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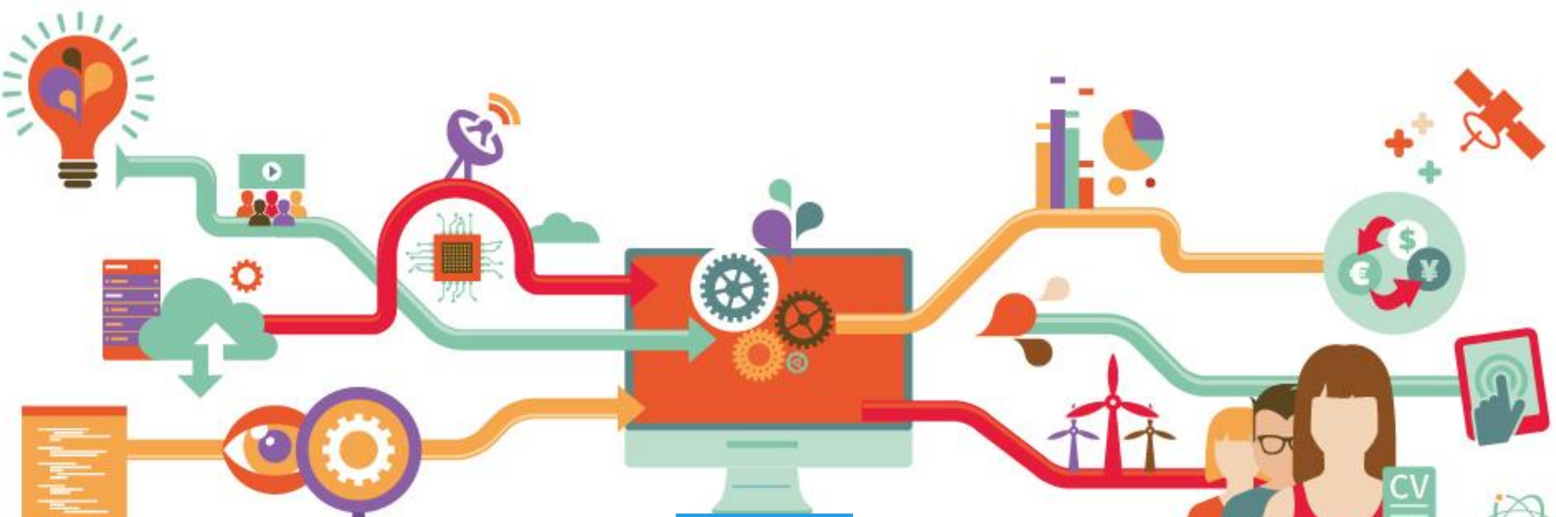

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Organization and geography of global R&D and innovation activities: insights from qualitative research on leading corporate R&D investors[1]

Mafini DOSSO[2] and Paulina RAMIREZ[3]

Abstract

This study examines the on-going structural changes in the international organisation of corporate R&D and innovative (RDI) activities. Insights are mainly drawn from interviews made to innovation representatives and managers of large R&D-investing companies in 2017 in the frame of the European Commission's project – Industrial Research and Innovation Monitoring and Analysis –. The research intends to complement the quantitative evidence available in the project on the worldwide leading corporate R&D investors in order to better characterize the on-going fragmentation of R&D and innovation activities. The study suggests directions for mapping innovation value chains beyond research and inventive activities and carries out important conceptual and policy implications for the configurations and sustainability of innovation systems in Europe.

Keywords: R&D and innovation value chains, MNEs, top R&D investors, interviews, qualitative research

JEL codes: O32, L22

[1] This Working Paper is issued in the context of the GLObal Research and Investment Analysis (GLORIA) activities that are jointly carried out by the European Commission's Joint Research Centre (JRC) – Directorate B, Growth and Innovation and the Directorate General Research and Innovation - Directorate A, Policy Development and Coordination.

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1. Introduction

The developments in the international R&D and innovative (RDI) activities of leading multinational firms (MNEs) over the past 30 years indicate on-going processes of both organisational and geographical reconfigurations of their R&D and innovation functions. These changes have resulted into a variety of geographically dispersed inter and intra-firm global innovation networks (GINs)[4]. These processes of organisational and geographical reconfiguration result from the complex and dynamic interplay of factors such as technological change, the strategies and organisational forms adopted by firms, developments in innovation systems as well as developments in international trade and investment frameworks.

The concept of GINs is associated with changes in the organisational form of the MNE, which have also influenced the organisation and location of MNEs R&D&I activities. Much of the literature on MNEs since the 1980s (Dicken, 1992; Gereffi, 1994; Dunning, 1993, 1995) has identified that MNEs have been breaking up their value adding activities to form global value chains[5] and global production networks. Yet, while they have focused on the production, there are indications that this is also affecting the organisation of RDI activities. Such changes have been labelled as the functional deepening, whereby global sourcing extends to more upstream and knowledge-intensive activities (De Backer, 2016; European Commission, 2014; De Backer et al, 2013). This is also consistent with the processes of fragmentation and outsourcing of tasks in high-value activities such as R&D and design (Ernst, 2009; Contractor et al, 2010). Acknowledging such trends, this paper contributes to a better understanding of the fragmentation of R&D and innovation activities and of the models through which MNEs distribute them across global networks of actors and places in order to create and bring innovations into the market. It brings complementary evidence on issues such as – what are the new trends in the geographical and functional organisation of R&D and innovation processes, activities or tasks? What novels conceptual or analytical frameworks and data are needed to capture and monitor these novels trends? Which models of innovation value chains and related networks are emerging with the new geography of innovation? – .

This study uses a combination of quantitative and qualitative data to examine the organisational fragmentation and geographical location of the R&D and innovation processes in MNEs. We do this in order to bring forward new directions for data collection on the geographical fragmentation and vertical disintegration of the RDI processes. To this end, the analysis exploits project level on data foreign direct investments (FDI) to analyse the international location of specific activities and a set of case studies and interviews of MNEs belonging to the *EU Industrial R&D Investment*

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[4] From now on, we use the term GIN to refer to internationally dispersed inter and intra-firm R&D and innovation networks (see also Ramirez 2018 for a literature review on Global Innovation Networks).

5 The concept of (global) value chains refers to the increasing geographical fragmentation (at worldwide scale) of the full range of activities that firms engage in to bring a product to the market, from conception to final use (i.e. including design, production, marketing, logistics, distribution and support to customers) (See OECD 2013, Gereffi et al 2005).

Scoreboard[6]. The EU Scoreboard ranks the world's top 2500 corporate R&D investors on a yearly basis.

The quantitative application exploits project level data on cross-borders Greenfield fDi Markets database of Financial Times[7]. This dataset has several advantages such as the availability of finer-grained data on the business activity actually undertaken by the investing firms in the destination country. The analysis focuses on Greenfield FDI activities that have been explicitly link to technology-related projects, i.e. Research & Development (R&D) and Development, Design and Testing (DDT) (The Global Innovation Index report, GII, 2016)[8]. Moreover, it includes Maintenance and Servicing and Education and Training industry activities. This allows accounting for those innovation capabilities which relate for instance to "daily" learning by doing activities or to improvements in absorptive capabilities through education and training.

The qualitative approach relies on both structured and semi-structured interviews in order to obtain more evidence on the organisational and geographical fragmentation of R&D and innovation processes. The structured interviews to companies' R&D managers were subcontracted to the consortium IDEA consult/VDI in the frame of the GLORIA project[9] and were conducted in 2017. They included more than 60 interviews with 10 MNEs (6 each) operating in the pharmaceuticals, automotive, aerospace and ICT sectors. The findings from the structured interviews were complemented by a set of more detailed semi-structured interviews conducted by the authors. The aim was to better explore the existence and nature of a small sample of corporate GIN and to suggest novel directions for complementary data collection and analysis at the company level.

The remainder of the report is organised as follows. Section 2 presents an overview of the literature with an emphasis of the structural changes in the organisation of RDI processes. Section 3 presents the mix of methodology employed to gain insights on the new trends. It then introduces the notion of Technology Readiness Levels tool (TRLs) and discusses the links with innovation value chains. Section 4 presents the results and provides detailed insights from semi-structured pilot interviews. Section 5 concludes and opens further data and policy perspectives for the EU territorial innovation policy.

