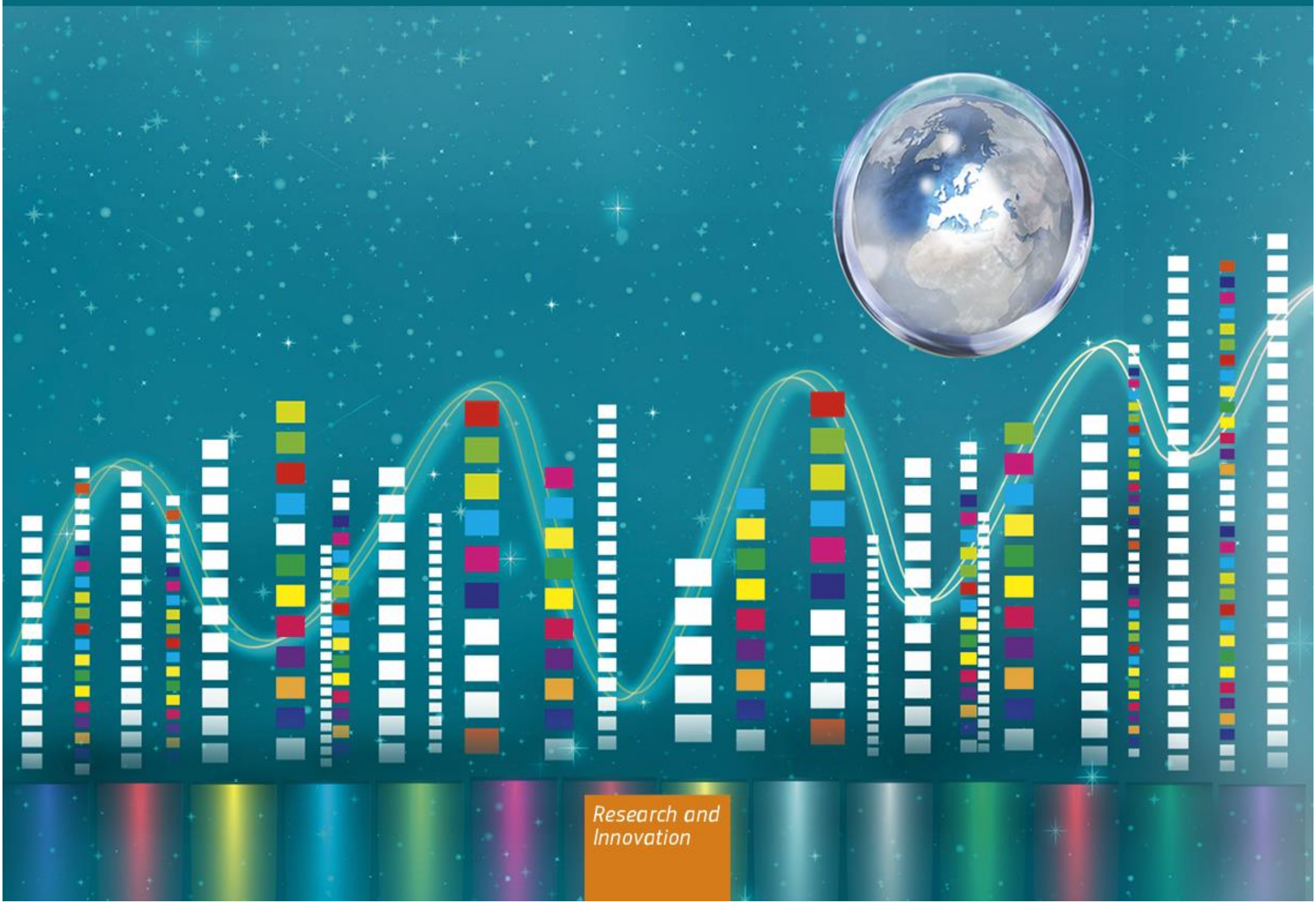
European Commission

Internationalisation of business investments in R&D and analysis of their economic impact (BERD Flows)

Final Report



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Internationalisation of business investments in R&D and analysis of their economic impact
(BERD Flows)

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About the authors

This report involved a collective effort involving the teams of the four partners in alphabetical order: AIT, IRCRES, NIFU, SPRU. It is important to recognize that a significant aspect of the report—and a substantial part of the work that went into it—is found in the annexes.

