation: the usual dichotomy of factory and headquarter economies and beyond

5.1. MOTIVATION

The descriptive analysis of the particular functional specialisation pattern carried out above shows that among EU countries some heterogeneity is observed with regard to the business functions performed across countries. Some groups of countries, primarily the EU-CEE, specialise in fabrication, while most Western economies are more oriented towards pre- and post-fabrication activities. This section substantiates the conclusions with regard to the functional specialisation of countries by statistical means. More precisely, clustering methods are used to establish groups of countries that are similar to each other based on their specialisation scores in pre-fabrication, fabrication and post-fabrication activities.

The starting point of the analysis is the pattern observed in an international production integration, i.e., a division between headquarter and factory economies. Baldwin (2006) first used the concept of 'Factory Asia' to describe the observed trend in Asian production processes in which Japanese companies headquartered in Japan manufacture high-tech parts in Japan and ship them to factories in East Asian countries for labour-intensive production steps, including assembly, and then distribute the final products to Western markets or back to Japan. Other countries, such as Taiwan, Singapore and Hong Kong, followed the Japanese practice, and together with Japan they are referred to by Baldwin as 'headquarter' economies, while the low-wage East Asian countries are referred to as 'factory' economies. The same distinction between headquarter and factory economies is found in Baldwin (2013) and Baldwin and Lopez-Gonzalez (2015) in global production networks. The emergence of factory economies, on the one hand, and headquarter economies, on the other, reflects a strong technological asymmetry between countries participating in international value chains. Headquarter countries possess advanced technologies (e.g. the US, Japan and Germany) and provide the production network, while low-wage countries (factory economies) provide predominantly the unskilled labour force. Headquarter economies also tend to diversify their partners on the demand and supply side, while factory economies tend to be heavily dependent on the nearest high-tech manufacturing giants – be it the US, Germany or Japan. The question to be explored here is whether we are dealing with a similar dichotomy in the EU context or whether the EU countries can be divided into a larger number of smaller, more homogeneous groups.

Our analysis of the patterns of functional specialisation is also related to the problem of external competitiveness of the EU economy and growth models for the EU economies, especially for the Central and East European EU members. The EU owes its economic success to its regional integration, especially its strong regional value chain along with its significant participation in the global value chain. However, Herrero and Turégano's (2020) analysis shows that the EU's role in the global value chain is shrinking and its external competitiveness is declining dramatically. The authors point out that the declining trend is particularly strong within the single market, i.e., the EU's market shares are declining at different production stages in the manufacturing value chain (especially in the electronics sector). This should be a major concern for the EU, and especially for the countries which continue to run an export-oriented model, such as Germany. The declining role of the EU in value chains is linked to technological innovation and human capital (WTO, 2021). Therefore we want to examine how the grouping outcomes among the EU28 countries change over time (at several points in time) and, on this basis, assess whether EU factory economies are converging towards the pattern of functional specialisation that is typical of headquarter economies and whether they can take over other functions (other than fabrication) in global value chains. We assume that EU factory economies will increase their competitive edge if they are able to take over different activities than before in global value chains.

There is a potential risk that some EU-CEE countries are stuck in the middle-income trap, i.e., a situation where wages are no longer low enough to compete with less developed countries, while innovation is not yet developed enough to compete with developed countries. Győrffy (2022) uses various statistical indicators to show that most EU-CEE countries have been on a convergence path with the EU average over the past decade, but not all have managed to escape the trap. While some countries have successfully adopted policies to follow the path of productivity- and innovation-driven growth (e.g. Czechia, Slovenia, Estonia and Lithuania), growth in several others (e.g. Hungary and Poland) has been supported mainly by low costs and loose monetary conditions, including substantial transfers from the EU. The evidence in favour of a middle-income trap (or not) is not only based on a flattening of per-capita income but also on a decline or stagnation of an economy's competitiveness. Our cluster analysis over time answers the question of whether EU factory economies are converging towards the pattern of functional specialisation typical of headquarter. If so, this could indirectly indicate a successful exit from the middle-income trap.

5.2. CLUSTERING METHODS

Clustering is about dividing objects into a certain number of ‘bins’ in such a way that the objects belonging to a cluster have similar characteristics. A fundamental element in any cluster analysis is distance measures. The smaller the distance between objects – in our application between countries – the more similar the objects. Elements separated by a small distance are grouped into clusters.[22] There are two major group methods in clustering, namely hierarchical clustering and non-hierarchical clustering. Hierarchical clustering is a method that assigns *n* objects into groups where the number of identified groups is unknown a priori, so we need to find the optimal number of groupings. The hierarchical clustering method works by grouping data into a tree of clusters. It starts by treating each object as a separate cluster, then it repeatedly performs the following two steps: first identify the two clusters which can be closest together, and then merge them. We need to continue these steps until all clusters are merged. The result of hierarchical clustering is a diagram called a dendrogram, i.e., a tree-like diagram that statistically represents the sequence of mergers (Hennig et al., 2015).

Non-hierarchical clustering is a method which leads to a pre-defined number of groups to be determined by the researcher. In this technique data are grouped to maximise or minimise certain evaluation criteria, i.e., algorithms will iteratively assign objects to different groups while searching for some optimal value of the criterion (Hakim and Hamid, 2020).

22 Among the best-known distance functions are Euclidean distance, Minkowski distance, Chebyshev distance and Mahalanobis distance (Everitt et al., 2011).

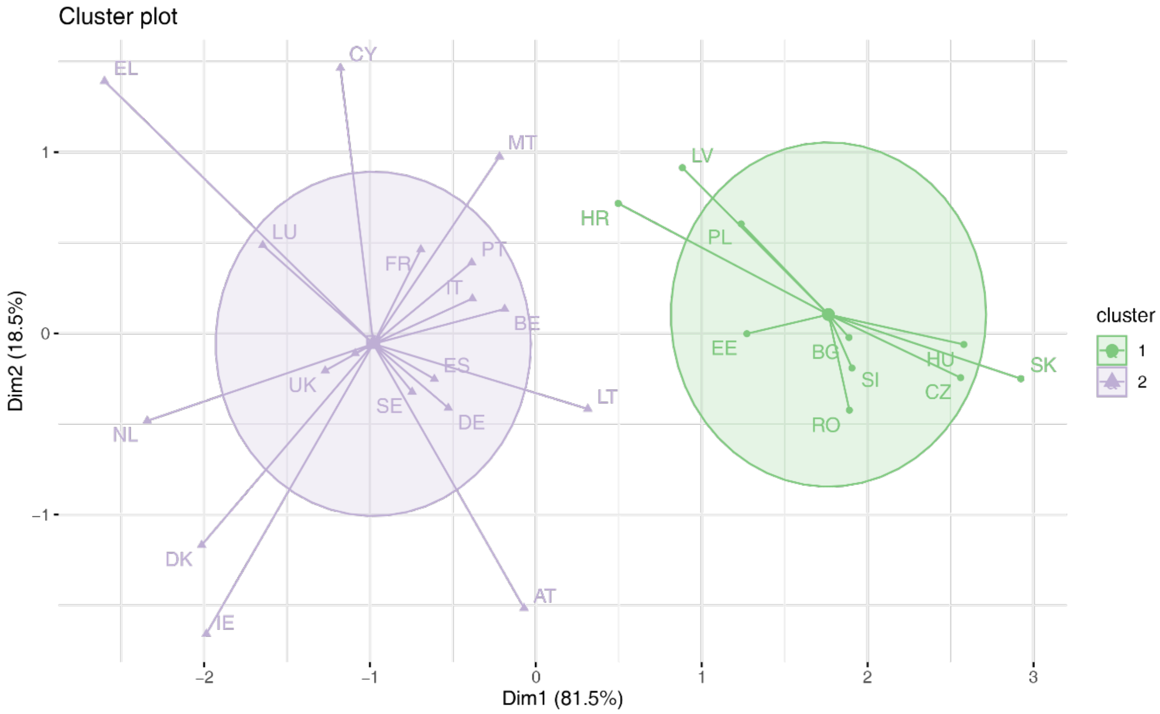
The clusters formed by different clustering methods can have different characteristics as well as different shapes (which are determined by a distance norm), sizes (the number of countries in the cluster), and densities (neighbourhood of a point in the cluster).[23]

All cluster analyses are based on a normalised version of the trade-based and the FDI-based RFS indicators. The goal of normalisation is to make every data point have the same scale, so that each feature is equally important. We use z-score normalisation, i.e., we subtract the mean value of the feature from the real value of the feature and then divide it by the standard deviation of the feature. The result of z-score normalisation is that the features will be rescaled so that they will have the properties of a standard normal distribution (mean equals 0 and standard division equals 1).

5.3. CLUSTERING RESULTS

In the non-hierarchical clustering method the number of clusters is predetermined. To determine the number of clusters the silhouette method is used. According to the silhouette method, the optimal number of clusters is determined as two. The results of the silhouette method are presented in Appendix 3. The k-means clustering results (Figure 15) are shown below.

Figure 15 / K-means clustering based on FDI greenfield investments, three value-chain functions, 2003-2021



Source: fDi Markets; authors' own calculations.

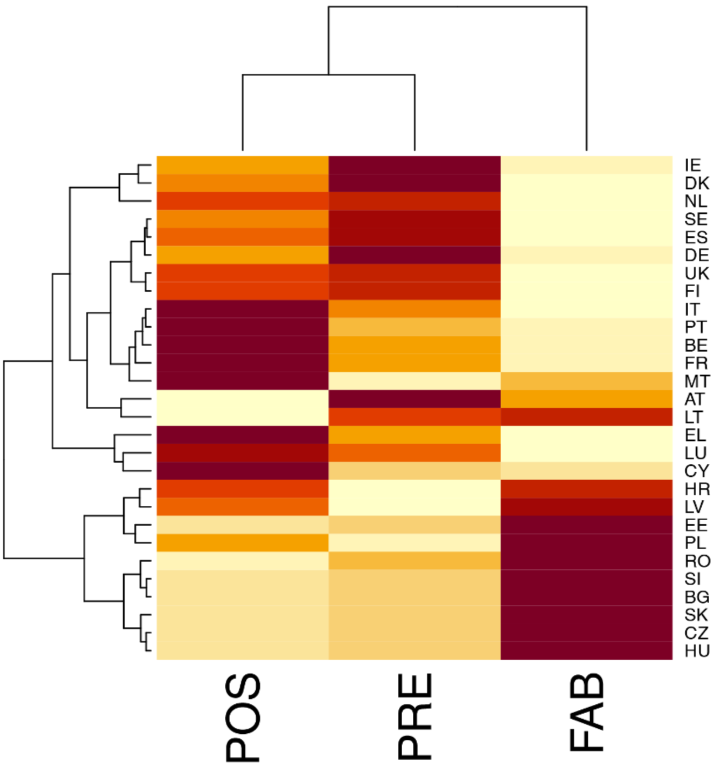
Based on the statistical properties of the data we divide the 28 EU countries into two clusters: cluster 1 (green colour in Figure 15), which contains 10 countries, and cluster 2 (purple colour) with 18 countries.

[23] Both methods are described in detail in Appendix 3.

The first cluster contains only countries that joined the EU after 2004: Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Poland, Romania, Slovakia and Slovenia. The second cluster is more numerous and includes 18 countries: the EU15 (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden and the United Kingdom) and three countries that joined the EU after 2004, namely Cyprus, Malta and Lithuania. To identify the characteristics of the clusters, the mean values of RFS are calculated for three functions of the value chain. In cluster 1, only for fabrication, the mean value of RFS is greater than 1 (1.3756) and at the same time significantly less than 1 for two functions of the value chain: prefabrication (0.4681) and post-fabrication (0.7170). It can be concluded that 10 countries grouped in cluster 1, mainly EU-CEE economies, have the status of 'factory economies'. In turn, the countries in cluster 2 have a mean value of the RFS index of more than 1 for pre- and post-production activities (1.334 and 1.2973, respectively) and do not have comparative advantages in fabrication (0.6687). Thus, the countries grouped in cluster 2 can be characterised as 'headquarter economies'. We can thus confirm that there is indeed a dichotomy between EU countries in terms of functional specialisation, and the dividing line is (with three exceptions) the division between the EU15 and the EU-CEE.

To assess how homogeneous the identified clusters are, we created so-called heat maps based on the clustering results.

Figure 16 / Heat maps of k-means clustering for FDI-based RFS, 2003-2021)



Source: fDi Markets; authors' own calculations.