2. Structural changes in the international organisation of corporate R&D and innovation activities

The literature on the internationalization of corporate RDI has greatly improved our knowledge about the geographical dispersion of knowledge generation and sourcing (e.g. Iammarino and McCann 2013; Dachs et al 2014; Moncada-Paterno-Castello et al

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[6] The *EU Industrial R&D Investment Scoreboard* provides economic and financial data and analysis of the top corporate R&D investors from the EU and from abroad. It is based on company data extracted directly from each company's Annual Report. The Scoreboard is published annually in order to provide a reliable, up-to-date benchmarking tool for comparisons between companies, sectors, and geographical areas, as well as to monitor and analyse emerging investment trends and patterns. See the annual editions at https://iri.jrc.ec.europa.eu/rd_monitoring

[7] Details about the fDi Markets database can be found at https://www.fdimarkets.com

[8] The GII is produced by the WIPO, Cornell University and INSEAD. The various editions are available at http://www.wipo.int/publications/fr/

[9] Former IRIMA project, see at https://iri.jrc.ec.europa.eu/home/

2011; OECD 2008; Daiko et al 2017; Dernis et al 2019, 2015). These works underline the role of MNEs as the main carriers of the international knowledge sourcing, IP transactions, mergers and acquisitions, foreign investments, research collaborations and contracting-out. These strategic behaviors often result from the need to adapt products and processes to host country conditions. The main rationales are to support corporate expansions abroad and the creation of new technologies by tapping into foreign RDI capabilities; in other words, MNEs undertake both exploration- and exploitation-oriented international RDI activities (Ritala et al, 2017).

In terms of geography, the EU, Japan and the US remain top locations, but emerging or non-traditional places are gradually climbing up the location hierarchy, for instance in Asia, especially in China and India (UNCTAD 2005; Thursby and Thursby 2006; Athreye and Cantwell 2007; D'Agostino et al 2013). Moreover, recent evidence at the city-region level indicate that this phenomenon also features a strong local or regional concentration (Belderbos et al 2016). These trends in the geo-organisational patterns of corporate RDI have been associated with the interplay of a complex set of factors which relate to the firm – investments, skills, know-how, organizational competences, knowledge capital, networks – , the industry – R&D intensity, scale economies, differentiation – and the home and host countries – market size, labour market, tax and regulatory environment, IPR system, scientific, technological and human resources, ICT infrastructure, support to R&D activities– (Hall, 2011).

Recent microeconomic datasets provide better descriptions of the distinct and or later stages of the global innovation value chains (GIVC), which are hardly measurable (solely) through patent counts. For instance, relevant information can extracted from industrial designs documents. *"Industrial designs refer to the visual features of shape, configuration, pattern or ornament, or any combination of these features, applied to a finished article. It involves the creative concepts, ideas, or products to create something which did not exist in the past … and covers a wide range of aspects for function, aesthetic appeal, manufacturing, sustainability or even for reliability or quality (DTI, 2005)"* (Kang, 2015, page 7-8). Designs can play an important role in new product development together with R&D, manufacturing, commercialization and marketing activities and affect economic growth and business performance. They are considered to be an element of innovation and an outcome of creative activities, also at the policy level.[10]

Design activities refer to plans and drawings targeting the planning and definition of procedures, technical specifications and operational characteristics required for the conception, development and manufacturing of new products and processes included in R&D activities (OECD 2015). They can entail significant variations in the functional characteristics or intended uses of the products. Many innovative firms consider design to be a part of the R&D processes, also labelled RD&D (DTI, 2005). The figures in Box 1 below suggest that, besides international inventive activities, large innovative firms also undertake global collaborations for their design activities. They also often combine industrial design protection with trademark and patent ones (see for instance Figure 4.9, page 51, Daiko et al, 2017).

[10] See also the emphasis of the EU policy agenda on Designs for innovation: https://ec.europa.eu/growth/industry/innovation/policy/design_en

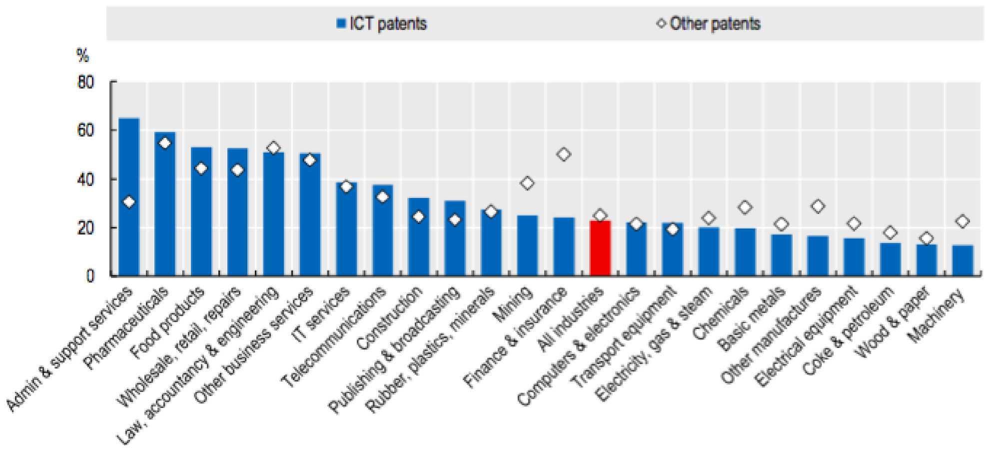
Box 1. Evidence on top corporate R&D investors' patents (GLORIA Project)

The increase in worldwide patenting has come with a multiplication of international co-invention activities, mainly led by MNEs. Since the mid-nineties, the number of co-inventions has been multiplied by more than five, reaching now more than 12,000 patents in 2013. More than than half of these co-patenting activities relate to MNEs, reflecting the global scope of their innovation networks (OECD 2017, PCT patents).

Three joint JRC-OECD reports on the world top R&D-investing firms confirm that these general trends hide important differences not only between industries, but also across technologies (Daiko et al 2017, Dernis et al 2015). The statistics suggest that such MNEs often resort to international knowledge sourcing and they do so depending on whether ICT or non-ICT-related technological developments are targeted.

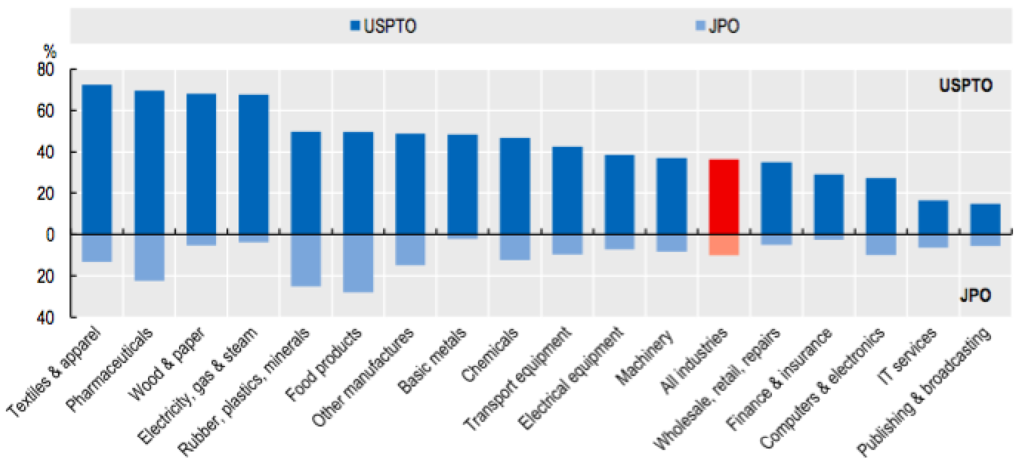
Figure 1. Top R&D investors' patents based on inventions made abroad

IP5 Patents with international teams of inventors 2012-14 – SB companies



Companies also rely on international knowledge pools for their creative activities as proxy by their industrial designs (Figure 2, Daiko et al 2017). Figure 2 suggests that such strategies would differ greatly across industries and depending on the international market of interest (in the report, this corresponds to the target intellectual property office).