The division of labour can be presented in terms of the seven tasks that underlie the Final Analysis Report. This report synthesises the results of this work. An attempt is made to attribute authorship in each chapter despite the fact that the underlying work may involve more people. The overall report was organised, compiled and edited by Eric Iversen.

The breakdown of contributors by task is:

1. Country-based analysis of foreign R&D investments: Parimal Patel and Fredrique Lang, SPRU (UK)
2. Patterns of cross-country business R&D investments: Bernhard Dachs, Thomas Scherngell and Georg Zahradnik, AIT (AT)
3. Drivers of foreign R&D investments:
    a. Bianca Poti, Giovanni Cerulli and Raffaele Spallone, IRCRES (IT)
    b. Eric Iversen and Mark Knell, NIFU (NO)
4. The attractiveness of the ERA for business R&D activities of non-European companies
    a. Bernhard Dachs, AIT (AT)
    b. Parimal Patel, SPRU (UK)
5. Impact of foreign R&D investments
6. Bianca Poti, Giovanni Cerulli and Raffaele Spallone, IRCRES (IT)
7. Most urgent data needs for future analysis: Bernhard Dachs and Georg Zahradnik, AIT (AT)
8. Policy implications related to the current situation and ongoing trends: Bernhard Dachs, Parimal Patel, Eric Iversen, Mark Knell and Bianca Poti

Summary

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Executive Summary

The internationalisation of economic activities is a defining aspect of our times. To a significant extent, this comprehensive internationalisation process builds on the internationalisation of business sector R&D expenditures. Established but changing global innovation systems can be seen both in manufacturing as well as service industries; from the automobile industry to machinery and equipment, from the chemicals industry to pharmaceuticals, from the electronics industry to software and services.

The landscape for the internationalisation of business R&D is undergoing a period of comprehensive change, in step with a range of general factors including shifts in the location of demand, production and innovation, changing technologies and technological regimes (e.g. green-tech, digitisation/IoT), and the longer term repercussions of the 'financial crisis' (stemming from the US sub-prime credit crisis). Other historical events of note include the expansion of EU membership in the mid-00s and the subsequent stages of extending economic activity with the eastward expansion states. But what is known about the extent and distribution of these investments across time, country and sector; and, moreover, what is known about causes and potential effects of their internationalisation?

Project Aim

This report provides a new analytical look at the internationalisation of business R&D investments in Europe. The focus is primarily on the period following the financial crisis, 2009-2013. In light of European priorities (Europe 2020 strategy and Research and Innovation as sources for renewed growth (Com (2014) 339), the overarching aim of this report is to improve the evidence base for R&I policy making in this area. To this end, the report uses current data from Eurostat (ESTAT) on the internationalisation of business R&D expenditures in Europe. This report describes and analyses the internationalisation of business R&D investments in the EU-28 and the wider context of the European Research Area.

The report builds on an earlier study (Dachs et al. 2012) and the material for the current project, including the underlying dataset. This analysis acts as a complement to three earlier stages of the study. The first stage reviewed the growing literature in the area (D1), the second laid out a methodology based on available, comparable and reliable data-sources, while the third went ahead to collect, compile and annotate core and secondary data that were identified to best analyse the topic. This report presents the final, analytic stage of the study. The goal of the work is to better understand these patterns in the European context, not least by improving the analysis of factors that can be said to influence inward flows of R&D investments and the effects that can be said to grow out of them in the different contexts.

An empirical approach to improve the basis for policy-making

R&D expenditure data are at the core of this study. Focusing primarily on developments since 2008, the report takes advantage of new data from official sources to describe patterns and trends at the levels of individual countries and of selected sectors. The core-data used in the study come from Eurostat. They are complemented by data from the OECD and national statistical offices, where compatible and available. The core-data is complemented by secondary (reference) data, including measures of country-size (GDP), measures of economic activity (turn-

over by sector), further measures of R&D performance (BERD, GBOARD), measures of innovation (patenting), etc. In addition, the report briefly explores complementary but completely distinct data-sources to explore adjacent areas (FT Markets fdi data and Eurostat's R&D and Community Innovation Surveys). The Data Report (D3) lays out the sources and coverage of the core data, including detailed information of data-availability at the national level.