A cluster heat map is a graphical representation of data in which the individual values contained in a matrix are represented as colours. In this tool the rows and columns of data in the matrix are ordered by the result of clustering, putting similar observations close to each other. To read the map, each column is a variable (i.e., RFS index for post-, pre- and fabrication activities), each row is a country, and each cell is a value of the RFS index (the closer to brown, the higher the value). A cluster heat map can help to find the variables that seem to be characteristic of each sample cluster or allows to find some subgroups in identified clusters. We analyse the heat map in Figure 16 by proceeding from the bottom to the top. Rows 1-10 (Hungary to Croatia) refer to cluster 1. A heat map shows that it is a very homogeneous group of countries, with a clear functional specialisation in fabrication for all countries and no specialisation in the other two business functions. This confirms the earlier conclusion that it is difficult to achieve a comparative advantage in other value-chain functions if the country already has it in fabrication. Rows 11-28 (from Cyprus to Ireland) refer to the countries grouped in cluster 2, which is characterised by much greater heterogeneity. This cluster includes at least three subgroups of countries. The first subgroup consists of three countries (Austria, Malta, Lithuania) which, in contrast to the other countries in cluster 2, have quite high values of RFS in fabrication, but at the same time gain a comparative advantage in pre- or post-production activity in value chains. The remaining countries in cluster 2 have a very low value of RFS in fabrication and have advantages in both pre- and post-production business functions. They can be divided into two subgroups: Ireland, Denmark, the Netherlands, Sweden, Spain, Germany, the UK and Finland have a greater RFS index in pre-production than in post-production. In turn, Italy, Portugal, Belgium, France, Greece, Luxembourg and Cyprus are more specialised in post-production activity than in pre-production activity.

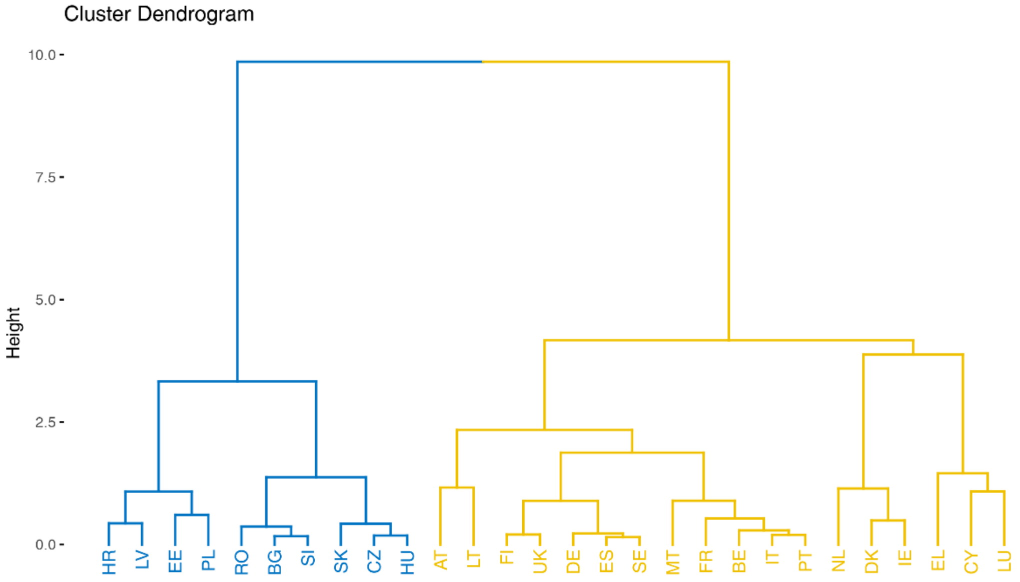
5.4. ROBUSTNESS OF COUNTRY GROUPINGS

To test the robustness of our clustering, three different methods were used. First, the one-way ANOVA method tests the stability of the country grouping. One-way ANOVA results (see the statistical test in Appendix 3) show that there is a statistically significant difference between the means of our clusters considering the three value-chain functions, which confirms that our countries are well grouped into clusters.

Second, we compare the country grouping with the clustering results using the hierarchical approach. The dendrogram analysis (Figure 17) shows that the EU countries have been grouped into two clusters according to the three functions of the value chain, which corresponds exactly to k-means clustering.

The dendrogram provides us with additional information, i.e., it shows the order in which the clusters are joined and the distance at which each grouping occurred. The dendrogram allows us to recognise patterns that might be missed from k-means clustering. In the case of cluster 1, the countries that are most similar in terms of business functions are also neighbouring each other. Thus, in cluster 1, the Visegrád countries (Slovakia, Czechia, Hungary) form the first group, the countries of Southeastern Europe (Romania, Bulgaria, Slovenia) form another group, and the Baltic countries (Latvia, Estonia) form group three, with the exception of Poland and Croatia, which are most similar to the Baltic group. In cluster 2 some spatial dependencies are also visible. Countries that are neighbours are clustered first, as seen for France and Belgium, or Greece and Cyprus.

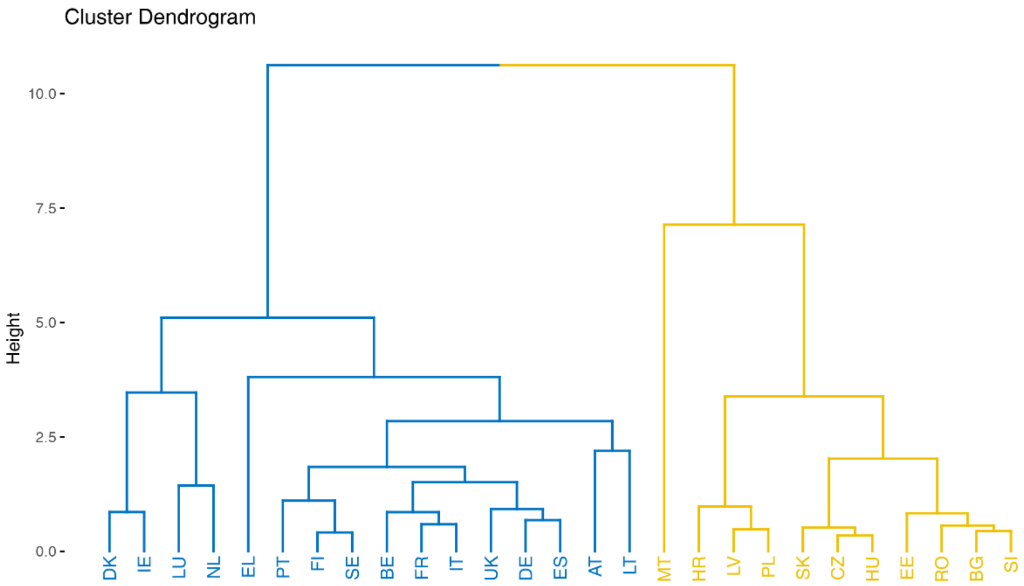
Figure 17 / Ward's hierarchical clustering for FDI-based RFS, three value-chain functions, 2003-2021



Source: fDi Markets; authors' own calculations.

Third, to test the robustness of our clustering, we compare the groupings obtained based on the three business functions with the groupings by five functions (Figure 18). We find that the clusters are maintained, with one small difference. Malta is no longer in the same cluster, i.e., headquarter economies, but now belongs to the factory economies. However, the distance (dissimilarity) between Malta and the other factory economies is large.

Figure 18 / Ward's hierarchical clustering method for FDI-based RFS, five value-chain functions, 2003-2021

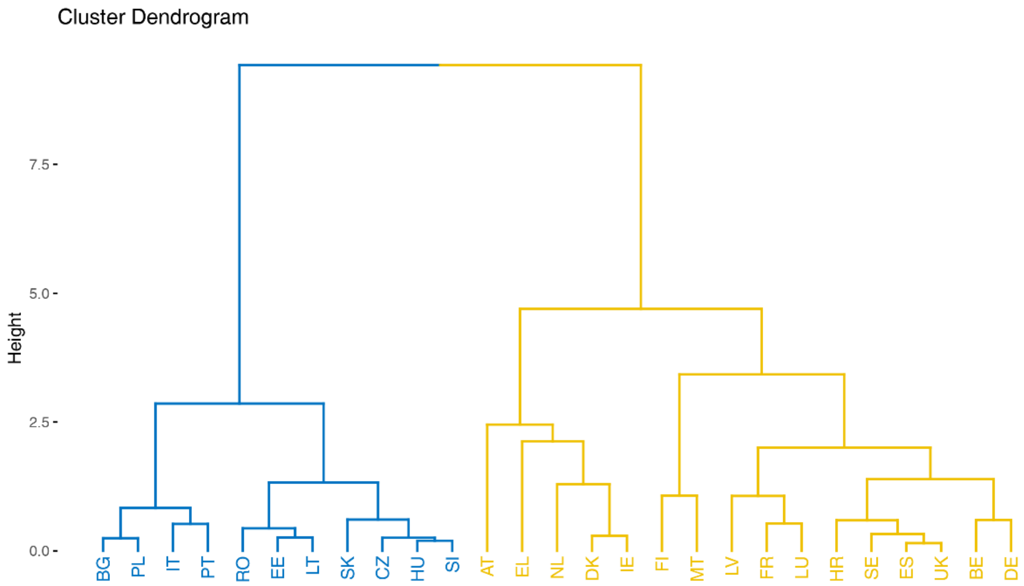


Source: fDi Markets; authors' own calculations.

5.5. CHANGES IN COUNTRY GROUPINGS OVER TIME

In order to assess whether the above-mentioned division of EU economies into headquarter and factories has changed over time, the clustering results for the beginning and the end of the study period are compared. Importantly, we want to show changes in the grouping of countries in terms of both FDI data and trade data. We start the analysis by comparing the trade-based clustering results and the FDI-based clustering results at the beginning of our sample period (2000 for the trade-based RFS and the period 2003-2007 for the FDI-based RFS) (Figure 19 and Figure 20). We only present the results of the grouping based on the hierarchical method, since the same results are also obtained with the k-means method.

Figure 19 / Ward's hierarchical clustering for FDI-based RFS, 3 value chain functions, 2003-2007

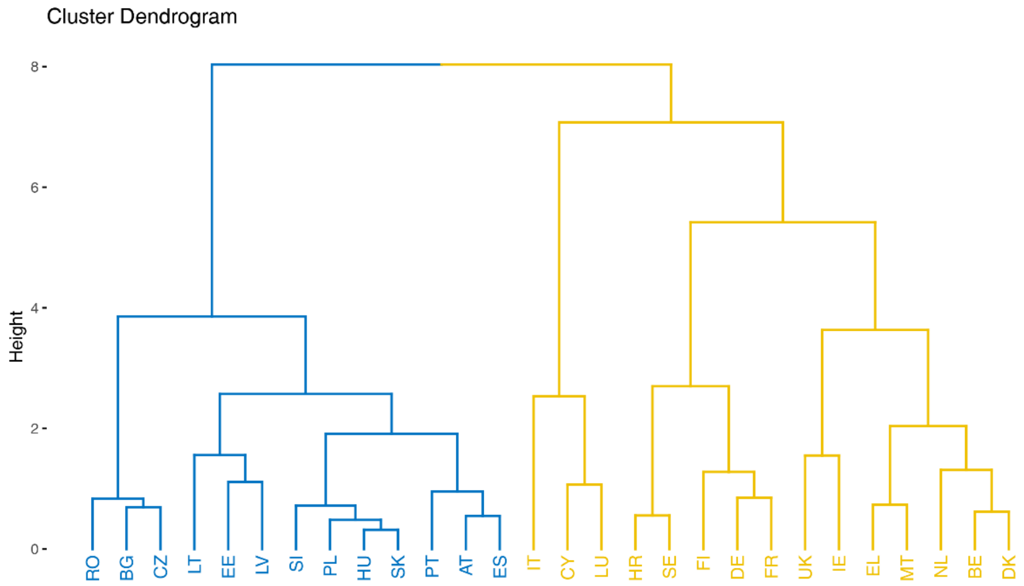


Source: fDi Markets; authors' own calculations.