Figure 2. Industrial designs with international teams of designers 2012-14



Source. Daiko et al, 2017, JRC-OECD report

The geographical extension of corporate intra-firm R&D and innovation networks has taken place at the same time as international inter-firm R&D networks between MNCs and innovative firms. At the same time, public and private sector research organisations have continued to grow (Hagedoorn and Schakenraad, 1990; Hagedoorn, 1993, 1995, 2002; Dunning, 1997; 2003; Zanfei, 2000; Saliola and Zanfei, 2009; Nieto and Rodriguez, 2011; Narula and Martínez-Noya, 2015; Martnez-Noya and Narula, 2018). A more recent trend is the process of fragmentation and 'outsourcing' of R&D activities and tasks to independently-owned, internationally dispersed contract research organisations (CROs) (Ernst, 2009; Massini and Miozzo, 2010; Howells, 1998; Contractor et al, 2010). Amongst the factors explaining the changes in the organisational architecture of GINs therefore are the processes of fragmentation and vertical disaggregation of the RDI process giving rise to technological alliances and networks. These latter ones are also more recently driven by the increasing adoption of 'open innovation' strategies (Chesbrough, 2006, Enkel et al, 2009, Mol, 2005), the 'fine-splicing' and outsourcing of high-value activities to independently-owned, geographically dispersed, contract research organisations (CROs) and research and technology organisations (RTOs) (Contractor et al, 2010; Massini and Miozzo, 2012).

Through these GINs, companies relate different functional internal groups and link to their external collaborators at a global scale (Liu et al, 2013; Ramirez, 2018 for a literature review on GINs). These networks are made up of different mixes of formal and informal relationships. They are typically asymmetric and hierarchical and their organisation is dominated by a few large MNEs (Ernst 2009). Their global reach differs across industries depending on the characteristics of the knowledge bases and the need for co-locality[11] for innovation creation. The picture that emerges from the developments in the last decade is that of the increasing organisational fragmentation and geographical dispersal of RDI 'value-chains' and networks. These value chains and networks are increasingly complex and mobile with patterns of location characterised by concentrated dispersion (Ernst and Kim, 2002). What these works also put forward is that the development of GINs is driven by relentless splicing and dicing of engineering, development and research (Ernst 2009). "*An increasing vertical specialisation ("fragmentation") of knowledge production has given rise to GINs that integrate dispersed engineering, product development, and research activities across firm boundaries and geographic borders*" (Ernst, 2007).

More research is thus needed to better understand what are the different forms of GINs in which firms participate both in terms of the various degrees of *globalness*, *innovativeness and networkedness* (Barnard and Chaminade, 2011). The implications of these trends for the knowledge-base and competitive position of European regions are as yet not well understood. Nevertheless a number of studies have pointed to the potential benefits of increased internationalisation in terms of the increasing productivity of firms and reverse knowledge flows (Criscuolo, 2009; Castellani and Pieri, 2013; and more cautiously Castellani and Pieri, 2016). Moreover, the link between the organisational and geographical configuration of GINs and the organisation and location of other value-chain activities (for example manufacturing) is an under-investigated topic (OECD, 2016).

[11] See the works on the co-location of R&D and manufacturing activities, for instance, European Commission (2014), Ramirez (2014), Buciuni and Finotto (2016), Ivarsson et al (2016)

The present study contributes to knowledge by analysing new trends in the organisational and geographical configuration of GINs. It combines insights from quantitative and qualitative data to better understand the international location of different types of RDI activities or tasks and to identify new forms or organisation of the RDI process. We exploit the outcomes of the structured interviews underlining the relevance of Technology Readiness Levels (TRLs) to better understand the (global) RDI processes in companies. Additionally, the project-level greenfield FDI data give finer evidence on the type of cross-borders activities undertaken. Furthermore, they allow singling out the activities that relate to technology development and learning by education and training.

A key aim is to put forward the need for better evidence on the breakup and sequencing of innovation processes beyond the research and discovery stages.

The next section details the mixed methods used to map structural changes within innovation value chains. It then introduces the notion of TRLs and its relevance to picture firms' innovation value chains, as highlighted by the interviews. Finally, a description of the greenfield FDI data and of the type of activities examined here in this study.

3. Mixed methodologies to map structural changes within innovation value chains: relevance of the TRL approach

Whilst patents are a measure of invention focusing attention on work associated with discovery and early stage research, innovation involves numerous activities related to the design, development and testing of new products and production processes (Pavitt, 1999). This process view of innovation is captured by the notion of an *innovation value chain* (IVC). IVC refers to the sequence of activities that have to take place in order to take a product from invention to the market place.

3. 1. Understanding new locational dynamics of RDI activities : interviews to R&D and innovation managers

Qualitative research is a theory-building methodology employed to identify-but not prove- patterns of behaviour and causal relations. The methodology adopts an exploratory approach with the aim of gaining an in-depth understanding of why and how phenomena occur resulting in new concepts, theoretical frameworks and interpretations.

Our analysis focuses on the role of actors, relationships and processes that lead to qualitative transformation in the organisation and location of MNC's innovative activities with the aim of identifying the causes and mechanisms of change. Qualitative data which capture companies' understanding of these processes are therefore appropriate. Given the industry-specific nature of technological development and innovation (Pavitt, 1984; Malerba and Orsenigo, 1996, Breschi et al, 2000, Herstad et al, 2014) one of the aims of our study is to understand industry differences in the processes of vertical disaggregation and fragmentation of RDI processes.

The study uses insights from structured and authors-led semi-structured interviews. Structured interviews have a closer resemblance to questionnaires and surveys in that they rely on standardized and pre-defined questions. Semi-structured interviews on the other hand are based on pre-defined themes that are explored with both close and open-ended questions. In semi-structured interviews the researcher has a clear set of issues to be addressed and questions to be answered but interviewees are encouraged to develop their ideas and speak more widely on the issues raised by the interview. One of the key strengths of this methodology is that there is flexibility for the interviewer to focus on particular points of interest or novelty that arise in the course of the interview so that semi-structured interviews can be used to explore new topics (Miles et al, 2014).

Based on a predefined questionnaire (see extract in Annex), the structured interviews to leading R&D investing companies were subcontracted to the consortium IDEA consult/VDI. Interviews took place in 2017 in close collaboration with the IRIMA team. In total, 60 interviews with R&D and innovation managers from a total of 10 MNEs operating in four sectors - pharmaceuticals, automotive, aerospace and ICT- took place. The interviews were organised using the TRLs as a generic innovation value chain (see IDEA/VDI 2018).

- *Semi-structured interviews*

Semi-structured interviews were conducted with senior R&D managers from two European MNEs, a manufacturer of electric equipment and appliances (three senior managers interviewed) and a pharmaceutical firm (one manager interviewed) as well as one industry expert from the automotive industry with knowledge of R&D and innovation.

The aim of these interviews was to gain an understanding of the impact of changes in the organisational form of MNEs on the structural and geographical configuration of RDI activities. Above all we were concerned with how processes of fragmentation and vertical disaggregation of high-value activities such as R&D and design (Ernst, 2009; Contractor et al, 2010) and productive activities (with a bearing on innovation) influenced the international location of innovative activities. Box 2 below gives the main topics addressed and the type of questions made to the representatives of firms.

Box 2. Semi-structured pilot interviews (2017) – Main topics and examples of questions

Recent trends in the organisation of R&D
Partitioning of R&D process, outsourcing of tasks & emergence of new networks partners
Location of different elements of the R&D function
Extent and nature of R&D alliances & networks
Impact of the vertical disaggregation of production on the R&D process
Emerging trends in the location of R&D activities
Effects of changes in innovation systems on location of innovative activities.

<u>Examples of questions: according to themes</u>
Where does the company have R&D subsidiaries?
What is the in-house international division of labour in R&D?
How subsidiaries in different regions do develop their specialisations?
Does the firm outsource of R&D? If so, what activities are outsourced?
Why does the firm outsource R&D?
What type of firms does the firm outsource R&D to and where are they located?
How do new trends in the organisation of production affect the organisation and location of R&D (e.g. how the outsourcing of the production of components impacts on the organisation and location of R&D)?
The factors driving the location R&D and how these change over time
The nature, mechanisms and extent of international knowledge transfer within the firm's R&D unit and between firm and internationally located R&D partners
How changes in national and regional innovation and business systems influence the locational decisions of R&D units (e.g. growth of markets and capabilities in developing countries but also the limitation of these locations)

Source: Authors' elaborations

- ***TRL to map generic firms' Innovation Value Chains***

The specific character of the *innovation value chain* will differ according to industry. However the Technology Readiness Level tool (TRL) are indeed a useful example of what a generic innovation value chain entails. The TRL approach was initially developed by NASA but today it is used as a tool for facilitating the decision making processes on RDI investments at the EU level.[12] Moreover, the structured interviews to companies also underlined the relevance of TRLs to have a finer picture of firms' innovation value chains.