Based on the official data, the report describes the current state of cross-country patterns of business R&D investments that involve European (ERA) countries. The goal is to better understand the patterns of cross-country R&D investments. However, the presentation goes beyond presenting the metrics. It pursues a composite approach consisting of both quantitative as well as more qualitative approaches. The qualitative analysis includes presentations of the underlying metrics and analysis at the country and sectoral level, with a focus on post 2008 period. The presentation uses qualitative information to flesh out a narrative around the metrics in comprehensive case studies. This presentation describes the relevant metrics over time, using qualitative material to discuss the developments in the context of 35 countries and of 7 sectors. The report emphasizes striking a balance between metrics and narrative.

On this basis, the study pursues more formal analyses. The project adapts a set of econometric techniques to analyse factors that can be said to influence inward flows of R&D investments and to analyse the effects that can be said to grow out of them. The emphasis on the country and the industry levels is followed up at this stage in exploring drivers and impacts. The econometric approaches are furthermore used to explore the effects of the financial crisis on the inward flow of business sector R&D ('inward BERD').

Different aspects of the internationalisation of business R&D has attracted current policy interest. In light of ongoing work in the field, the report also discusses policy conclusions, including ways to improve the quality of international R&D expenditure flow data: informed policy builds on solid empirical data. Its goal is to improve the evidence-base for R&I policy making in light of European policy priorities.

Chapter Highlights

We briefly review some of highlights of the report.

Chapter 2 From the country perspective:

Following the introduction, the first chapter describes and analyses business R&D internationalisation in terms of the extent and relative significance of inward R&D investments in different national contexts across the ERA. Over thirty country reports provide evidence for single countries based on available data. The extensive case-work combines presentations of key metrics from the core-dataset with qualitative information for other reliable sources, such as the IUS Scoreboard. The resulting country reports serve to introduce the core-data and to illustrate what this empirical material reveals about business R&D internationalisation during recent years at the level of individual countries. The chapter provides an analytic basis on which to explore what drives the inward BERD and what consequences it may have for these countries.

The country perspective reveals that the vast majority of European countries (20 out of 24) exhibit a high or a medium level of foreign control of business R&D. The EU-15 countries tend to have higher and stable levels of inward BERD as % of GDP, while EU-13 countries tend to have lower levels but higher growth rates. In total, nine EU countries register increasing levels of internationalisation and 10 are in the stable category. The largest increases of overall inward R&D intensity can be found for the EU-13 countries such as Slovakia, Poland or Slovenia— among the most recent members of the EU. This might be traced back to widely known R&D

internationalisation patterns, stating that in most cases, the internationalisation of R&D follows the internationalisation of production.

The country perspective also points to factors at the sector level that contribute to changes in the picture. relative decline of the importance of Pharmaceuticals in inward BERD, going from 28% of the total in 2008 to 11% in 2013. This is also an industry where R&D is dominated by foreign firms. Some notable anomalies emerge at the country level between patterns of domestic BERD and inward BERD. For example, over half of the EU countries with high levels of inward BERD perform well below the EU average in the IUS Scoreboard. Meanwhile, Denmark and Finland, which are among the most innovative in the same scoreboard, harbour relatively low levels of foreign R&D.

Chapter 3. Cross-country analysis and the attractiveness of Europe for inward BERD: Chapter three investigates how countries are inter-related by international flows of R&D resources in light of the effects that may have on host and home countries. One question that is raised in this context involves the attractiveness of the European Research Area (ERA) for R&D activities of non-European firms. The background is anecdotal evidence that the strong role of Europe is being eroded. Based on available data particularly from the US, the chapter modifies this impression.

The chapter demonstrates that the overall size of inward BERD grew during the last decade in almost all countries. A constant and slightly increasing level of inward BERD intensity is observed in most of the high as well as the low intensity countries. In contrast, a considerable level of volatility is found in the medium intensity countries. Most of the R&D activities of non-EU firms in Europe and the European Union can be attributed to US multinationals. The US share on total inward BERD from non-EU countries is 66%, and 81% if we extend the geographical scope to ERA countries. This corresponds to the prominent role of the USA in R&D internationalisation. The US is – by far - the country with the highest inward BERD as well as outward BERD in the world.