The clustering results clearly point to a strong dichotomy between the EU28 countries at the beginning of the twenty-first century. Regardless of the clustering method used, the EU28 countries are divided into two distinct clusters. Irrespective of the data used, cluster 1 (left cluster tree in Figure 19 and Figure 20) always includes almost all EU-CEE countries, and these countries have only one specialisation: fabrication. The mean value of RFS calculated for cluster 1 is greater than 1 only for the fabrication function (1.12 based on FDI data; 1.23 based on trade data). Hence, it can be confirmed that the countries grouped in cluster 1 are indeed factory economies. It is interesting to note that at the beginning of the twenty-first century Portugal, Austria, Spain and Italy were also classified as factory economies. According to the clustering results based on trade data, cluster 1 included also Portugal, Austria, Spain and, based on FDI data, Portugal and Italy. According to the European Commission (2010), these four economies belonged to the group of countries with the lowest summary innovation index among the EU15 in the period 2004-2008, which may confirm the inability of these countries to take over the pre- and post-production functions in the GVCs in this period. In turn, the countries in cluster 2 (on the right in Figure 19 and Figure 20) consist mainly of EU15 countries, regardless of the clustering method and data. The countries in cluster 2 specialise purely in headquarter functions. There is a mean value of the RFS index of more than 1 only for pre- and post-production activities (1.93 and

1.71, respectively) and, based on trade data, only for R&D, marketing and management functions (1.16, 1.06 and 1.07, respectively). We can thus call the countries grouped in cluster 2 headquarter economies.

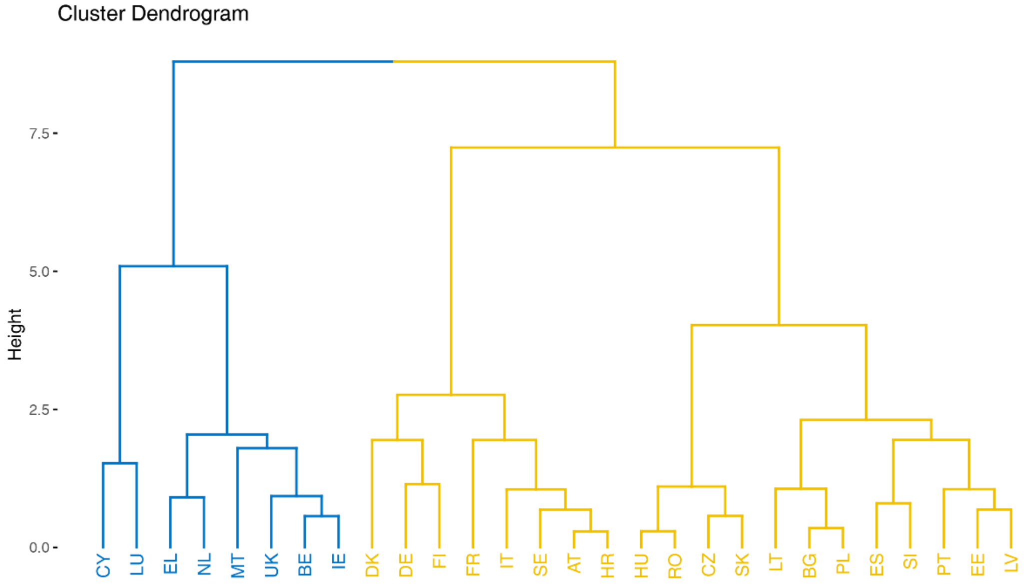
Figure 20 / Ward's hierarchical clustering method for trade-based RFS, four value chain functions, year 2000



Source: WIOD2016; authors' own calculations.

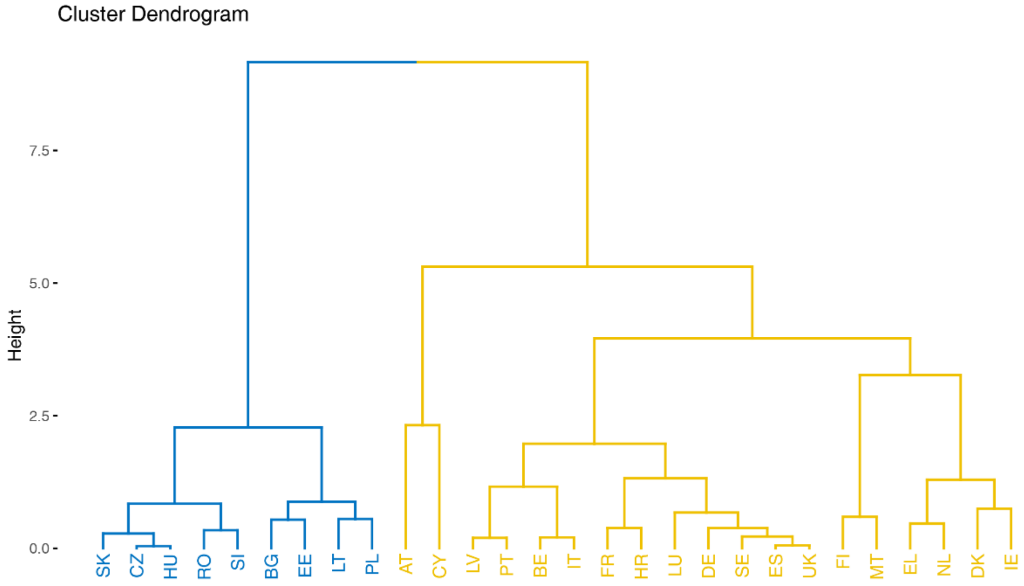
As a next step we use the most recent trade data available (2014) for the cluster analysis and compare them with the results of the cluster analysis based on the FDI data for the next period, i.e. 2008-2013. In this case, regardless of the methods we use, the EU28 countries are divided into three clusters based on the trade data. Few changes can be seen in the factory economy cluster (Figure 21, cluster tree on the right). Only Austria has left this cluster, while the EU-CEE countries remain in this cluster specialised in fabrication (the average RFS index value for fabrication is greater than 1). The novelty, however, is a comparative advantage also in the management function, which could suggest that a new value-chain function has been adopted by the factory economies over the years. In turn, the countries that belonged to the group of headquarter economies in 2000 are still characterised by a lack of comparative advantage in fabrication (RFS for fabrication < 1), but they are now divided into two separate groups. Group 1 (Figure 21, left cluster tree) includes eight countries for which the mean value of the relative functional specialisation index for management and marketing activities is significantly above 1 (1.33 and 1.32, respectively). These are the main fully or partially insular EU countries, such as Cyprus, Malta, the UK, Ireland and Greece, and small countries such as Belgium and Luxembourg. Cluster 2 (Figure 21, middle cluster tree) also includes eight countries (Denmark, Germany, Finland, France, Italy, Sweden, Austria and Croatia), which are mainly specialised in R&D activities (RFS index of 1.27) and have a small comparative advantage in marketing (1.08). Cluster analyses based on trade data thus show the deepening of specialisation in headquarter countries, but also the slow conquest of headquarter functions by factory economies.

Figure 21 / Ward's hierarchical clustering method for trade-based RFS, four value chain functions, year 2014



Source: WIOD2016; authors' own calculations.

Figure 22 / Ward's hierarchical clustering method for FDI-based RFS, three value chain functions, 2008-2013

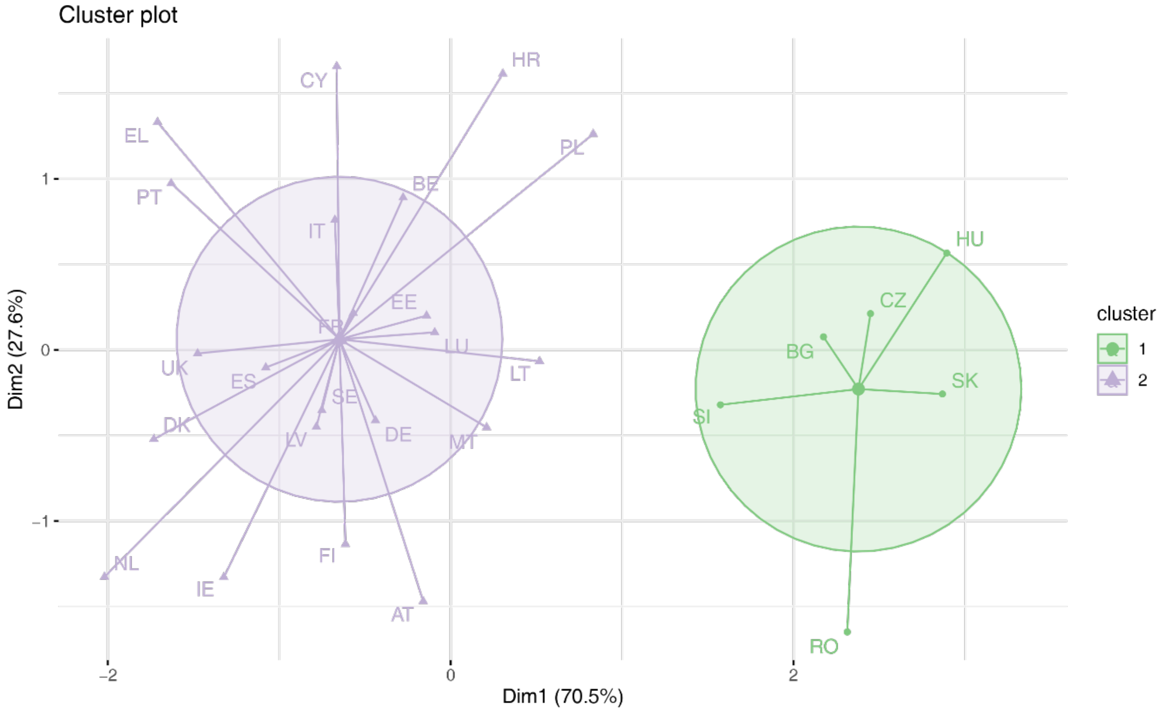


Source: fDi Markets; authors' own calculations.

The above results of the cluster analysis based on 2014 trade data can be compared with the results of the grouping of countries based on FDI data for the period 2008-2013 (Figure 22. The results obtained with both the hierarchical and non-hierarchical method show that the EU28 countries are divided into two clusters. A clear dichotomy can also be observed during the study period: the left cluster groups nine EU-CEE countries that are identified as factory economies with a comparative advantage only in fabrication, and the right cluster groups other EU countries that can be identified as headquarter economies owing to their comparative advantages in pre- and post-fabrication functions. It can be concluded that most EU-CEE countries are still specialised in fabrication a decade after EU accession.

Of course, the question remains whether there was convergence between the 'new' and the 'old' EU countries in terms of their patterns of functional specialisation in the later period, i.e., after 2014. To answer this question we have used a further grouping of countries based on FDI data for 2014-2019 (trade data are not available). Regardless of the method used, a process of slow convergence has indeed taken place. Cluster 1 (green) in Figure 23, characterised by competitive advantages only in fabrication activity, has shrunk from nine to six countries. This cluster includes EU-CEE countries with still relatively low labour costs, such as Romania, Bulgaria and some Visegrád countries – Czechia, Hungary and Slovakia – which are important for the German automotive industry and trade more heavily with Germany than with China or the United States. Our analysis shows that countries such as Poland and the Baltic states have shown functional specialisation in recent years that does not differ from the headquarter economy. This is not evident when analysing the data for the whole period 2003-2021. Hence, if our results are confirmed in the future, we can refer to a slow emergence of some EU-CEE countries from the 'functional trap'.

Figure 23 / K-means clustering for FDI-based RFS, 3 value chain functions, 2014-2019



Source: fDi Markets; authors' own calculations.

To sum up the main findings of the cluster analysis of the EU28 economies in relation to their relative functional specialisation, we confirm the existence of a dichotomy in the labour division of EU value chains. The hypothesis about the division of EU28 countries into headquarter and factory economies is still valid, and the dividing line largely coincides with the division into old and new EU countries. However, our study reveals a new trend based on the most recent data for 2014-2019. Some of the

EU-CEE countries are seen to gain comparative advantages in pre- and post-fabrication activities. This can be treated as an expression of the slowly growing external competitiveness of these countries This is a positive phenomenon, although the process is gradual and uneven, which coincides with the industry-level analysis in Section 4, and the differences with Western Europe remain large. The ability to take on new functions in the global value chain becomes particularly important in view of the changes in the supply chain caused by the COVID-19 pandemic (supply disruptions, transport obstacles, forced absences of factory workers). Certainly, the practice of automating and reshoring production processes closer to the headquarter economies in Europe is anticipated to intensify, which can present an opportunity for the EU-CEE countries to accelerate and broaden the adjustment of their patterns of functional specialisation.