Hence, our study also exploits the idea that TRLs are relevant a basic and generic IVC. For semi-structured interviews, it helps guiding the collection and analysis of both

[12] Technology Readiness Levels (TRL) are a measurement system employed to assess the maturity level of a particular technology based on the projects progress (see at https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html and https://www.nasa.gov/pdf/458490main_TRL_Definitions.pdf). Today, the TRLs scale is mainly used as a tool for facilitating the decision making process on R&D&I investments at the EU level (see at https://ec.europa.eu/research/industrial_technologies/pdf/workshop-innovation-report_en.pdf)

quantitative and qualitative data in order to examine the organisation and location of MNC's innovative activities.

Table 1. Technology Readiness Levels (TRL)

TRL1 - Basic principles observed	Scientific research is at initial stages. Initial results are being translated into future research and development plans.
TRL 2 - Technology concept formulated	Once the basic principles have been studied and initial findings can be applied to practical applications. At this stage the technology is very speculative as there is little or no experimental proof of concept.
TRL 3 - Experimental Proof of concept	When active research and design begin.. Generally both analytical and laboratory studies are required at this level to see if a technology is viable and ready to proceed further through the development process. Often during TRL 3, a proof-of-concept model is constructed.
TRL 4 - Technology validation in lab	At this stage multiple component pieces are tested with one another.
TRL 5 - Technology validation in relevant environnent	Continuation of TRL 4, however, at this stage a technology must undergo more rigorous testing . Simulations should be run in environments that are as close to realistic as possible.
TRL 6 - Demonstration in relevant environment	At this stage a technology has a fully functional prototype or representational model.
TRL 7 - Demonstration in operational environment	The technology requires that the working model or prototype be demonstrated in a space environment.
TRL 8 - System complete and qualified	The technology has been tested and is ready for implementation into an already existing technology or technology system.
TRL 9 - Successful missions operations	Once a technology has been proven

Source: Adapted from NASA

3.2 Exploiting greenfield FDI data to map international location of RDI by type of activity

The fDi Markets database of Financial Times[13] provides information on cross-border Greenfield investments projects such as the origin, destination, investing company, month of operation, type of investment, industry, estimated capital and jobs created. In

[13] Details about the fDi Markets database can be found at https://www.fdimarkets.com

addition, every FDI project is associated with a business activity, which is not sector-specific but reflects the actual activity being performed by the new investment. Only projects, which created new direct jobs and investments, are included. The main sources of information include FT newswires, media sources, industry organisations, investment agencies as well as other specialized private companies.

For the purpose of the study, we focus on Greenfield FDI activities that have been explicitly link to technology-related projects i.e. Research & Development (R&D) and Development, Design and Testing (DDT) (Cornell University, INSEAD and WIPO, 2016)[14]. We also show statistics related to Greenfield FDI inflows in Maintenance and Servicing and Education and Training industry activities (see Box 3 for illustrations of FDI projects description). Including these latter activities allow also considering innovation capabilities that are linked for instance to "daily" learning by doing or plant-level activities, as well as to direct improvements in local absorptive capabilities through professional and technical education and training.

Box 3. Examples of project description

Research and Development (R&D): "*a pharmaceutical company, has opened a new global medicines development facility in Bangalore, India. The centre, which is one of nine worldwide, will focus on oncological, respiratory, cardiovascular and metabolic diseases. It will create 30 new jobs.*"

Design Development and Testing (DDT): "*a power and automation specialist, has set up a new robotics application centre in China. The centre, …, aims to integrate resources in south-west China by providing robots, application, system integration and related customer service. The centre will develop robots for its clients from various industries, including automobiles, computers, communications, consumer electronics, equipment and consumer goods manufacturing.*"

Maintenance and Servicing: " *an engine manufacturer, has opened a new service delivery centre in Bangalore, India. It is the company's first such facility in the country and provides support for more than 750 defence engines used by the Indian Armed Forces. Located in Manyata Technical Park, the facility provides fleet management, service engineering and supply chain co-ordination as well as serving as a base for field service representatives to provide technical support across the country.*"

Education and Training: "*a supplier of photolithography systems for the semiconductor industry, has signed a memorandum of understanding with China-based public research consortium Shanghai Integrated Circuit Research & Development Center to establish a training centre in Shanghai, China. The facility will provide training to the local customer support workforce as well as to existing and potential customers in the local IC industry.*"

Source: fDi Markets database, Financial Times (access in October 2018)
Note: the description of the project is only available for some projects

[14] The Global Innovation Index reports (GII) is available at http://www.wipo.int/publications/fr/

4. Towards a better understanding of firms' IVCs: results and discussion

4.1 International location of RDI by type of activity: descriptives on cross-borders greenfield FDI investments

For each business activity of interest, Figures 3 show the number of Greenfield FDI projects, the estimated capital and jobs for selected top destination countries including Brazil, Canada, China, France, Germany, India, Spain, UK, and United States on three periods between 2006 and 2017 (2006-2009; 2010-2013; 2014-2017).

As illustrated in the Figures 3, India and China feature as the most important host-countries for greenfield FDI in Design, Development and Testing (DDT) in terms of number of projects, estimated capital expenditures and jobs. Greater capital investments seem to have favour jobs creation in these fast-catching up economies at these IVC stages, that is beyond TRL 1-3.

Upward trends are also visible for greenfield FDI to India in Education and Training (E&T). Such activities involve transfers of knowledge and know-how to the host country and can lead to learning and greater absorptive capabilities, which are essential to further strengthen existing innovation capabilities.[15] Maintenance and Servicing greenfield FDI towards India and China has involved higher levels of capital expenditures. In terms of number of jobs, China, US and the UK have been able to attract higher gFDI volumes, as measured by estimated jobs creation.

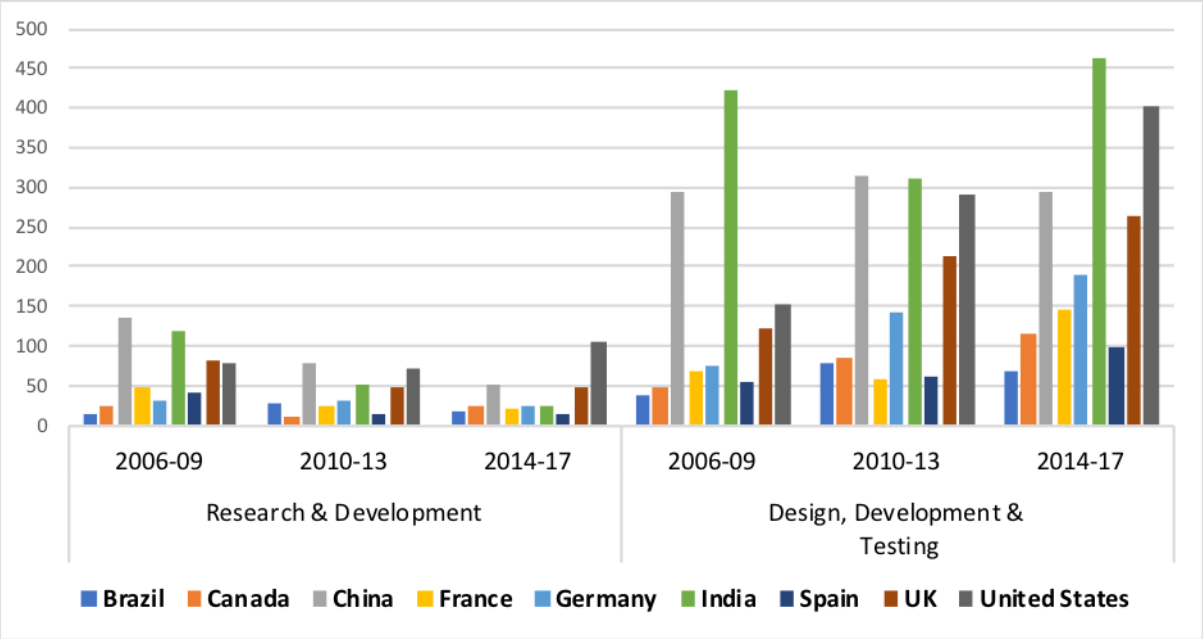
Interestingly the US and, to a lesser extent the UK and Germany, also attracted an increasing number of DDT projects and, overall higher capital expenditures between 2006 and 2017. Yet, such trends do not appear to be associated with (direct) estimated jobs creation.

Looking at R&D projects, closer to TRL 1 and 2-related activities, lower levels of inward gFDI appear as a common trend in the economies shown. China and India experienced significant decline as suggested by the three indicators.

[15] See Li et al (2017) and Khachoo and Sharma (2016) for empirical studies dedicated to the link between FDI and innovative performance in China and India.