In Europe, Germany is by far the largest host country for US R&D activities in 2013, followed by the UK, Switzerland, and Canada. Belgium is more important as an R&D location for US firms than India, while France still attracts more inward BERD than China. In general, the UK and Netherlands are among the most preferred locations for the European headquarters of non-EU firms and therefore also attract a high share of their R&D activities in Europe.

In absolute terms, US outward BERD in the EU has more than doubled, from 12 billion USD to 25 billion USD, since the year 2000. Now, emerging economies such as China and India are quickly gaining importance, both in absolute and relative terms. The undeniable erosion of the position of the EU should be put into perspective. US outward BERD to emerging economies remains well below that to Europe: in 2013, Asia and Latin America together account for 18.3% of total US outward BERD, or 8.9 billion USD. The share of US outward BERD is in fact lower than that of 'other', non-EU OECD countries, including Canada, Switzerland, Israel, South Korea and Mexico. Moreover, the rise of China or India has not led to a reduction of US activity in Europe.

Chapter 4 The Sector Perspective

The report moves on to investigate the internationalisation of business R&D at the level of individual industries. There are significant differences between industries for example in terms of labour and R&D intensity. Such inter-industry differences shape firm-level decisions to locate R&D abroad and therefore can lead to different degrees of internationalisation at the sectoral level.

This chapter looks more closely at seven industries, six in manufacturing. One case looks at the services sector where despite the strong rise in the importance of international R&D, data remains poor. In general, the chapter finds a trend towards a wider variety of countries involved in the internationalisation of business R&D at the sectoral level. The seven industries attracted between 3.8 billion PPS EUR (chemicals) and 21.7 billion PPS EUR (pharmaceuticals) inward BERD in 2013 worldwide. The chapter shows that:

Inward BERD is by far greatest in the pharmaceuticals industry, where it is highly concentrated in a small number of countries, predominantly the US. But massive total amounts of cross-border BERD in this sector means that the remaining countries still attract significant absolute inflows. The US appears to be the most attractive region in the world for R&D investment in the health related sectors, especially biopharma. Besides the US, only two more countries, the UK and Belgium, account for more than 5% of the total sectoral inward BERD.

In the automobile industry, inward BERD accounts for 11.44 billion PPS EUR (2013). Germany dominates with about 3 billion PPS Euro of inward BERD. The sector is relatively concentrated. Three large countries accounting for a third of the sectoral inward BERD dominate motor vehicles, the second largest sector in terms of worldwide inward BERD. The share of BERD performed abroad has remained relatively stable in the European Union since 2005. Internationalisation of automotive R&D has focused on development, while research remains concentrated near the home bases of lead firms. Countries close to the German border had a relatively higher growth of inward BERD.

In the chemicals industry, the EU attracts about two thirds of total inward BERD (3.8 billion PPS EUR). The qualitative analysis indicates that there is a migration of petrochemical and basic chemical industries out of Europe, mainly to the Middle East, but increasingly also in China, leading to important changes in the European chemical industry. In Europe, the Belgian chemicals industry is one of the most diversified and integrated chemical clusters in the world. The highest increase of the inward investments in R&D since the financial crisis have been in the Czech Republic.

Producers of computers, electronic and optical products generate a total of 9.52 billion PPS EUR inward BERD worldwide (2013). The cumulative share of the EU is with 58% and the share of the US is 35%. Within the EU more than 2/3 of inward BERD is concentrated in the three large countries Germany (16% of sectoral inward BERD worldwide), France (14%) and the UK (10%). Europe depends heavily on the United States and east Asia, which means that research networks will play an important role in transferring technology and fostering innovation

Total sectoral BERD worldwide for electrical machinery and apparatus is about 2.7 billion PPS EUR. European firms accounted for about half of global R&D in the industry in 2013. Internationalisation of electrical equipment R&D has focused mostly on development, while research remains concentrated near the home bases of lead firms. But inward BERD is generally higher than domestic BERD in virtually all countries. Labour appears to be higher in the countries with inward FDI, except for the Netherlands.