6. The regional dimension

The analyses conducted so far were at the country or country-industry level. This section discusses the specialisation patterns at the regional level, which is an important aspect as the country-level results may hide significant variations in the functional specialisation patterns across regions within countries. The importance of the regional dimension is evident given the regional disparities within the EU and the related cohesion efforts. Almost one third of the EU's budget (the Multiannual Financial Framework) in the period 2021-2027[24] is allocated to its Cohesion Policy.

The regional analysis is performed at the NUTS-3 level, the most detailed harmonised regional territorial units in EU statistics. Owing to data limitations it is restricted to the FDI-based functional specialisation. The underlying data are the same as for the country-level analysis, where the regional data set comprises 90% of the overall sample.[25] The period analysed is 2003-2021.

Figure 24 and Figure 25 provide a first overview of the (normalised) RFS in R&D and fabrication (which we regard as polar cases of functional specialisation) for the 1,348 EU NUTS-3 regions. Both maps categorise the regions according to their RFS, where the categories are 'no projects' in the respective function, 'strongly negative' and 'mildly negative RFS', 'mildly positive' and 'strongly positive RFS' as well as 'full functional specialisation'. The latter refers to situations where in the respective regions only greenfield FDI projects of the value-chain function under consideration were realised. Both maps show that there is a considerable heterogeneity in the RFS in both R&D and in fabrication within countries. Eyeballing these results also suggests that the Western European countries tend to feature more regions with a mildly positive or highly positive RFS than the EU-CEE countries.

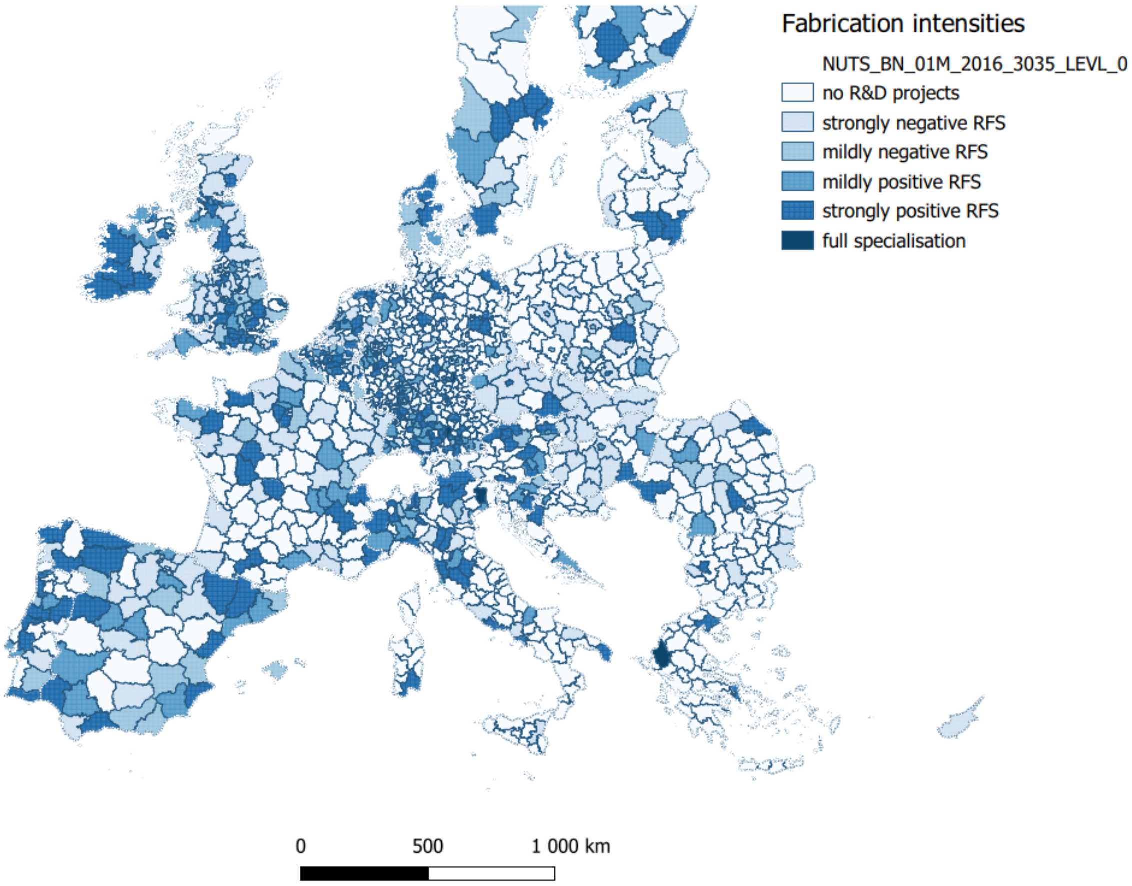
There is, for example, a concentration of regions with a strong functional specialisation in R&D in Ireland, the western part of Germany, Belgium, the Netherlands and northern Italy. Conversely, in EU-CEE countries such as Poland, Czechia or Slovakia there are comparatively fewer regions that feature a relative specialisation in R&D, although they do exist. Examples include Iaşi (RO213) in Romania, Sofia (София, BG411) in Bulgaria, Prague (Hlavní město Praha, CZ010) in Czechia or Karlovačka županija (HR04D) in Croatia. Not surprisingly, capital regions or metropolitan areas are often specialised in R&D activities that are related to the R&D infrastructure they provide, notably universities.

Some regions in Germany are fully specialised in R&D, in the sense that they have only attracted greenfield FDI projects related to R&D, such as Rhein-Pfalz-Kreis (DEB3I) or Kronach (DE24A). These regions are less informative, though, because they have only attracted very few projects. More telling are the regions that have a high number of greenfield FDI projects as well as a high RFS in R&D. The best examples here are Munich (Landkreis München, DE21H) and Karlsruhe (Landkreis Karlsruhe, DE123).

24 See: https://ec.europa.eu/regional_policy/en/policy/what/investment-policy/#1.

25 We lose some observations because not all greenfield FDI projects registered in the fDi Markets database hold information on the destination region.

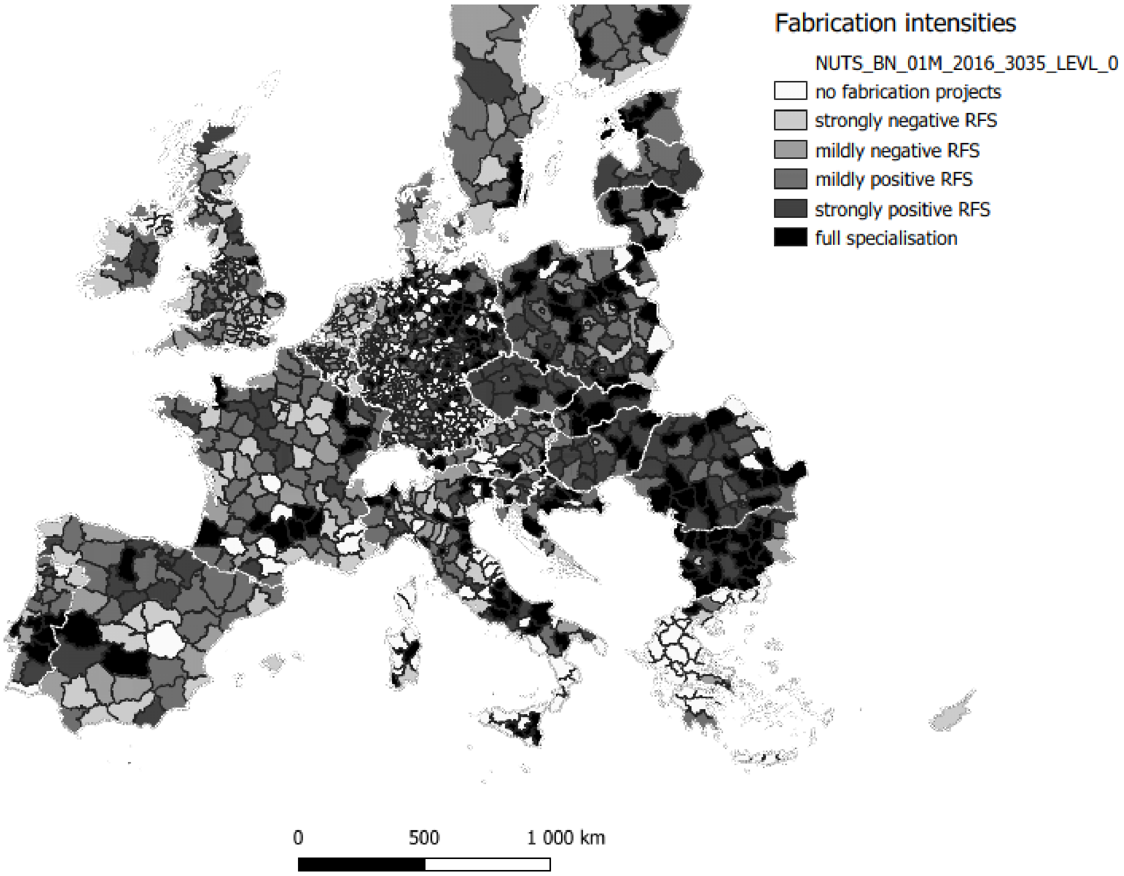
Figure 24 / Overview of relative functional specialisation of EU regions in R&D activities, 2003-2021



Note: Normalised RFS values based on cumulated greenfield FDI data. Strongly negative RFS indicates a value below -0.25; Mildly negative RFS indicates a value below 0 and above -0.25; Mildly positive RFS indicates a value above 0 and below 0.25; Strongly positive RFS indicates a value above 0.25. Full specialisation in R&D activities corresponds to a value of 0.8372. NUTS-3 region classification as of 2016.
Source: fDi Markets, WIOD2016; authors' own calculations.

A completely different picture emerges when we turn to the functional specialisation in fabrication. While the dispersion of functional profiles within countries is similarly large, the EU-CEE countries show predominantly regions in darker grey, indicating a strong RFS in fabrication. Moreover, a difference emerges within Germany, with many regions in the eastern part of the country showing a functional specialisation in fabrication. In the case of fabrication there are also 133 regions which are completely specialised in this function (compared with five regions for the R&D function). Some of these are 'fully specialised', despite a considerable number of projects realised or planned there, such Stara Zagora (BG344, Стара Загора) in Bulgaria with 18 projects, or Pomurska region (SI031) in Slovenia with 13 projects.

Figure 25 / Overview of relative functional specialisation of EU regions in fabrication, 2003-2021



Note: Normalised RFS values based on cumulated greenfield FDI data. Strongly negative RFS indicates a value below -0.25; Mildly negative RFS indicates a value below 0 and above -0.25; Mildly positive RFS indicates a value above 0 and below 0.25; Strongly positive RFS indicates a value above 0.25. Full specialisation in of fabrication activities corresponds to a value of 0.3276. NUTS-3 region classification as of 2016.
Source: fDi Markets, WIOD2016; authors' own calculations.

Having referred to the importance of considering the number of projects, or respectively, the number of jobs created by these projects, it is insightful to look at what may be called 'lead' regions in each of the value-chain functions, i.e. those regions which attracted the highest number of projects serving the respective value-chain functions (Table 5).

This type of ranking is certainly influenced by the size of the regions, although it does not necessarily bias the results towards larger countries. Rather, it is capitals and metropolitan areas in general which appear to be slightly over-represented due to their larger populations.[26] Nevertheless, these rankings pick up important regions as they typically have both a high number of jobs created in the function under consideration as well as a high RFS. An obvious exception is Barcelona, whose inclusion in the list of fabrication-oriented regions is in this case primarily explained by the large number of jobs created by

[26] NUTS-3 regions, which are considered here, generally have a population of between 150,000 and 800,000 inhabitants. See: https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=LEGISSUM:g24218. There are, however, marked deviations from this tentative population bracket.

greenfield FDI in the region. And despite this outlier it is clear from the regions listed in Table 5 (panels a-e) that the EU-CEE regions are dominating the list for the value-chain function fabrication (panel c), and only this function. In all other functions regions from Western Europe seem to be in the majority, although EU-CEE regions are also represented, but again mostly by capitals and metropolitan areas. This is true for both pre-production (panels a and b) and post-production activities (panels d and e).