Figures 3. Greenfield FDI by type of activity: R&D, Design Development & Testing, Maintenance & Servicing and Education & Training, by destination countries

Figure 3.1 - Number of projects



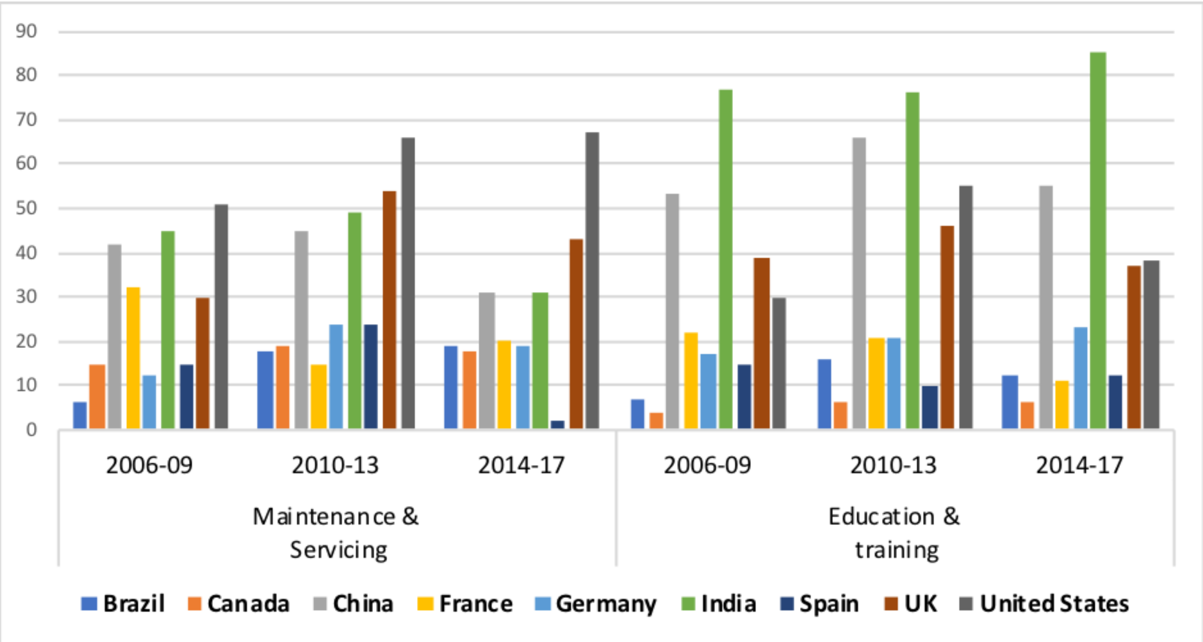
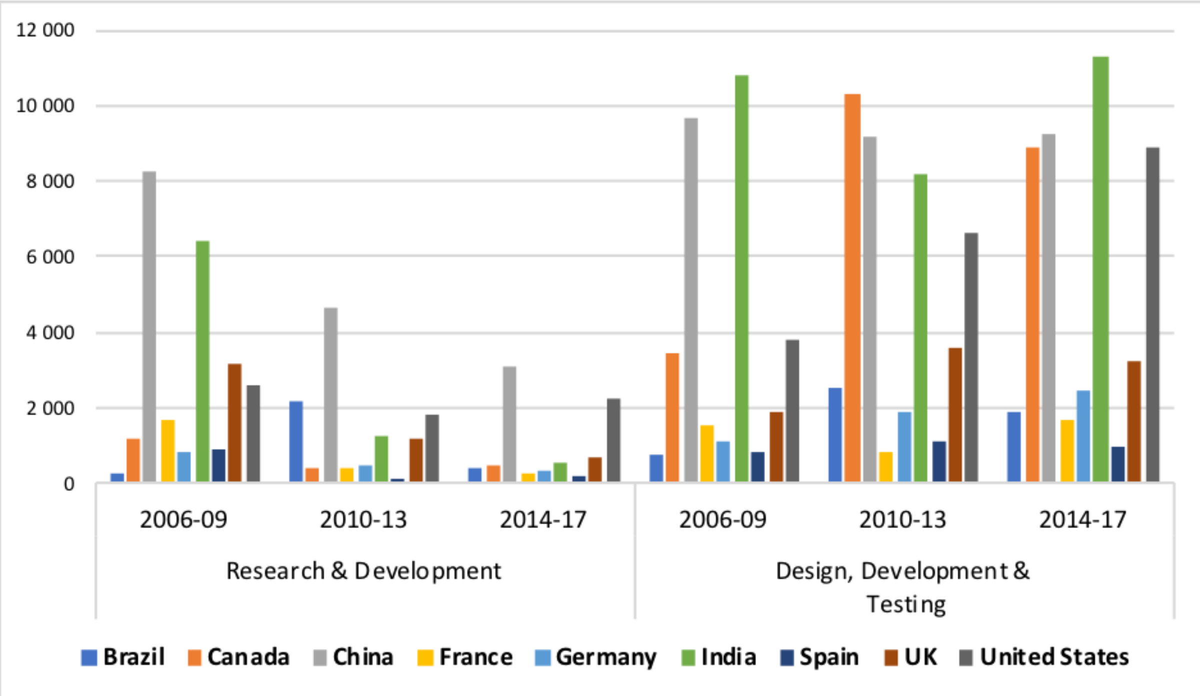


Figure 3.2 - Capital expenditures

(euro millions, estimated)