In the machinery and equipment industry, EU member countries together attract more than 2/3 thirds of total inward BERD in this sector. The average R&D intensity of European firms was higher than in US firms (3.2% vs. 2.9%), but many firms have experienced negative growth in recent years. Among the European countries, Belgium has the most internationalized R&D activities, followed by Denmark and Hungary. Eastern European countries have experienced the most important increase of inward BERD in the recent years. Upstream and downstream linkages are essential to the innovativeness of the industry.

There are no recent figures for France Germany or Italy for the service sector example, computer programming and related activities. Industrial R&D is highly concentrated in software and computer services, and it is much higher in absolute terms in the US and East Asia than in Europe. There is a significant gap for the EU vis-à-vis the US in terms of number of companies and R&D investment in software.

Apparent labour productivity appears higher in virtually all of the foreign affiliates compared to domestic counterparts.

Chapter 5 Drivers and effects of inward BERD

To complement the mixed approaches of the case studies, the report goes on to employ a set of econometric techniques to analyse factors that can be said to influence inward flows of R&D investments and of outcomes that can be said to grow out of them in the different contexts.

Determinants of inward BERD: This chapter first analyses what may be driving the patterns observed in the chapters on country and industry. Two approaches are used. Following a standard analysis (a Cobb-Douglas model), the chapter fits a (Random coefficient regression) model that measures the 'responsiveness' of a number of factors on total inward BERD. This approach allows one to rank countries and sectors according to their driver responsiveness, to detect most influential driver; and to detect both factor importance and heterogeneous response. The analysis points to the importance of the sector-size, of labour cost, of resident patenting, and of the domestic R&D as factors that positive effect inward BERD in general. The analysis allows us to group European countries in those in which drivers are mostly related to the «market augmenting» (size etc.) and those which demonstrate more «asset augmenting» drivers (in terms of scientific and technological strength, and strength in R&DI. Sector level differences were also analysed in detail.

Impacts of inward BERD: The second main level of analysis evaluates the impact of inward BERD on important measures at the country level: Labour productivity, domestic BERD, and resident patenting as proxy of innovation capabilities of the host economy. An Average Treatment Effects (ATEs) approach is followed using a counterfactual sample (Country and sector with that have not received inward BERD) with a one-year time lag as to mitigate endogeneity problem only for the overall sample. Based on the data at hand, this exercise produces mixed results. In terms of labour-productivity, there are indications of a positive relationship (significant) among the EU-15 countries but a negative one for EU-13 countries. Patenting and domestic BERD showed a more positive impact. The impacts are positive and significant for the complete sample and for EU-15 countries. For the EU-13 countries these impacts are positive but not significant. The presentation shows how these impacts change as the share of inward BERD increases.

Two Special Topic Reports: In addition, the chapter reports on two special topics exploring the tools used to address two policy-relevant questions: (i) what effects has the fiscal downturn in 2008 had on inward BERD in Europe and (ii) how do fiscal incentives (particularly tax-based incentives) affect inward BERD. The full studies of these special topics are found in the annex. As explorative studies, they serve to illustrate the usefulness of the tools applied, given the data we have.

Effects of the crisis: The report explores the effects of the financial crisis, looking the importance of factors before and after the crisis. This excursion indicates that three factors increased their strength in the aftermath of the crisis, namely GDP, Labour cost and FDI. While the first two are positive and significant, Foreign direct investments have increase their strength but, as in the pre-crisis period, are still not significantly correlated with Inward BERD. In contrast, GBAORD and the "total labour force tertiary educated", in part decreased their importance as drivers.

Effects of fiscal incentives: The role of fiscal incentives is an important topic in the literature and in the academic discussion. This special topic study explores the effect of fiscal incentives on inward BERD. Four types of R&D tax incentives are included. The analysis suggests that total tax incentives had a positive effect on inward BERD. The analysis is more indicative rather than conclusive.

Chapter 6 Data needs for future analysis

The last chapter underlines that there remain shortcomings in the available data on R&D internationalisation. In light of the work with the data currently publically available, chapter 6 discusses the most urgent data needs for future analysis of inward and outward R&D expenditures. The chapter discusses limitations and recommends ways to address them. In addition, the case work on other data sources is referred to here.