Table 5 / EU lead regions in value-chain function, 2003-2021

(a) Headquarter

					jobs created		nb of
Country	**Region**	**Name of region**	**RFS**	**RFS norm**	**total**	**in function**	**projects**
IE	IE061	Dublin	4.710	0.650	83,545	21,703	245
UK	UKI31	Camden and City of London	2.890	0.486	122,867	19,585	499
NL	NL329	Groot-Amsterdam	6.775	0.743	41,904	15,659	185
ES	ES511	Barcelona	2.097	0.354	109,927	12,714	151
FR	FR102	Seine-et-Marne	1.814	0.289	70,335	7,038	130
ES	ES300	Madrid	1.870	0.303	61,749	6,369	98
DE	DE212	München, Kreisfreie Stadt	4.090	0.607	22,564	5,090	62
AT	AT130	Wien	3.780	0.582	23,277	4,853	31
UK	UKJ11	Berkshire	4.918	0.662	12,162	3,299	75
DE	DE300	Berlin	2.402	0.412	22,061	2,923	70

(b) R&D

					jobs created		nb of
Country	**Region**	**Name of region**	**RFS**	**RFS norm**	**total**	**in function**	**projects**
ES	ES511	Barcelona	1.642	0.243	109,927	15,992	227
IE	IE061	Dublin	1.645	0.244	83,545	12,177	168
UK	UKN07	Armagh City, Banbridge, Craigavon	3.887	0.591	33,287	11,463	140
UK	UKI31	Camden and City of London	0.984	-0.008	122,867	10,714	126
ES	ES300	Madrid	1.540	0.212	61,749	8,424	75
RO	RO321	Bucureşti	1.562	0.219	52,459	7,260	50
BG	BG411	София (столица)	2.429	0.417	31,749	6,833	55
HU	HU110	Budapest	1.657	0.247	42,815	6,287	68
PL	PL213	Miasto Kraków	2.116	0.358	31,861	5,974	67
IE	IE042	West	3.082	0.510	21,566	5,889	69

(c) Fabrication

					jobs created		nb of
Country	**Region**	**Name of region**	**RFS**	**RFS norm**	**total**	**in function**	**projects**
HU	HU212	Komárom-Esztergom	1.974	0.327	31,556	29,739	123
ES	ES511	Barcelona	0.555	-0.286	109,927	29,119	221
CZ	CZ080	Moravskoslezský kraj	1.835	0.295	32,090	28,117	90
PL	PL514	Miasto Wrocław	1.083	0.040	51,747	26,749	75
CZ	CZ042	Ústecký kraj	1.888	0.308	29,215	26,340	122
CZ	CZ032	Plzeňský kraj	1.793	0.284	30,043	25,724	87
SK	SK023	Nitriansky kraj	2.005	0.334	26,388	25,260	86
CZ	CZ020	Středočeský kraj	1.675	0.252	27,703	22,155	83
HU	HU211	Fejér	1.924	0.316	23,826	21,885	79
PL	PL711	Miasto Łódź	1.358	0.152	32,613	21,147	80

contd.

Table 5 / EU lead regions in value chain function, 2003-2021 (contd.)

(d) Sales and distribution

Country	Region	Name of region	RFS	RFS norm	jobs created total	jobs created in function	nb of projects
UK	UKI31	Camden and City of London	2.012	0.336	122,867	85,404	3,477
FR	FR102	Seine-et-Marne	2.282	0.391	70,335	55,451	1,847
ES	ES511	Barcelona	1.281	0.123	109,927	48,670	825
PL	PL911	Miasto Warszawa	2.162	0.368	60,245	45,008	468
IE	IE061	Dublin	1.465	0.189	83,545	42,300	629
ES	ES300	Madrid	1.470	0.190	61,749	31,359	806
RO	RO321	Bucureşti	1.589	0.227	52,459	28,797	284
HU	HU110	Budapest	1.588	0.227	42,815	23,492	251
NL	NL329	Groot-Amsterdam	1.346	0.147	41,904	19,483	668
PT	PT170	Área Metropolitana de Lisboa	1.737	0.269	31,425	18,857	262

(e) Technical support

Country	Region	Name of region	RFS	RFS norm	jobs created total	jobs created in function	nb of projects
HU	HU110	Budapest	3.818	0.585	42,815	5,443	36
UK	UKI31	Camden and City of London	1.036	0.017	122,867	4,236	81
RO	RO321	Bucureşti	2.146	0.364	52,459	3,748	25
ES	ES511	Barcelona	0.938	-0.032	109,927	3,432	41
BG	BG411	София (столица) (Sofia)	3.111	0.513	31,749	3,288	20
IE	IE061	Dublin	1.128	0.060	83,545	3,138	59
PL	PL514	Miasto Wrocław	1.752	0.273	51,747	3,019	12
ES	ES300	Madrid	1.342	0.146	61,749	2,758	39
DE	DE712	Frankfurt am Main, Kreisfreie Stadt	4.236	0.618	16,790	2,368	56
NL	NL329	Groot-Amsterdam	1.494	0.198	41,904	2,084	42

Note: NUTS-3 region classification as of 2016.
Source: fDi Markets, WIOD2016; authors' own calculations.

The inequality – or dispersion – of jobs created by greenfield FDI is a particularly interesting aspect of the functional analysis at the regional level. As previously mentioned, regional economists tend to interpret the RFS itself as a dispersion measure. Here, however, we want to investigate other inequality measures, namely the Gini coefficient and the Theil T index. For both measures higher values indicate a greater dispersion, that is, a greater degree of inequality among regions with respect to how many jobs they were able to attract. In this analysis the focus is on the inequality across all regions within individual value-chain functions. Table 6 shows that the Gini coefficients – which range between 0 (uniform distribution) and 1 (all jobs going to one region) – are relatively high, reaching 0.92 in the case of headquarter functions.[27] Among all the functions, fabrication is the least unequally distributed value-chain function, which can be attributed to the fact that assembly and other fabrication activities are typically the means by which locations link into international value chains.

[27] The Gini coefficients become lower when observations for regions which do not attract any project within a certain function are excluded but the observed patterns do not change.

Table 6 / EU dispersion of jobs created by value-chain function, 2003-2021

	Headquarter	R&D	Fabrication	Business services	Technical support
Gini	0.9207	0.8713	0.7594	0.8375	0.8921
Gini (excl. regions w/o jobs)	0.7861	0.7565	0.7294	0.8069	0.7047
Theil T index	2.5861	1.8792	1.1848	1.7572	2.0032
between component	*0.5711*	*0.3459*	*0.6578*	*0.2764*	*0.3705*
within component	*2.0149*	*1.5333*	*0.5270*	*1.4809*	*1.6327*
Theil T index (excl. regions w/o jobs)	1.5935	1.2417	1.0671	1.5842	0.9967
Herfindahl index (normalised)	0.0322	0.0108	0.0041	0.0127	0.0107
Gini coefficient by country					
AT	0.9133	0.7766	0.6604	0.8018	0.9018
BE	0.8219	0.7381	0.7702	0.7642	0.8218
BG	0.9571	0.9545	0.4521	0.9214	0.9458
CY					
CZ	0.7881	0.7047	0.3860	0.6083	0.6871
DE	0.9274	0.8750	0.7193	0.8233	0.9332
DK	0.7570	0.6618	0.5493	0.6571	0.5502
EE	0.8000	0.7723	0.4106	0.6775	0.6627
EL	0.8905	0.8741	0.5705	0.8403	0.9185
ES	0.9249	0.8405	0.6856	0.8266	0.8779
FI	0.8888	0.8237	0.5800	0.8953	0.8923
FR	0.9028	0.8343	0.6317	0.8183	0.8374
HR	0.9035	0.9023	0.4279	0.8092	0.8342
HU	0.8658	0.8212	0.3598	0.7378	0.8355
IE	0.7457	0.5575	0.2510	0.6937	0.5374
IT	0.9555	0.8702	0.7084	0.8670	0.8936
LT	0.9000	0.8428	0.4966	0.8107	0.7460
LU					
LV	0.8333	0.8333	0.4266	0.6997	0.8333
MT	0.5000	0.4086	0.4801	0.4971	0.5000
NL	0.8587	0.7753	0.5446	0.7219	0.8417
PL	0.9283	0.9024	0.5659	0.7929	0.8927
PT	0.9347	0.8332	0.6528	0.8887	0.9025
RO	0.9322	0.8736	0.4921	0.8569	0.8983
SE	0.8543	0.8151	0.5974	0.8001	0.7415
SI	0.8876	0.7835	0.5307	0.7359	0.8760
SK	0.8545	0.3822	0.1562	0.6329	0.6932
UK	0.8233	0.7959	0.5968	0.7400	0.7698

Note: NUTS-3 region classification as of 2016.
Source: fDi Markets, WIOD2016; authors' own calculations.

Even if expected, this result is nevertheless important and also interesting in connection with the finding of a relatively high stability of the functional profile, in particular in fabrication. Taken together, these characteristics point to the risk of path dependencies in numerous regions within the EU.

The result regarding the more equal distribution of FDI projects serving fabrication is fully confirmed by the Theil T index. This metric has the advantage that it can be decomposed into a within component (within countries) and a between component (between countries). This is a useful characteristic of the

Theil index and in this case reveals that the within country component tends to be more important, with the exception of fabrication. So once more, the fabrication function differs here from all the others because the between component (0.66) is slightly larger than the within component (0.53). In other words, the functional differentiation between EU member states is greatest in fabrication. At the same time, where a country is specialised in operating as a 'factory economy', it tends to be rather uniformly specialised in this manner across the regions.

Both the Gini coefficient and the Theil T index are popular measures used in the study of economic inequality. Therefore, the analysis is complemented by a concentration measure from the trade literature, the (normalised) Herfindahl index. The message remains the same, though: the concentration of jobs in only a few regions is less pronounced in fabrication than in the other value-chain functions. Finally, it is noticeable that this pattern is consistently found for the distribution of jobs within individual member states. With the exception of Belgium, the country-specific Gini-coefficients are lower in the fabrication function than in the pre-fabrication and post-fabrication segments.[28]

[28] It is much more difficult to identify patterns in the inequality of distributions across countries, and such an analysis would have to be treated with care in any case, due to the differences in the average size of the regions between countries.

7. Conclusions

The focal point of this paper was to identify the value-chain functions that are performed by EU members states in the context of fragmented production within global value chains. As functions are a comparatively new dimension of specialisation, the empirical evidence regarding functional specialisation patterns is only limited. Against this background we employed two methods of quantifying the magnitude of this specialisation, using a measure of revealed comparative advantages dubbed 'relative functional specialisation', or 'RFS' for short, as the main indicator. The two approaches are the trade-based approach, on the one hand, and the FDI-based approach, on the other. The aim of both RFS measures was to identify different value-chain functions in which a specific location holds a comparative advantage.

Applying both the trade-based and the FDI-based RFS to our analysis, we focused on the division of labour within the EU. Reliance on both approaches allowed us to compare the results derived based on the two methods and check the robustness of our results. The core objective of our analyses presented in this paper was to gain a better understanding of the functional divisions present between the 'Western' EU economies and the EU-CEE countries, particularly in the region referred to as the 'Central European manufacturing core'.[29] Our results echo previous analyses of the region – see, for example, Stöllinger (2019; 2021) and Timmer et al. (2019) – and illustrate that regardless of the approach used, the EU-CEE countries prove to be highly specialised in fabrication activities, while the most advanced EU countries generally perform tasks that precede or succeed fabrication or oversee the entire process (such as R&D, management, or marketing and sales). At the same time the results show that this specialisation pattern proves quite robust over time, implying a certain degree of lock-in in the roles played by different EU countries in international production networks. In this regard, the particular stickiness of the fabrication role was highlighted, which was further supported by the finding that the fabrication-oriented EU-CEE countries showed the greatest resistance to change in their specialisation patterns over time. Hence, these results can be interpreted as suggestive of a 'factory' and 'headquarter' dichotomy[30] present between the most advanced and converging EU nations, and indicative of a possible growth trap for the EU-CEE region.

Benefiting from the fact that RFS measures are calculated independently from industries, the paper also focused on functional specialisations present in different parts of the economy. Here, an interesting finding is that RFS values are generally characterised by greater deviations from economy-wide patterns across EU-CEE industries than in Western EU countries. Industry-level results shed light on some functional diversification taking place in the EU-CEE, although the capacity of these emerging industries to change economy-wide specialisations has so far remained limited.

In order to examine more closely the issue of the hypothesised 'factory' and 'headquarter' labour division in the EU, the paper followed with a cluster analysis based on both RFS approaches. This confirmed that this dichotomy is indeed present at the EU-level, with an apparent distinction between the EU15 and

[29] See Stehrer and Stöllinger (2015) and Stöllinger (2016).