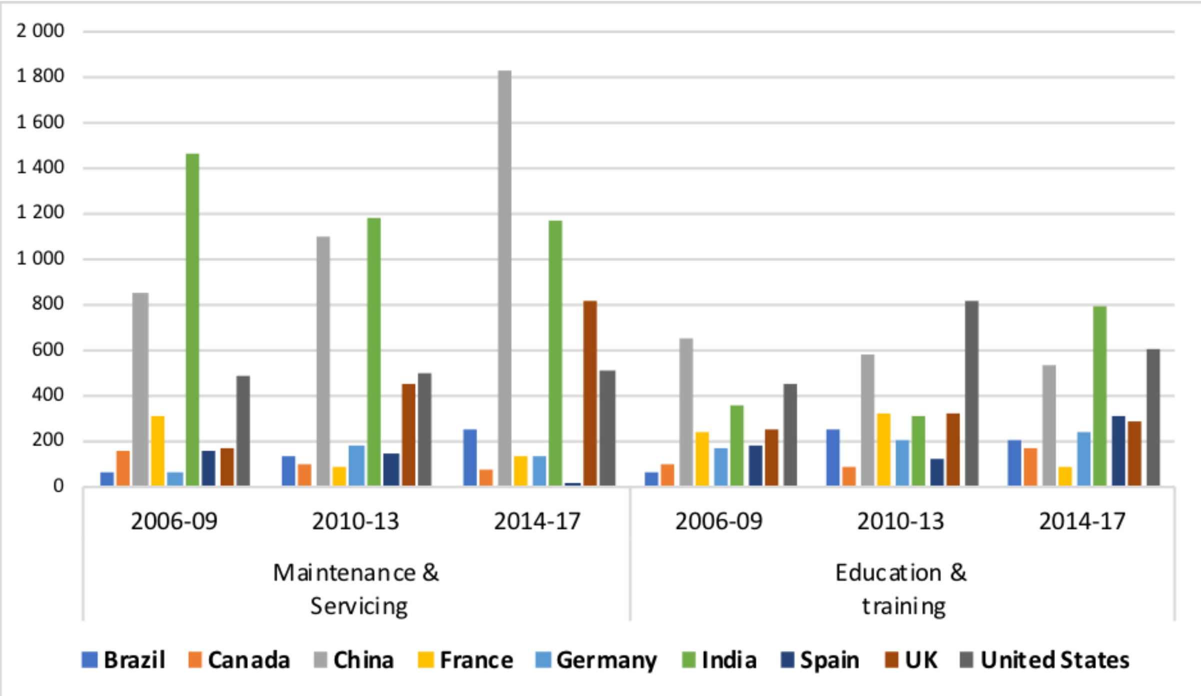
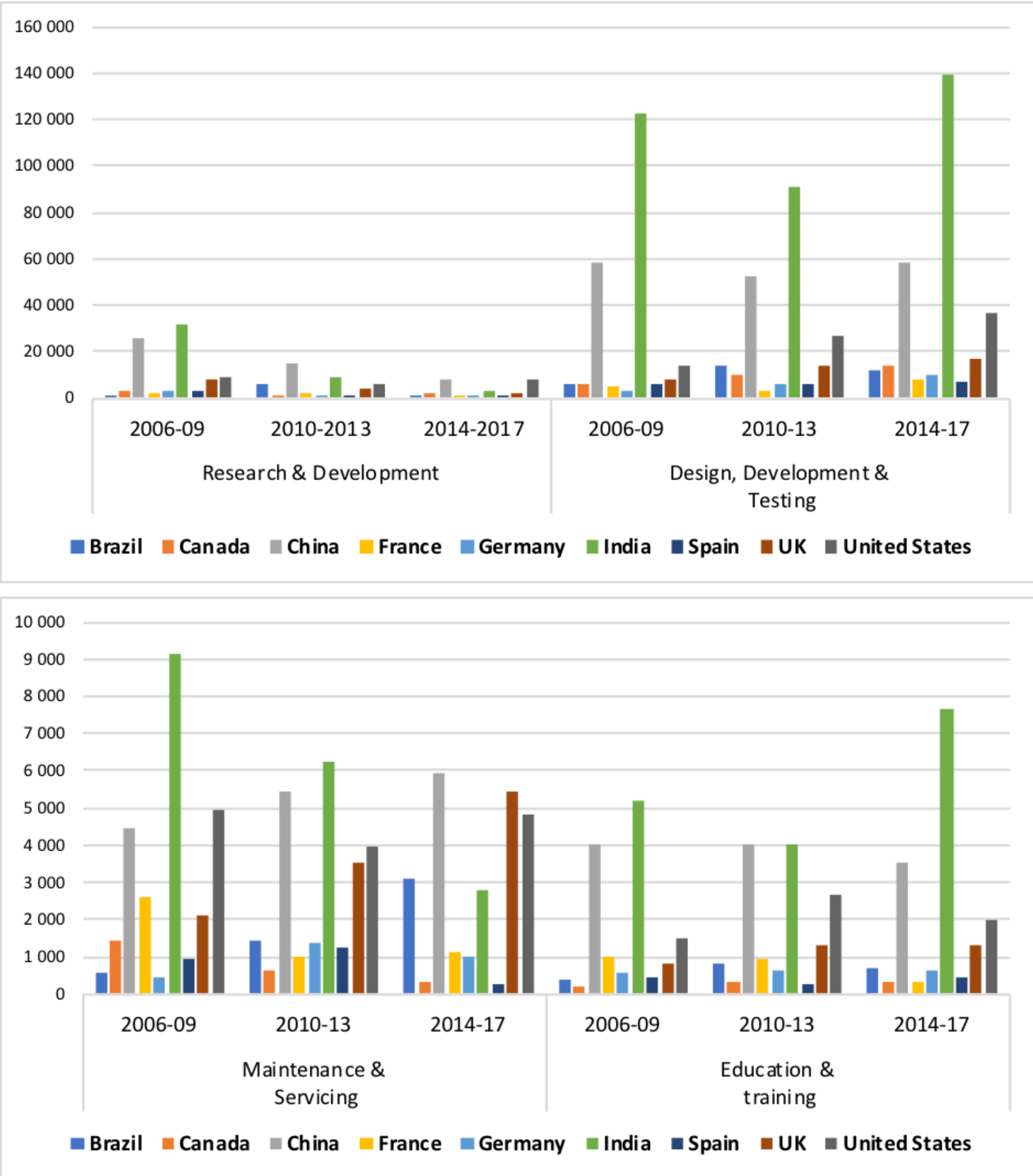


Figure 3.3 - Number of Jobs

(estimated)



Source: Authors' elaborations from the Financial Times's fdi Markets database (data downloaded from https://www.fdimarkets.com on October 2018)

Project-level Greenfield FDI data provide relevant information about later stages of the innovation value chain or higher TRLs. Combined with patents, which proxy better the lower TRLs, they enable to improve our understanding of the geographical and functional organisation of firms' international innovation processes.

What gFDI data initially confirm is that R&D and innovation activities should not be treated as homogeneous sets of activities. They rather combine differentiated activities or tasks, which in addition can be subject to distinct locational dynamics. This later point was also highlighted during the companies interviews discussed further below.

4.2 Overview of the findings from structured interviews (secondary data)

Structured interviews from the sample of 10 companies indicate that, even within the same industry, companies aggregate their R&D expenditures in different ways so that it is not always possible to identify exactly what percentage of a company's total R&D expenditure goes to a specific TRL stage. However, the interviews did reveal that the maximum that these high-technology firms spend on TRL1 is 10% of their total budget. Most of the firms interviewed spend most of their R&D budgets in activities related to product testing and demonstration (see IDEA/VDI, 2018).

The Table 2 below highlights selected outcomes from the structured interviews.

Table 2. Insights from structured interviews

<table>
<tr><th rowspan="2">PROPOSITIONS</th><th rowspan="2">Pharma companies</th><th colspan="2">Mobility</th><th rowspan="2">ICT-manufacturing companies</th></tr>
<tr><th>Auto companies</th><th>Aerospace companies</th></tr>
<tr><td>Location determinants and patterns are highly dependent on the type of RDI activity (i.e TRL).</td><td>++</td><td>+</td><td>+</td><td>+</td></tr>
<tr><td>The extent to which R&D&I activities are collocated with production activities are strongly dependent on the type of R&D&I activity involved.</td><td>+/-</td><td>+</td><td>+</td><td>++</td></tr>
<tr><td>The organization of RDI activities is industry/sector specific. Industry differences are observed at the level of the location decision, the impact, the governance mode. Even within industry, differences can occur depending on the RDI activities (TRL scale) of the company.</td><td colspan="4">+</td></tr>
<tr><td>The international fragmentation of R&D&I activities is highly dependent on the R&D&I sub-functions/activities or tasks. Highly capital-intensive industries concentrate key R&D&I activities to a larger extent than less capital-intensive industries.</td><td colspan="4">+</td></tr>
<tr><td>There are a broad range of corporate governance mechanisms and modes to sustain different RDI activities. A trend towards global RDI networks (originating due to alliances, collaboration and/ or subcontracting) can be observed, although they are often difficult to manage. The corporate strategy will however be determinant for the decision on the governance mechanism.</td><td>+</td><td>+</td><td>+/-</td><td>+</td></tr>
</table>

Source: GLORIA project's internal report – IDEA consult/VDI 2018

Note to Table 2: the signs can be interpreted as it follows: ++ means that the structured interviews suggest that the trends are confirmed in the interviews; + means that the structured interviews suggest that the trends are confirmed in most interviews, but that other major strategic or explanatory factors also play a role; +/- means that structured interviews suggest that the trend is visible but that other or explanatory factors may be much more determinant (see also further explanations and conclusions in IDEA consult/VDI, 2018)

Structured interviews with this small sample of high-technology firms suggest that, even in these sectors, **industrial innovation is highly concentrated in activities related to product design, testing and demonstration**. The interviews also indicate that locational **patterns/choices are influenced by a complex combination of industry-specific factors, type of TRL activity and tasks, as well as firm-specific strategy and governance mode**. Highly capital-intensive industries tend to concentrate key R&D&I activities to a larger extent than less capital-intensive industries. Moreover, some R&D&I activities need to be collocated with production, though this appears less strong in pharmaceuticals. These tentative results however need to be statistically tested in order to establish their significance.

The structured interviews undertaken for this project focused mainly on the configuration of firms' intra-firm innovative activities using the TRL as a broad guide to the partitioning of R&D&I activities. However, the interviews did not explore more recent trends in the modularisation and fragmentation of the GIVC, which gives more detailed information about the organisational and locational configuration of R&D&I tasks. A number of semi-structured interviews undertaken by the authors with senior corporate R&D managers and one industry representative complement the main project. They give insights that are more detailed on the changes in the organisational and geographical configuration of the R&D function as a result of the modularisation, partitioning and outsourcing of R&D tasks across global innovation networks (GINs).

The next section presents the findings from the semi-structured interviews conducted by the authors.

4.3. Detailed insights from pilot semi-structured interviews

The discussion for each sector focuses on the following dimensions: Intra-firm global innovation networks (GINs), Inter-firm GINs, Alliances with universities and research organisations, Outsourcing relationships with contract research organisations and potential links between GINs and GVCs (see a state of the art on GINs, Ramirez, 2018) .

Manufacturer of electric equipment and appliances

The sources of innovation for this firm are both developments in the science-base as well as market needs. In the last period the firm has been moving away from an innovation strategy based on advances in science to one which focuses more on consumer needs. As a result, locating R&D close to the firm's main markets has become more important.