An important limitation is that lack of data for the service sector. Indications are that the service sector makes up around a third of inward BERD and are increasing quickly. An another example is the lack of aggregate statistics for the EU that can be compared with the US. Data availability is limited by a number of issues including confidentiality issues due to thresholds for number of firms in many countries. As a result, it is not possible to compare inward BERD for the EU as a whole. There is a need for a single EU aggregate for inward BERD from different home countries. This would also help to study the sectoral dimension and would make comparisons with the US easier and more accurate. In addition, there is a need to align survey methods with non-EU countries, more complete data for all EU countries, and more timely data. It would also be useful to publish outward BERD data for all countries.

Chapter 7 Policy Conclusions

It is important to emphasise that the current levels of R&D internationalisation in Europe described in the report have developed without the aid of concerted targeted policy interventions. This is consistent with the consensus in the literature that sound economic and innovation policy is more important than special incentives to attract foreign firms. Policy can contribute by focusing on the framework condition that foster innovation and R&D of both, domestic and foreign firms. Relevant policy areas include funding R&D, integrating foreign firms in the local innovation system, refining education policies, facilitating an appropriate level of mobility among academic and corporate researchers, as well as ensuring the availability of relevant data and promoting analytic work.

In thinking more specifically about how policy can improve what European countries gain from BERD, policy should also be vigilant about its potential costs. It should also be noted that there are existing frameworks, such as investment agreements or the Single Market SET boundaries for policies towards internationalisation, which shape policymaking in this area. In general, there is considerable scope for general innovation policy that promotes innovation capabilities of all firms in the economy, regardless of ownership status. There is also need for coordination between levels of policy. In addition, the report indicates that expertise is clearly integral to shaping specific decisions about the extent and direction of inward BERD, and the study shows that its role varies in different industries. Above and beyond a good educational system and an active domestic research community, one dimension that policymakers could look into in more detail is the role of measures to facilitate and foster mobility of research personnel.

A final conclusion involves coordination. While there is general consensus in national policies about the policy instruments employed, there are areas of divergence. For example, there is no consensus about opening national R&D programmes to non-domiciled firms. There is also little consensus about promotion of firms that want to go abroad with R&D. These are among more specific areas where further analysis may help to refine policymaking.

Chapter 1.

Introduction

Eric Iversen and Bernhard Dachs

Chapter 1. Introduction

Eric Iversen & Bernhard Dachs

This report provides a new analytical look at the internationalisation of business R&D investments in Europe. It describes and analyses the internationalization of business R&D investments in the EU28 and the wider context of the European Research Area. The report builds on an earlier study (Dachs et al. 2012) and material from earlier stages of the current project. The first stage reviewed the growing literature in the area, the second laid out a methodology based on available, comparable and reliable data-sources, while the third went ahead to collect, compile and annotate core and secondary data that were identified to best analyse the topic.

Focusing primarily on developments since 2008, the report takes advantage of new data from official sources to describe patterns and trends at the levels of individual countries and of individual sectors. The presentation uses qualitative information to flesh out a narrative around the metrics in comprehensive case studies. This presentation describes the relevant metrics over time, using qualitative material to discuss the developments in the context of 35 countries and of 7 sectors.

One analytical challenge is to disentangle factors that may affect inward business R&D investments and effects that might come from observed R&D activity. Others include what effects outside shocks (e.g. the fiscal downturn) or other activities (e.g. fiscal incentives offered by some governments) may have. The report applies new methods to better understand the factors that motivate cross-country R&D investments as well as the effects that these flows may have especially in terms of the host countries. In light of European priorities (e.g. Com (2014) 339), this report aims to improve the evidence base for R&I policy making given the rising significance of internationalization of business R&D investments. The report ends by discussing policy conclusions, including ways to improve the quality of international R&D expenditure flow data.