[30] Term coined by Baldwin and Lopez-Gonzalez (2015).

the EU-CEE. However, consistent with the insights gained through the industry-specific analysis, most recent data also showed promising deviations from past trends in the EU-CEE countries. Still, this functional diversification turned out to be quite uneven and gradual, and only subsequent analysis can reveal the future trajectory.

Finally, it was shown that a specialisation in different business functions does not stop at the country level but is also prevalent at the subnational level. As one would expect, capitals and major cities were found to dominate the R&D function, which can be explained by the presence of suitable infrastructure such as universities and other research institutions. At the same time, the distinction between Western EU countries and EU-CEE countries was also discerned at the regional level. Regions in EU-CEE countries were again found generally to dominate the fabrication function, while regions in Western EU economies featured more heavily as R&D specialists. An interesting takeaway from the regional analysis is the fact that that the fabrication function displayed the least unequal distribution among individual regions. In conjunction with the particular stability of fabrication RFS values over time, it was argued that this finding contributes further to the possibility of a path dependency in fabrication specialisation.

The persistence of functional specialisation patterns is definitely one of the main insights gained from this investigation. In spite of the apparent movements in the structure of greenfield FDI projects and in the structure of DVA in exports towards pre- and post-fabrication activities, which are observed especially in the EU-CEE group, the duality of factory economies and headquarter economies continues to exist. At the same time, there are also some indications of functional changes. First of all, the CEE-EU economies have diversified their functional profile in some industries, e.g. the pharmaceutical sector. Second, within most EU countries there are some 'headquarter'-type regions (mainly the capital regions). This means that a complete functional 'lock-in' in fabrication is less likely than suggested by the country-level patterns. Hence, while the results point towards major difficulties of functional diversification beyond the fabrication stage in the EU-CEE countries and regions, there is also a silver lining in the functional developments within the EU.

All the analyses presented in this paper are deemed instrumental to gaining a better understanding of the nature of the participation of EU countries in global value chains. While it is emphasised that a direct application of Shih's (1996) smile curve to the industry and the economy level faces some caveats, one can draw parallels between the RFS results presented here and the smile curve hypothesis in a location's ability to capture value added based on specialisations in different stages of the production process. Still, it must be remembered that the RFS is merely a relative specialisation measure, implying that it does not carry information related to performance. Hence, our results provide a basis for further study in this direction to understand fully the implications of functional specialisations for economic development. In this regard, the main contribution of this paper lies in the in-depth examination of labour division patterns in the EU context, suggesting that even in a complex web of cross-border and inter-firm production chains comparative advantages appear to drive country and regional specialisations in value-chain functions.

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Appendix

APPENDIX 1: CLASSIFICATION OF FUNCTIONS AND INDUSTRIES

Appendix Table A.1.1 / Functional specialisation in trade approach – business functions and ISCO88 occupations

Occupations	1-digit ISCO88	3-digit ISCO88	Business functions	Example of occupation
Legislators, Senior Officials and Managers	1	111-131	management	directors and chief executives
Professionals	2	211-235	R&D	mathematicians, statisticians and related professionals
		241-247	marketing	business professionals
Technicians and Associate Professionals	3	311-323, 331-334	R&D	physical and engineering science technicians
		341-348	marketing	business services agents and trade brokers
Clerks	4	411-422	marketing	client information clerks
Service Workers and Shop and Market Sales Workers	5	511-522	marketing	shop, stall and market salespersons and demonstrators
Skilled Agricultural and Fishery Workers	6	611-615	fabrication	fishery workers, hunters and trappers
Craft and Related Trades Workers	7	711-744	fabrication	electrical and electronic equipment mechanics and fitters
Plant and Machine Operators and Assemblers	8	811-834	fabrication	automated-assembly-line and industrial-robot operators
Elementary Occupations	9	911-916	marketing	street vendors and related workers
		921-933	fabrication	manufacturing labourers

Source: Authors' elaboration based on Timmer et al. (2019), 'Online appendix with replication files'.

Appendix Table A.1.2 / The scheme of occupational database

		Business functions – the share of income				Sum
		R&D	Management	Fabrication	Marketing	
Country 1	Industry 1					1
Country 1	Industry 2					1
…	…					…
Country 2	Industry 1					1
Country 2	Industry 2					1
…	…					…

Source: Authors' elaboration based on Timmer et al. (2019), 'Online appendix with replication files'.

Appendix Table A.1.3 / Mapping of activities into value chains functions

Activity in the fDi cross-border monitor	Value-chain functions (narrow categories)	Value-chain functions (broad categories)
Research & Development	R&D and related services	Pre-production
Design, Development & Testing		
Headquarter	Headquarter services	
Manufacturing	Production	Production
Recycling		
Extraction*		
Business Services	Sales, marketing, logistics, retail and other business services	Post-production
Logistics, Distribution & Transportation		
Retail		
Sales, Marketing & Support		
Customer Contact Centre		
Shared Services Centre		
ICT & Internet Infrastructure	Technical services, maintainance & training	
Technical Support Centre		
Education & Training		
Maintenance & Servicing		

Note: * For chemicals sector only.
Source: fDi Markets database, authors' own classification.

Appendix Table A.1.4 / NACE Rev. 2 industries used for the analysis at the function-industry-country level

Description	NACE Rev. 2
Manufacture of	
food and beverages	10
textiles; wearing apparel; leather	13-15
chemicals	20
pharmaceuticals	21
metals and metal products	24-25
computer, electronic and optical products	26
electrical equipment	27
machinery and equipment	28
motor vehicles	29
other transport equipment	30

Appendix Table A.1.5 / Mapping from fDI Markets cross-border investment monitor to NACE Rev. 2 industries

Sector	Sub-sector	NACE Rev. 2 correspondence
Aerospace	Aircraft	30
	Aircraft engines, other parts & auxiliary equipment	30
	Other (Aerospace)	30
Automotive Components	Automobiles	29
	Communication & energy wires & cables	27
	Motor vehicle body & trailers	29
	Motor vehicle brake systems	29
	Motor vehicle electrical & electronic equipment	29
	Motor vehicle gasoline engines & engine parts	29
	Motor vehicle seating & interior trim	29
	Motor vehicle stamping	29
	Motor vehicle steering & suspension components	29
	Motor vehicle transmission & power train parts	29
	Other motor vehicle parts	29
Automotive OEM	All other transportation (Automotive OEM)	29
	Automobiles	29
	Heavy duty trucks	29
	Light trucks & utility vehicles	29
	Motor vehicle gasoline engines & engine parts	29
	Motor vehicle transmission & power train parts	29
	Other motor vehicle parts	29
Beverages	Breweries & distilleries	10
	Other (Beverages)	10
	Soft drinks & ice	10
Biotechnology	Biological products (except diagnostic)	21
	In-Vitro diagnostic substances	21
	Other (Biotechnology)	21
Building & Construction Materials	Asphalt paving, roofing, & saturated materials	23
	Cement & concrete products	23
	Other (Building & Construction Materials)	23
	Commercial & service industry machinery	28
	Computer & peripheral equipment	26
	Other (Business Machines & Equipment)	26
Business Services	Accounting, tax preparation, bookkeeping, & payroll services	69
	Advertising, PR, & related	73
	Architectural, engineering, & related services	71
	Business schools, computer & management training	62
	Business support services	82
	Custom computer programming services	62
	Educational support services	74
	Employment services	78
	Environmental consulting services	70
	General purpose machinery	28
	Heavy & civil engineering	71
	Legal services	69
	Management consulting services	70
	Other support services	74
	Professional, scientific & technical services	72
	Specialised design services	74
Ceramics & Glass	Clay product & refractory	23
	General purpose machinery	28
	Glass & glass products	23
	Other (Ceramics & Glass)	23

contd.

Appendix Table A.1.5 / Mapping from fDI Markets cross-border investment monitor to NACE Rev. 2 industries (contd.)

Sector	Sub-sector	NACE Rev. 2 correspondence
Chemicals	Basic chemicals	20
	Other chemical products & preparation	20
	Paints, coatings, additives & adhesives	20
	Pesticide, fertilisers & other agricultural chemicals	20
	Resin & artificial synthetic fibres & filaments	20
	Soap, cleaning compounds, & toilet preparation	20
Communications	Communications equipment	29
	Navigational instruments	26
Consumer Electronics	Audio & video equipment	26
	Household appliances	27
	Other (Consumer Electronics)	26
Consumer Products	Audio & video equipment	26
	Cosmetics, perfume, personal care & household products	20
	Cutlery & handtools	28
	Dolls, toy, & games	32
	Furniture, homeware & related products (Consumer Products)	31
	Jewellery & silverware	32
	Office supplies	47
	Other (Consumer Products)	n.a.
	Pesticide, fertilisers & other agricultural chemicals	20
	Sign manufacturing	25
	Sporting goods, hobby, books & music	n.a.
Electronic Components	Aircraft engines, other parts & auxiliary equipment	30
	All other electrical equipment & components	26
	Audio & video equipment	26
	Batteries	27
	Communication & energy wires & cables	27
	Computer & peripheral equipment	26
	Electric lighting equipment	27
	Electrical equipment	27
	Magnetic & optical media	26
	Wiring devices	27
Engines & Turbines	Engines & Turbines	28
	Other (Engines & Turbines)	28
Food & Tobacco	All other food	10
	Animal food	10
	Coffee & tea	10
	Dairy products	10
	Fruits & vegetables & specialist foods	10
	Seafood products	10
	Seasoning & dressing	10
	Snack food	10
	Sugar & confectionary products	10
	Tobacco	12
	Bakeries & tortillas	10

contd.

Appendix Table A.1.5 / Mapping from fDI Markets cross-border investment monitor to NACE Rev. 2 industries (contd.)

Sector	Sub-sector	NACE Rev. 2 correspondence
Industrial Machinery, Equipm. & Tools	Agriculture, construction, & mining machinery	28
	All other industrial machinery	28
	Boiler, tank, & shipping container	28
	Commercial & service industry machinery	28
	Cutlery & handtools	28
	Food product machinery	28
	General purpose machinery	28
	Measuring & control instruments	27
	Metalworking machinery	28
	Paper industry machinery	28
	Plastics & rubber industry machinery	28
	Power transmission equipment	28
	Printing machinery & equipment	28
	Sawmill & woodworking machinery	28
	Semiconductor machinery	28
	Semiconductors & other electronic components	26
	Textile machinery	28
	Ventilation, heating, air conditioning, and commercial refrigeration eq. manuf.	28
Medical Devices	Electromedical and Electrotherapeutic Apparatus	26
	Medical equipment & supplies	26
	Other (Medical Devices)	26
Minerals	Lime & gypsum products	23
	Other (Minerals)	23
	Other non-metallic mineral products	23
Metals	Alumina & aluminium production and processing	24
	Architectural & structured metals	24
	Coating, engraving, heat treating, & allied activities	25
	Forging & stamping	25
	Foundries	24
	Hardware	25
	Iron & steel mills & ferroalloy	24
	Machine shops, turned products, screws, nuts & bolts	25
	Nonferrous metal production & processing	24
	Other (Metals)	24
	Other fabricated metal products	25
	Other non-metallic mineral products	23
	Spring & wire products	25
	Steel products	24
Non-Automotive Transport OEM	All other transportation (Non-Automotive OEM)	30
	Motorcycle, bicycle, & parts	29
	Motorcyle, bicycle, & parts	29
	Railroad rolling stock	30
	Ships & boats	30
Paper, Printing & Packaging	Converted paper products	17
	Other (Paper, Printing & Packaging)	17
	Plastic bottles	22
	Pulp, paper, & paperboard	17
Pharmaceuticals	Medicinal & botanical	21
	Other (Pharmaceuticals)	21
	Pharmaceutical preparations	21
	Unspecified	21
Plastics	Artificial & synthetic fibres	22
	Laminated plastics plates, sheets & shapes	22
	Other plastics products	22
	Plastic bottles	22
	Plastic pipes, pipe fitting & unlaminated profile shapes	22
	Plastics packaging materials & unlaminated film & sheets	22
	Polystyrene foam products	22
	Urethane, foam products & other compounds	22

contd.

Appendix Table A.1.5 / Mapping from fDI Markets cross-border investment monitor to NACE Rev. 2 industries (contd.)