– **Intra-firm GINs**

The firm retains a strong internal R&D effort with a central research organisation composed of a central hub a number of sister laboratories and some smaller units which represents approximately 1% of turnover. The central laboratory is located in the home country while the sister facilities are located in Cambridge (UK), Massachusetts (USA) and a smaller facility with relevance in the past that still operates near Paris (France). There are smaller units in Bangalore and Shanghai and smaller hubs in Brazil and Nairobi.

In addition to the central R&D organisation the various business groups or product divisions of the firm have their own R&D facilities. The R&D work performed by the business units represents approximately 7% of total turnover and focuses on product development. One of the roles of these laboratories is to convert the results from the central organisation into new products and, when necessary, adapt products to local market. These facilities are very internationally spread however their focus is on product development for global markets rather than local adaptation. For example, a lot of the company's lighting development is in China and in the US and that is mainly for the global market. These facilities can be very big.

The firm's locational decisions with respect to R&D investment are mainly driven by the existence good national and regional innovation eco-system as well as dynamic markets. Since the financial crisis the firm has closed some of its R&D facilities in the US and Europe and has relocated some in-house research effort in regions with more innovation-friendly eco-systems. Interviewees note however that there are limits to the locational mobility of R&D facilities as much of the knowledge-base of the firm is concentrated in its historic R&D facilities. Closure of such sites risks the loss of key R&D personnel and firm-specific know-how. Changes in the location of R&D facilities therefore are done with great care so as not to destroy existing knowledge.

Much of the locational shift of the internal R&D effort of the company occurs through changes in the rate of growth of R&D investment in different in-house facilities with faster growth in some locations rather than others. In this context interviewees note the expansion of R&D investment and upgrading of responsibilities of the company's laboratories in Asia, above all China and India. It is noted that these R&D facilities in developing countries have increasingly assumed responsibilities for the development of global products. For example, the Indian subsidiary located in Bangalore is today mainly focused on software development for a number of the company's global products. The Chinese facility is also assuming responsibility for innovation in specific product groups. These mainly, though not always, concern products that will be used in other developing countries with very large markets. For example, the firm's Chinese laboratories are responsible for the development of cheaper imaging equipment to serve tier two and tier three cities in China as well as other developing countries. Interviewees note that the establishment of R&D facilities in large developing countries such as China (the firm's second largest market) is motivated by the potential growth of local markets rather than costs. While some interviewees describe the growth of R&D facilities in Asia not as a shift away from Europe or the US but as an expansion into Asia others noted that the share of R&D investment in Europe was not increasing.

- **Inter-firm GINs**

Collaborations with universities and scientific research institutions

The firm has multiple collaborations with universities and research institutes. These collaborations have increased in importance as the firm has moved away from performing basic research in-house. Laboratories tend to collaborate with local partners so European based laboratories collaborate with European universities and research institutes while the company's Chinese laboratories will collaborate with Chinese universities (this is different from pharmaceuticals where collaborations are organised via therapeutic areas so that a European facility may collaborate with a Chinese partner). The company's R&D managers believe that locational proximity is important for collaboration with external partners in order to understand partners' culture and ways of doing things.

Collaboration with CROs

From the interviews there is no evidence that the firm is outsourcing R&D tasks to contract research organisations.

Collaborations with manufacturing suppliers… where GINs meet GVCs

Today the firm mainly focuses on product design, setting the specifications of the technical content of products and high-end manufacturing. In some product areas the need for integration between product development and high-end production is still strong so that high-end production remains in-house and the two activities are collocated. At the same time, a significant amount of the manufacturing activities of the firm has been outsourced to independent suppliers who over time have assumed responsibility for the R&D and product development of components and parts. As suppliers increasingly assume responsibility for the R&D of systems or parts of systems, R&D collaborations between the firm and its manufacturing suppliers has become increasingly important. These suppliers often outsource some of their work to T1, T2 and T3 suppliers. This suggests that in some of the firm's product groups there are strong links between GINs and GVCs in the area of product development. It is important to note that the outsourcing decisions are made by individual business units so there is no single outsourcing strategy for the whole firm.

Many of the firm's manufacturing suppliers are today located in Eastern Europe and China so much of the product development activities now also take place in those locations.

Response to market need is becoming increasingly important as a source of innovation for this firm. As a result, product development groups that are internationally spread have become more important in the R&D activities of the firm. Much of the R&D still carried out in-house with little outsourcing of R&D tasks. However, manufacturing suppliers have become increasingly important for innovation undertaking increasing responsibility for innovation in components systems and parts. As a result, collaboration between the firm and its manufacturing suppliers has become increasingly important for product innovation. This indicates the importance of the link between GINs and GVCs in this industry.

European Pharmaceuticals MNE

- **Intra-firm GINs**

The company differs from other leading pharmaceutical companies in that it mainly concentrates in-house R&D in two large laboratories located in the home country. The company has two small facilities in biologics in the US but these are very small compared to the two sites in the home country. In this respect the firm is less internationalised than similar firms in the industry.

- **Inter-firm GINs**

With universities and research institutes

The company has major collaborations with academic institutions and biotechnology firms in its home country and the US. Over the last five to ten years the nature of these collaborations has changed. They have become bigger and more holistic. This means that the firm not only works on well-defined problems in specific research projects with its partners but they now work together on a broad set of common goals which are jointly defined such as bringing a certain number of compounds into development and into the clinic. These collaborations require significant resources from both the firm, academia and biotech companies in terms of resources. For example, a typical collaboration would now require 30 to 40 employees from each partner. This way of working and the scale of these partnerships did not exist ten years ago.

Collaborations with contract research organisations (CROs)

The firm retains a fully integrated R&D organisation but also outsources an important percentage of its research activities to contract research organisations (CROs). The activities outsourced include tasks that are essential to the product development process and the success of the innovative strategy of the firm. The interviewee describes the CROs as the 'extended workbench' of the firm and explains that outsourcing is seen as a means of maintaining product development projects when faced with internal capacity constraints. Outsourcing to CROs is therefore seen as a strategy that gives the firms' R&D function flexibility to pursue projects that would otherwise be dropped.

The firm has a number of large outsourcing contracts with two well established Chinese and three European CROs. Some of these contracts involve routine work such as the synthesis of large number of compounds required for the R&D process. But in other cases contracts with CROs also involve some problem-solving and creative work. In recent years the firm has increasingly outsourced R&D work to Chinese CROs as these companies become established and develop their capabilities to international standards. Some of the more well established Chinese companies have reached the same high standards as European CROs in terms of their productivity and quality of their research work. A key criterion for choosing CROs is that they adopt a 'research services business model' as this reduces the chances of leakages of the intellectual property (IP) of their client. Any evidence of IP leakage and the CRO would lose all their research services clients.

Linkages with CROs do involve training and knowledge transfer above all with regards the processes of the firm rather than basic scientific knowledge which the CRO should already have.

Car Industry (Interview with industry expert-representative)

The pace of innovation is accelerating in this industry and one of the key challenges for firms is how to ensure that inventions from the research system are successfully implemented so that they become innovations. The manner in which RDI activities are organised and where they are located depends on the segment of the industry as well as where the firms are located regionally (i.e. whether they are in northern Europe, southern Europe, middle Europe).

A key characteristic of this industry is the relationship between lead firms or Original Equipment Manufacturers (i.e. the owners of brands) and their various tiers of suppliers.

According to the industry expert for some types of innovations car manufacturers (from now on OEMs) strongly protect their work and limit the number of partners involved in the collaborations. In other cases, innovative work will involve a triangle between the OEMs, their research providers and their manufacturing suppliers.

- **Intra-firm GINs**

OEMs, the owners of the brands, are global firms with very strong in-house R&D capabilities. The key factors that govern the decision of where to locate in-house R&D facilities include the existence of eco-systems that include partners with the knowledge and expertise needed by OEMs and the ease with which collaborations can be set up. The interviewee noted that the industry appears to be more mobile in terms of their R&D activities than in the past and that the existence of historically-grown facilities was not an important or decisive factor when it came to the decision of whether R&D would be located in Europe or globally.

Significantly, the interviewee noted that though technologies were often developed in Europe, the production and capitalisation of those advances often took place in other geographies. Battery technology was highlighted as an example where much of the advances in knowledge took place in Europe but where the innovation and monetisation was mainly developed by Japanese and Korean companies. The argument was made that in Europe it is still difficult to bridge the gap between research and its implementation. According to the interviewee the main reason for this is that when companies start innovating they do not have a clear idea of the end result and so they do not have a clear idea about how their innovations will be implemented.

- **Inter-firm GINs**

University collaborations: Firms in this industry collaborate closely with numerous international universities and research institutions.