Background and scope

There is a recognised need to improve the evidence-base for R&I policy making in light of European priorities to promote research and innovation as a key way towards ‘renewed growth’ (cf. Europe 2020) and more openness in R&I (‘Open Innovation, Open Science, Open to the World’). The internationalisation of research and innovation activities are an increasingly important part of this picture. The R&D investment decisions made by business are a cornerstone of the internationalisation of research and innovation systems. They are increasingly an important element when firms go abroad to realise the potential of markets and production systems, particularly in certain sectors and countries (cf. GIN, GVC). Moreover, they link national innovation systems and increase openness of countries in science and technology. This integral aspect of the ‘globalisation’ process holds potential to improve growth and promote learning across borders, but it may also raise challenges (e.g. substitution, hollowing-out).

The financial crisis of 2007-2008 provided an unexpected shock to globalisation in general and it is thought to have negatively affected the internationalisation of business R&D investments in particular. But what is known about the extent and distribution of these investments across time and country, and what can be said about causes and potential effects of their internationalisation?

The work reported here presents an updated analysis of current trends of internationalisation of business R&D investments that involve European countries. It should be seen in light of recent as well as ongoing work in the area. In particular, the work builds on a previous study on BERD Flows (Dachs et al, 2012)[1]. The scope and aim of the two projects are broadly similar, but include some important differences (see below). Both projects collected, collated and presented empirical information about the internationalisation of business R&D investments with an eye to inform policy-making. One particular type of data has made up the core dataset, namely R&D expenditures of foreign-owned firms. R&D expenditures of foreign-owned firms link together countries by way of inward and outward flows. Both investigate various drivers to explain the share of foreign-owned firms in total R&D expenditures of a country, while considering the magnitude and overall shape of relations between countries.

More generally, the work here builds on renewed efforts in the statistical community to provide better measures of this important R&DI activity. In so doing, this report contributes to ongoing work in the academic and policy communities to utilise the resulting metrics to better understand how business R&D investments are evolving across borders and what these developments might mean in different contexts. In this respect, this report complements other current work that is being undertaken to better understand the changing patterns and importance of private-sector R&D expenditures in different contexts (see also chapter 7).

In this report, the geographical scope consists of countries in the European Research Area (ERA), with a focus on the current 28 EU Member States. Here, the aim is broadly in line with the study of 2012. There are however some major differences in the two studies. One difference is linked to the reference period of the core data. The earlier study was primarily based on data for 2004-2007 while this report is primarily based on data the most current data from Eurostat, which included the period 2009-2013(2014).

As alluded to, there are a number of developments in the latter period that should be noted. The potential impact of the financial crisis is one element. In addition, the period included the further integration of the EU eastwards with the A10 countries in 2004, followed by the formal accession of Bulgaria and Romania in 2007 and Croatia in 2013. It also encompasses changes in the status of some candidate countries. A more instrumental change involves the availability and coverage of key datasets. As reported in the methodology section (cf. D3 Methodology), there are a number of developments that affect analysis on this front. This report will follow up this issue.

Theoretical landscape

The literature on R&D internationalisation originates in the 1960s, and has rapidly expanded during the past 15 years. This report builds on the significant advances in the academic discourse on the topic; moreover, it attempts to contribute to the further progress of the field based on its use of official metrics that are now available. Two currents of the literature are of particular relevance: what drives R&D internationalisation and (ii) what types of impacts or effects R&D internationalisation has on host and home countries. These aspects are introduced here and followed up in later chapters.

Drivers of R&D internationalisation

A first important regional or country level driver is income and market size. Income is an important driver, because high income and high income growth attracts FDI (Ekholm and Midelfart 2004; Blonigen 2005; Jensen 2006, Athukorala and Kohpaiboon

[1] *See project EUR 25195 EN, Internationalisation of business investments in R&D and analysis of their economic impact, DG Research and Innovation. See also https://ec.europa.eu/research/innovation-union/pdf/internationalisation_business-rd_final-report.pdf*

2010, Hall, 2010). Another important attractor of R&D of MNEs is a skilled workforce and the quality of the education system. In turn, a growing demand for engineers and scientists in the home country is often a motive for firms to go abroad with R&D. The presence of spillovers as a determinant for R&D location decisions point to the importance of the quality of university research as a driver of R&D internationalisation at the country level (Belderbos et al. 2009, Siedschlag et al. 2013).