Sector	Sub-sector	NACE Rev. 2 correspondence
Rubber	Other rubber products	22
	Rubber hoses & belting	22
	Tyres	22
Semiconductors	Other (Semiconductors)	26
	Semiconductor machinery	28
	Semiconductors & other electronic components	26
Software & IT services	All other information services	63
	Business support services	82
Space & Defence	Guided missile & space vehicles	30
	Military armoured vehicle, tank, & components	30
	Other (Space & Defence)	30
Textiles	Apparel accessories & other apparel	13
	Apparel knitting	13
	Clothing & clothing accessories	14
	Cut & sew apparel	14
	Footwear	15
	Furniture, homeware & related products (Textiles)	31
	Leather & hide tanning and finishing	15
	Other (Textiles)	13
	Other leather & allied products	15
	Resin & artificial synthetic fibres & filaments	20
	Textiles & Textile Mills	13
Transportation	Freight/Distribution Services	49
	Truck transportation	49
Warehousing & Storage	Warehousing & storage	52
Wood Products	Furniture, homeware & related products (Consumer Products)	31
	Furniture, homeware & related products (Wood Products)	31
	Other (Wood Products)	16
	Wood products	16

APPENDIX 2: ADDITIONAL RESULTS ON RELATIVE FUNCTIONAL SPECIALISATIONS

Appendix Table A.2.1 / FDI-based normalised relative functional specialisation across value chain functions, EU, 2003-2021

Country	Headquarter	R&D	Fabrication	Business services	Technical support	*Functional differentiation*
AT	**0.30**	**0.25**	-0.01	-0.12	-0.28	*0.96*
BE	**0.09**	-0.05	-0.07	**0.09**	-0.12	*0.42*
BG	-0.86	-0.15	**0.17**	-0.22	-0.05	*1.46*
CY	**0.27**	-0.83	-0.30	**0.30**	-1.00	*2.70*
CZ	-0.76	-0.29	**0.23**	-0.39	-0.21	*1.88*
DE	**0.28**	**0.06**	-0.11	**0.05**	**0.12**	*0.61*
DK	**0.44**	**0.31**	-0.37	**0.10**	**0.31**	*1.53*
ES	**0.14**	**0.13**	-0.13	**0.09**	**0.00**	*0.49*
EE	-0.49	-0.09	**0.11**	-0.12	**0.01**	*0.81*
FI	**0.01**	**0.23**	-0.22	**0.15**	-0.01	*0.62*
FR	-0.04	**0.03**	-0.16	**0.16**	-0.01	*0.41*
UK	**0.23**	**0.17**	-0.25	**0.15**	**0.10**	*0.90*
EL	-0.24	**0.18**	-0.70	**0.36**	-0.16	*1.64*
HR	-0.63	-0.15	**0.01**	**0.09**	-0.36	*1.24*
HU	-0.80	-0.40	**0.23**	-0.37	-0.04	*1.86*
IE	**0.53**	**0.29**	-0.35	**0.07**	**0.15**	*1.39*
IT	-0.14	**0.10**	-0.10	**0.12**	-0.25	*0.71*
LT	-0.74	**0.26**	**0.01**	-0.11	**0.37**	*1.50*
LU	**0.40**	-0.20	-0.36	**0.24**	**0.04**	*1.25*
LV	-0.69	-0.38	**0.05**	**0.06**	-0.06	*1.23*
MT	-0.16	-0.25	-0.10	-0.11	**0.75**	*1.37*
NL	**0.56**	-0.01	-0.50	**0.21**	**0.09**	*1.37*
PL	-0.67	-0.33	**0.10**	-0.02	-0.10	*1.21*
PT	-0.58	**0.15**	-0.11	**0.12**	**0.04**	*1.01*
RO	-0.56	-0.05	**0.18**	-0.31	0.00	*1.11*
SK	-0.82	-0.42	**0.26**	-0.46	-0.39	*2.35*
SI	-0.42	-0.21	**0.18**	-0.27	**0.04**	*1.11*
SE	**0.00**	**0.23**	-0.15	**0.09**	-0.02	*0.50*

Note: Bold numbers indicate normRFS>0; functional differentiation is the sum of the absolute values of the deviations of each function from 0. A country which has exactly the functional profile of the EU would have a value of 0.
Source: fDi Markets; authors' own calculations

Appendix Table A.2.2 / Trade-based normalised relative functional specialisation across value chain functions, EU, 2000-2014

Country	Management	R&D	Fabrication	Marketing	*Functional differentiation*
AT	-0.03	**0.04**	-0.01	**0.00**	*0.08*
BE	**0.16**	**0.05**	-0.15	**0.02**	*0.38*
BG	-0.02	-0.11	**0.10**	-0.06	*0.29*
CY	-0.09	-0.27	-0.32	**0.27**	*0.95*
CZ	-0.12	**0.06**	**0.10**	-0.09	*0.36*
DE	-0.06	**0.17**	-0.05	-0.02	*0.30*
DK	-0.09	**0.14**	-0.08	**0.04**	*0.35*
ES	**0.05**	-0.04	-0.01	**0.00**	*0.10*
EE	**0.20**	-0.15	**0.06**	-0.12	*0.53*
FI	**0.05**	**0.19**	-0.01	-0.13	*0.37*
FR	**0.09**	**0.21**	-0.11	-0.06	*0.47*
UK	**0.30**	**0.01**	-0.23	-0.02	*0.55*
EL	**0.11**	-0.13	-0.07	**0.06**	*0.37*
HR	-0.18	**0.07**	-0.01	**0.04**	*0.31*
HU	-0.11	**0.00**	**0.08**	-0.04	*0.24*
IE	**0.31**	-0.05	-0.21	-0.01	*0.58*
IT	-0.06	-0.04	-0.02	**0.06**	*0.17*
LT	**0.10**	-0.25	**0.14**	-0.12	*0.61*
LU	-0.11	-0.07	-0.40	**0.26**	*0.84*
LV	**0.11**	-0.15	**0.03**	-0.02	*0.31*
MT	**0.16**	-0.07	-0.12	**0.05**	*0.39*
NL	**0.09**	**0.07**	-0.19	**0.08**	*0.42*
PL	-0.02	-0.12	**0.13**	-0.09	*0.36*
PT	**0.11**	-0.15	**0.01**	-0.01	*0.28*
RO	-0.34	**0.02**	**0.16**	-0.09	*0.61*
SK	-0.06	-0.05	**0.09**	-0.05	*0.25*
SI	**0.04**	**0.06**	**0.05**	-0.10	*0.25*
SE	-0.15	**0.13**	-0.05	**0.04**	*0.36*

Note: Bold numbers indicate normFS>0; functional differentiation is the sum of the absolute values of the deviations of each function from 0. A country which has exactly the functional profile of the EU would have a value of 0.
Source: WIOD database; authors' own calculations.

Appendix Table A.2.3 / FDI-based relative functional specialisation across value-chain functions, EU, 2003-2021

Country		All functions	Headquarter	R&D	Fabrication	Business services	Technical support	*Function differentiation*
AT	RFS		**1.8573**	1.6644	0.9788	0.7837	0.5644	*1.41*
	#jobs	70,783	6,639	10,137	33,337	19,292	1,378	
BE	RFS		**1.2012**	0.9107	0.8655	1.2007	0.7819	*0.15*
	#jobs	129,211	7,838	10,125	53,809	53,954	3,485	
BG	RFS		0.0741	0.7342	**1.4143**	0.6372	0.8969	*1.24*
	#jobs	129,931	486	8,208	88,422	28,795	4,020	
CY	RFS		1.7321	0.0924	0.5407	**1.8529**		*3.30*
	#jobs	3,144	275	25	818	2,026		
CZ	RFS		0.1336	0.5509	**1.6009**	0.4396	0.6565	*1.75*
	#jobs	257,184	1,735	12,191	198,111	39,323	5,824	
DE	RFS		**1.7867**	1.1175	0.8043	1.1002	1.2738	*0.76*
	#jobs	354,458	31,982	34,082	137,187	135,632	15,575	
DK	RFS		**2.567**	1.8875	0.455	1.217	1.9078	*4.41*
	#jobs	28,157	3,650	4,573	6,164	11,917	1,853	
ES	RFS		**1.3368**	1.3049	0.7744	1.1871	1.0067	*0.29*
	#jobs	360,587	24,342	40,487	134,368	148,868	12,522	
EE	RFS		0.3462	0.8418	**1.2528**	0.783	1.0124	*0.56*
	#jobs	23,567	412	1,707	14,207	6,418	823	
FI	RFS		1.0102	**1.6127**	0.6429	1.3439	0.9706	*0.62*
	#jobs	36,559	1,865	5,073	11,310	17,087	1,224	
FR	RFS		0.9187	1.0708	0.7173	**1.3865**	0.9898	*0.24*
	#jobs	328,794	15,254	30,294	113,476	158,544	11,226	
UK	RFS		**1.6003**	1.4183	0.6007	1.3394	1.226	*0.86*
	#jobs	648,846	52,436	79,181	187,538	302,251	27,440	
EL	RFS		0.6191	1.4503	0.1737	**2.1142**	0.7265	*2.35*
	#jobs	15,802	494	1,972	1,321	11,619	396	
HR	RFS		0.2297	0.7464	1.0147	**1.2072**	0.4665	*0.99*
	#jobs	20,694	240	1,329	10,104	8,688	333	
HU	RFS		0.109	0.4239	**1.5967**	0.4548	0.9145	*1.79*
	#jobs	306,528	1,688	11,181	235,507	48,483	9,669	
IE	RFS		**3.2475**	1.8297	0.4868	1.1432	1.3557	*6.15*
	#jobs	182,340	29,903	28,707	42,709	72,494	8,527	
IT	RFS		0.7576	1.2188	0.8119	1.2806	0.6042	*0.38*
	#jobs	110,932	4,244	11,634	43,337	49,405	2,312	
LT	RFS		0.1463	1.6984	1.0238	0.8005	**2.1874**	*2.67*
	#jobs	51,302	379	7,497	25,273	14,282	3,871	
LU	RFS		**2.3330**	0.6609	0.4678	1.6179	1.0886	*2.56*
	#jobs	8,335	982	474	1,876	4,690	313	
LV	RFS		0.1842	0.4533	1.1056	**1.1189**	0.8862	*1.00*
	#jobs	19,562	182	763	10,407	7,612	598	
MT	RFS		0.7202	0.5996	0.8152	0.8056	**6.9468**	*35.67*
	#jobs	7,424	270	383	2,912	2,080	1,779	
NL	RFS		**3.5225**	0.9823	0.335	1.5388	1.196	*7.13*
	#jobs	144,196	25,650	12,188	23,241	77,168	5,949	
PL	RFS		0.2012	0.5047	**1.2135**	0.9614	0.8159	*0.96*
	#jobs	595,162	6,048	25,846	347,522	198,995	16,751	
PT	RFS		0.2653	**1.366**	0.8009	1.2823	1.0933	*0.80*
	#jobs	69,869	936	8,212	26,927	31,159	2,635	
RO	RFS		0.2798	0.9021	1.435	0.5276	0.9931	*0.94*
	#jobs	315,521	4,458	24,491	217,871	57,892	10,809	
SK	RFS		0.0964	0.4103	**1.6958**	0.3700	0.4393	*2.36*
	#jobs	193,931	944	6,846	158,247	24,955	2,939	
SI	RFS		0.4116	0.6495	**1.4275**	0.573	1.0779	*0.84*
	#jobs	16,837	350	941	11,565	3,355	626	
SE	RFS		1.005	**1.6124**	0.743	1.2078	0.9543	*0.49*
	#jobs	49,395	2,507	6,853	17,660	20,749	1,626	

Note: Functional differentiation is the sum of squared deviations of each function from 1, that is, $\sum_f (RFS_f - 1)^2$. A country which has exactly the functional profile of the EU would have a value of 0.
Source: fDi Markets; authors' own calculations.