Contract-research organisations (CROs)

OEMs do outsource some of their R&D activities to research provider organisations or CROs with whom they collaborate closely on specific developments. Some of the research provider organisations own and sell their own IP to the OEMs while others operate as providers of research services. In this latter case the main business of the CROs is to provide a research service to the OEMs and they are not concerned with the final application or the IP generated in the contract. In the automotive industry there are many European CROs that are globally active and operate in all parts of the world. Geographical proximity is still important in this industry so OEMs tend to work with organisations that are located close by. The importance of co-location for innovation in this industry explains the internationalisation of the research services industry.

GINs and GVCs

Automotive has been described is a modular industry (Sako 2003, Pandremenos et al 2009) which means that products can be partitioned into distinct modules or components. Since the 1980s there has been a process of vertical specialisation in the area of production which has also affected the organisation of R&D in this industry. One important change is that tier 1 (T1) suppliers have invested in innovation and have established strong innovative capabilities. They are also more integrated into the networks for R&D with universities and research provider organisations. These suppliers have increasingly taken on the responsibility for innovation in components and sub-systems, thus prompting the need for intensive collaborations between OEMs and their T1 suppliers in the area of innovation. This has resulted in complex GINs which are closely linked to GVCs. One example of this is how T1 suppliers from the US and Asia (e.g. Delphi and Denso) with strong innovative capabilities have become closely integrated into the European supply chains.

Innovative ideas are also being developed by suppliers in the lower tiers (T2 and sub-tiers) but these innovations are much more difficult to implement. One of the difficulties for new entrants in the industry and lower tier suppliers is that although they may have some very good innovative ideas they do not always understand the regulatory framework and boundary conditions in which the industry operates. The types of suppliers discussed here include both high-technology electronic start-up firms and software developers as well as less technology-intensive suppliers that are trying to enter the industry.

Concluding remarks (semi-structured interviews)

GINs based on universities and research institutes are widespread in the cases studied though, as suggested by the interview with the pharmaceutical firm the nature of these collaborations may be changing in their scope and magnitude.

GINs based on collaborations with geographically spread contract research organisations exist in the pharmaceutical and automotive firms interviewed but little is known about them, their role in the innovation strategy of firms, how they are integrated in the R&D value chains of MNEs and how this changes the geographical configuration of the R&D function of these large firms.

The interviews suggest that the process of vertical disaggregation of firms' value-adding activities and the creation of GVCs has resulted in an increasing role for suppliers of components and sub-systems in the R&D of final products. This suggests the extension of R&D networks to T1 and even T2 suppliers. This is likely to be very important in industries with modular products such as electronics and automotive but less so in more integral industries such as pharmaceuticals. This would suggest that the geographical configuration of firms' supply chains could have important implications for the dynamics of GINs however this is still a poorly understood area.

V. Conclusion

The developments in the organisational and geographical configuration of R&D and the IVC of MNCs require new conceptualisations of the processes of R&D&I internationalisation and new avenues for data collection as well as deeper interpretations of existing datasets. One important result from the project-level FDI data is the need to understand the organisational and locational patterns of the design, development and testing activities of MNCs (i.e. TRLs below tier 1) as they account for the overwhelming share of the R&D&I expenditure of firms. As the report from the structured interviews suggests, our results indicate that trends in R&D (TRL 1) can differ significantly from those of other R&D&I activities (i.e. TRLs below level 1). They will also differ according to the industry. The qualitative data also underline the importance of international facilities undertaking design, development and testing activities for learning and capability accumulation. They present a few examples of the upgrading of activities from developing and testing for local markets to designing products for global markets. The data suggest that international facilities, including those located in developing countries, can increase their strategic role in knowledge creation and innovation processes.

Similarly, understanding how MNCs are partitioning and outsourcing different R&D&I tasks and the nature and configuration of the inter-firm GINs they create as a result is now required. Indeed it will allow better assessing the impact of R&D&I internationalisation on regions and local ecosystems. In this context it is important to gain more detailed knowledge of the characteristics, role and needs of R&D&I suppliers and service providers as well as their organisational and locational configuration. Industry differences are again important in this context as in some industries R&D&I will be outsourced to contract research organisations; in other industries the outsourcing of production has meant that manufacturing suppliers are increasingly taking on a larger role in the R&D&I activities of MNCs. Whilst in some cases these suppliers will own the patents or will patent in collaboration with MNCs, this is not always the case.

The results have important implications in particular for territorial or regional innovation policies attempting to attract specific activities or segments of strategic value chains or value creation networks. In these cases finer mapping (for instance exploiting

TRLs) to understand which factors are likely to attract and embed different innovation value chains activities would help targeting relevant types of firms and activities. Such efforts can contribute to bring better evidence to support the reorganization of industrial value chains and the EU actions to boost its global leadership in key strategic and future-oriented industrial sectors[16]. These trends to a higher dispersion, and also servitisation of research, observed at the global level “in a growing number of high-value, traded-sector industries and productions systems that are geographically fragmented” (European Commission, 2019) impact the local learning and technological accumulation systems, as well as the diversification of investments in these different RDI activities. Importantly for some industries the need for co-location is important for production and innovation. While it gives several opportunities for regional smart specialisation strategies, it also implies that the loss of manufacturing can result in the loss of important R&D&I activities and capabilities.

How local R&D&I institutions and suppliers as well as manufacturers integrate into the GINs and GVCs of MNCs and the opportunities this offers for learning and upgrading can also have important implications for innovation and territorial/regional development. The outsourcing of R&D&I tasks to independently-owned, internationally dispersed, contract research and manufacturing suppliers means that territories/regions can participate in the global economy even without FDI. This requires greater attention to the needs of local R&D&I suppliers as well as manufacturing sub-contractors, needs which are often different to those of the MNCs. These suppliers can become the basis of new industries and value chains (local or global) and new industries and therefore possible opportunities for regional and industrial innovation-led development. Understanding the dynamics and links between national systems of production and innovation is therefore important even for high-technology, R&D intensive sectors.

[16] See the press release “Industrial policy: recommendations to support Europe's leadership in six strategic business areas” of November 5th 2019 at https://ec.europa.eu/commission/presscorner/detail/en/ip_19_6204

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Annex. Extract of the questionnaire for structured interviews

R&D&I activities

1. How important are the following innovative activities in your company? Approximately how much investment would fall into each of the categories? Which major changes do you expect for your innovation activities in the next 3-5 years?

R&D innovation activities	(a) Fundamental research (*Basic principles observed)*
	(b) Technological research (*Technology concept formulated, experimental proof of concept, technology validation in lab)*
	(c) Product demonstration (*Tech. validation in relevant environment, demonstration in relevant environment, demonstration in operational environment, sstem complete and qualified)*
	(d) Competitive manufacturing (*Succesful mission operations)*
Non-R&D innovation activities	(e) Management of R&D&I projects
	(f) Staff training
	(g) Technology forecasting/ corporate foresight
	(h) Acquisition of machinery and equipment
	(i) Design to improve/adapt existing products & processes
	(j) other (please specify):

2. What is the main change you expect for R&D&I & non-R&D&I activities in the next 3-5 years?

GVCs of R&D&I vs. products

1. To better understand the relation between your R&D&I activities and your most relevant products, could you provide an overview of the Global Value Chain (GVC) of your most relevant products (groups)?

2. Where are the company R&D&I activities across this product GVC located (geographically and functionally)? Which R&D&I sub-functions/tasks are directly attached to the product GVC and which not? Are activities co-located with other company activities?

3. For the R&D&I and production activities of the GVC of your most relevant products, how large is the foreign share for each of the following innovative activities in your company? Please state the biggest regions where they are located and (if possible) the share of the most important regions.

   (a: none, b:1-5 percent, c:6-10 percent, d: 11-50 percent, f: more than 50 percent)

4. What is the main change you expect in the next 3-5 years?

5. What are the drivers behind the location of R&D&I activities and the co-location of R&D&I activities with other company activities?

Governance: Please select the most important modes of governance for the different outsourced/offshored R&D&I and production activities

- Alliance and JV
- M&A
- Subcontracting
- Collaborations
- Subsidiaries
- IP-licensing
- Other?

Location

9. How is geographical location of R&D&I activities and sub-functions decided? What are the key drivers?

10. What is the main change you expect in the next 3-5 years? Which R&D sub-functions will be the target of these changes? Do you expect differences with other industry players?

11. To which degree does the type of R&D&I activity (e.g. non R&D innovation activities versus R&D activities, Research versus Development activities) determine where it is located?

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