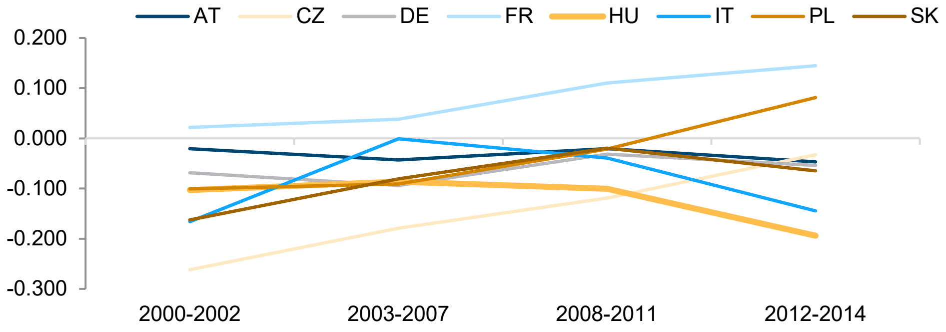
Appendix Table A.2.4 / Deviations of industry-level trade-based RFS from economy-wide specialisations (2000-2014)

Country	Chemicals	Electrical equipment	Machinery	Pharmaceuticals	Vehicles
AT	0.11	0.19	0.14	0.01	0.02
BE	0.36	0.26	0.35	0.44	0.06
BG	0.39	0.08	0.37	0.71	1.70
CY	2.69	2.77	2.44	0.62	3.12
CZ	0.14	0.38	0.20	0.18	0.60
DE	0.11	0.29	0.45	0.07	0.65
DK	0.30	0.36	0.00	0.87	2.34
ES	0.01	0.07	0.26	0.12	0.24
EE	0.52	0.07	0.73	2.11	1.03
FI	0.12	0.02	0.30	0.65	1.70
FR	0.08	0.02	0.01	0.14	0.04
UK	0.02	0.23	0.06	0.23	0.11
EL	0.39	0.63	2.22	0.04	3.93
HR	0.18	0.09	1.11	0.11	2.51
HU	0.25	0.10	0.12	0.32	0.19
IE	0.49	1.85	1.44	1.18	3.22
IT	0.04	0.11	0.66	0.31	0.00
LT	0.28	0.72	1.29	1.51	1.79
LU	2.61	2.11	2.21	1.01	3.38
LV	0.97	0.47	1.33	0.04	2.37
MT	2.37	0.30	0.24	0.20	3.41
NL	0.11	0.70	0.05	0.05	1.40
PL	0.13	0.10	0.07	0.45	0.09
PT	0.38	0.08	0.90	1.09	0.04
RO	0.29	0.15	0.19	1.97	0.08
SK	0.71	0.05	0.06	1.19	0.51
SI	0.03	0.59	0.02	1.34	0.02
SE	0.38	0.02	0.09	0.19	0.12

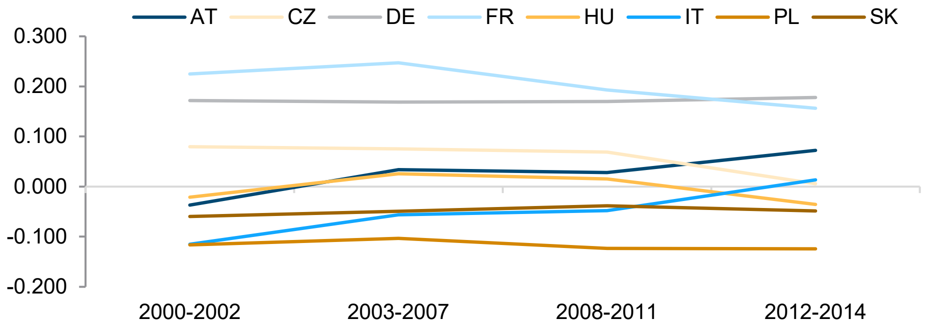
Note: Deviations calculated as sums of squared differences between industry-level and country-level RFS values of each value chain function. The darker the colour of the field, the greater the deviation of industry-level results from the country-level values.
Source: WIOD2016; authors' own calculations.

Appendix Figure A.2.1 / Trade-based functional specialisation over time, selected countries

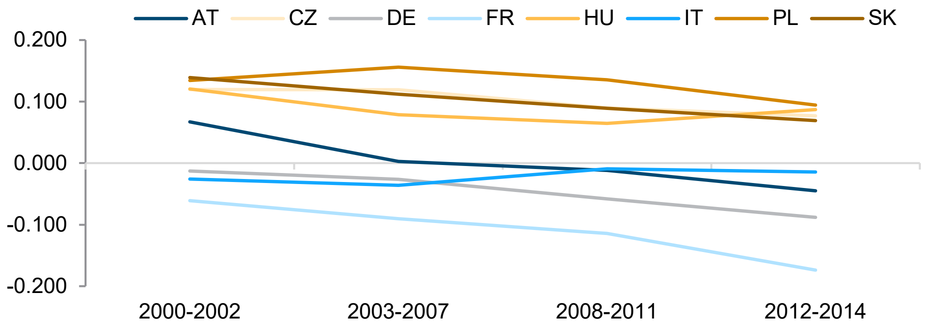
(a) Management



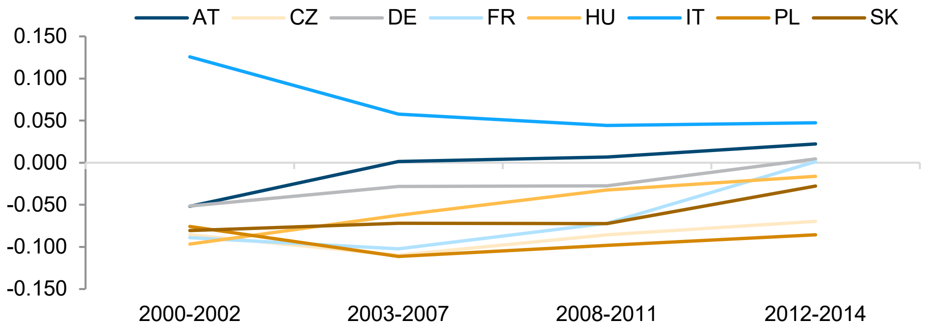
(b) R&D



(c) Fabrication



(d) Marketing



Source: WIOD 2016, authors' own calculations.

APPENDIX 3: CLUSTER ANALYSIS METHODOLOGY

The **K-means** method belongs to centroid-based clustering methods, i.e., each cluster is represented by its centre (centroid), which corresponds to the mean of points assigned to the clusters. This method assumes that the number of clusters is already known. The basic idea behind k-means clustering consists of defining clusters so that on each step of the clustering process the total intra-cluster variation (known as a total within-cluster variation) is minimised. There are several k-means algorithms available. However, the standard algorithm defines the total within-cluster variation as the sum of squared distances (Euclidean distances) between items and the corresponding centroid.

K-means clustering steps are as follows (Pérez-Ortega et al 2019):

1. Specify *k* – the number of clusters to be created.

2. Select randomly *k* objects from the dataset as the initial cluster centers.

3. Assign each object to its closest centroid, based on the Euclidean distance between the object and the centroid (the mean of points assigned to the clusters).

4. For each of the *k* clusters recompute the cluster centroid by calculating the new mean value of all the data points in the cluster.

5. Iteratively minimise the total within variation. Repeat Step 3 and Step 4 until the centroids do not change or the maximum number of iterations is reached.

The total within-cluster variation is defined as:

(1) $$\sum_{k=1}^{k} W(C_k) = \sum_{k=1}^{k} (x_i - u_k)^2$$

where:

› x_i is a data point belonging to the cluster

› u_k is the mean value of the points assigned to the cluster

The number of clusters (k) is the most important parameter in k-means clustering. If we do not know the optimal value of k, there are several methods to find the optimal/best value of k. The most popular are two: the elbow method and the silhouette method. The latter method is considered the most effective, so we use it in our clustering process (Jayashree and Shivaprakash, 2022).

In a silhouette method the silhouette coefficient is calculated, which measures how similar an object is to its own cluster (cohesion) compared with other clusters (separation). Calculating the silhouette coefficients for each point and averaging them for all samples, we obtain the silhouette score.

Steps to determine the silhouette coefficient (Si) of an *i*-th point:

› Calculate a(i): the average distance of this point to all other points in the same clusters.

› Calculate b(i): the average distance of this point to all points in the closest cluster to its cluster.

› Calculate s(i) - the silhouette coefficient of the *i*-th point using the formula below.

(2) $$S(i) = \frac{b(i) - a(i)}{\max\{a(i), b(i)\}}$$

The silhouette score ranges between [1, -1], where a high value indicates that the object is a good fit to its own cluster and a poor fit to neighboring clusters. If most objects have a high value, the cluster configuration is appropriate. If many points have a low or negative value, then the cluster configuration may have too many or too few clusters. The optimal number of clusters (k) belongs to this clustering result with the highest silhouette score.

Ward's method is an alternative method of clustering (hierarchical clustering) to the k-means method. The Ward method uses analysis of variance to estimate the distance between clusters. The goal of the Ward method is to minimise the total variance within clusters. At each step, the pair of clusters with the smallest distance between them is merged.

Ward's method starts with *n* clusters, i.e. all clusters are singletons (clusters containing a single point). These *n* clusters are combined to make one cluster containing all objects. At each step find the pair of clusters that leads to a minimum increase in total within-cluster variance (E) after merging.

The following calculations are made to find *E:* (1) find the mean of each cluster; (2) calculate the distance between each object in a particular cluster, and that cluster's mean; (3) square the differences from Step 2; (4) sum (add up) the squared values from Step 3; (5) add up all the sums of squares from Step 4 (Murtagh and Legendre, 2014).

In Ward's method, to merge all objects into the clusters the following steps are needed (Mongi et al. 2019):

Step 1: Starts with *n* clusters i.e., all clusters are singletons

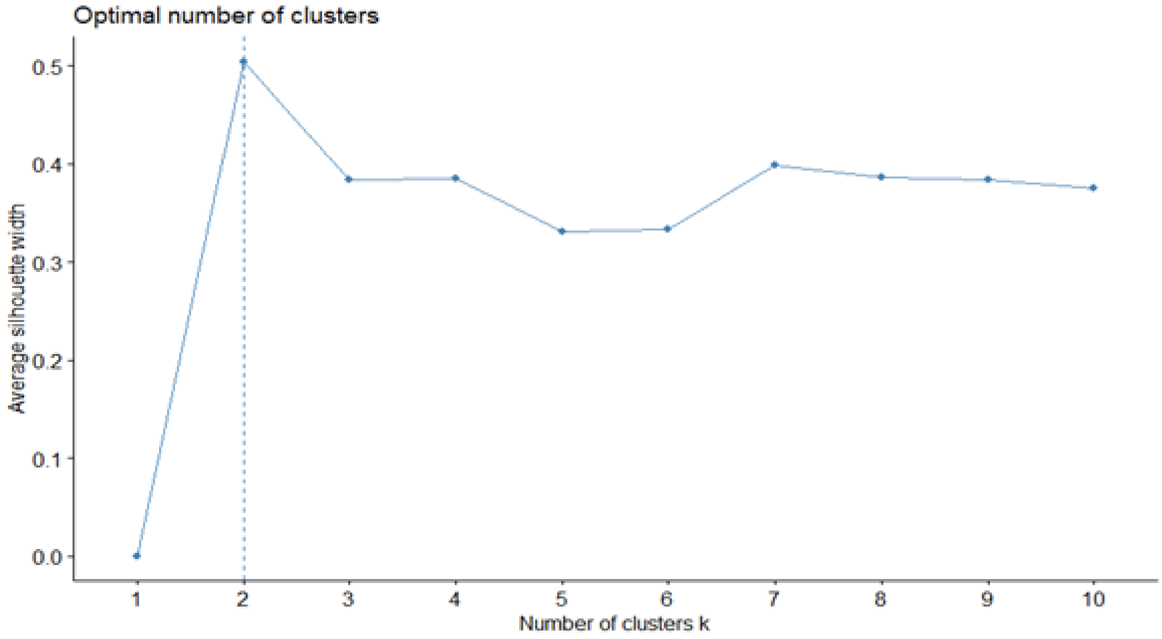
Step 2: Calculate the E index for each cluster

Step 3: Merge two clusters with the lowest sum of E index

Step 4. Repeat steps 2 and 3

This method works very well in practice, which means that the clusters created are very homogeneous on the one hand, and it tends to create clusters of similar and small sizes, on the other.

Appendix Figure A.3.1 / Optimal number of clusters - silhouette method (FDI greenfield investments, three value chain functions, 2003-2021)



Appendix Table A.3.1 / One-way ANOVA for three business functions (FDI-based RFS 2003-2021)

	Pre-fabrication	Fabrication	Post-fabrication
SSBG	15.1301	19.1818	14.257
sum-of-squares between groups			
SSWG	11.8699	7.8182	12.743
sum-of-squares within groups			
df between groups	1	1	1
df between groups	26	26	26
F-statistics	33.1414	63.7903	29.0893
p-value	0.0000	0.0000	0.0000

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