Previous research has also pointed out that geographical proximity between host and home country leads to higher levels of cross-border R&D investments (Guellec and van Pottelsberghe de la Potterie 2001). This distance effect is often explained by additional co-ordination costs, the cost of transferring knowledge over distance, and a loss of economies of scale and scope when R&D becomes more decentralised. Differences in labour cost between the home country and locations, in contrast, does not play an important role as a driver for the internationalisation of R&D (Thursby and Thursby 2006; Kinkel and Maloca 2008; Belderbos et al. 2009).

A number of empirical studies has investigated the role of policy for R&D location decisions (Cantwell and Mudambi 2000; Kumar 2001; Cantwell and Piscitello 2002; Thursby and Thursby 2006; De Backer and Hatem 2010; Athukorala and Kohpaiboon 2010). There is a consensus from this work that special financial incentives and a positive discrimination of foreign-owned firms in general are not an appropriate instrument to attract foreign R&D. Governments that want to attract R&D of foreign multinational firms should instead focus on the economic fundamentals and provide political stability, good public infrastructure, reasonable tax rates, and a stable legal system including the protection of intellectual property rights.

Besides locational factors, characteristics of the sector and the firm are also positively related to R&D internationalisation. Multinational firms are in all likelihood large firms from high-income countries operating in knowledge-intensive sectors such as pharmaceuticals, computer and software, research, or the automotive industry (Markusen 2002). These firms are also most likely to have R&D activities abroad.

Potential benefits – and therefore factors that drive overseas R&D activities – are gains from the international exploitation existing competences, or the building up new competences (Kuemmerle 1999, Cantwell and Mudambi 2005). See also the discussion in Chapter 5. The costs of a decentralised organisation of R&D include foregone economies of scale and scope from specialisation, involuntary technology spillovers, higher co-ordination efforts and the cost of transferring knowledge between different parts of the enterprise group (Sanna-Randaccio and Veugelers 2007; Gersbach and Schmutzler 2011).

Impacts of R&D internationalisation on host and home countries

A second important component of the literature focuses on the effects of the internationalisation of business R&D of the different country contexts. R&D activities of MNE affiliates may also influence the innovation systems of their host and home countries to a considerable degree. The literature has identified various potential challenges and opportunities for host and home countries from the internationalisation of R&D and innovation:

- First, multinational firms spend huge amounts on R&D, even compared with aggregate R&D expenditure of countries (OECD 2010, p. 121). A new R&D venture of an MNE may therefore considerably affect aggregate R&D activity of the host country.
- A second benefit for the host country is the diffusion of information and knowledge (knowledge spillovers) to host country organisations. Potential receivers of this knowledge are domestic firms, universities, or research centres. The literature gives considerable attention to knowledge diffusion and spillovers by foreign-owned firms (see the surveys by Keller (2004, 2010) or Mayer and Sinani (2009)). Finally, foreign-owned firms can also contribute to

structural change towards a higher share of technology-intensive firms and to the emergence of clusters in the host country.

We now turn to potential challenges for host countries that emerge from the presence of foreign-owned firms. One striking aspect of the literature on FDI spillovers is the number of studies that report negative effects for host countries (see, for example, Castellani and Zanfei 2002; Marin and Sasidharan 2010; Damijan et al. 2013, Rojec and Knell, 2015). One potential downside involves the labour market: stronger demand for high-skilled labour due to market entry of foreign-owned firms may crowd out demand by domestic firms. Fears that a high share of foreign-owned firms on aggregate R&D expenditure may lead to negative effects are also reinforced by more general concerns about hosting enterprises that are headquartered elsewhere. A concern of this section of the literature (see Barba Navaretti and Venables 2004; Jensen 2006) builds on a composite set of assumptions, namely;

- the assumption that the internationalisation of R&D leads to a loss of control over domestic innovation capacity, since decisions on R&D of foreign-owned firms are made by corporate headquarters abroad;
- the assumption that MNEs are more 'footloose' than domestically owned firms, since they mainly pursue economic activities that can be easily transferred between countries;
- the assumption that foreign-owned enterprises may act in ways that are not in accordance with the national interest;
- together with the assumption that an important motive for R&D internationalisation is rent-seeking.

Another concern in the literature about foreign ownership is that R&D of foreign-owned firms may be associated with a higher degree of adaptation and a lesser degree on basic, strategic research, since MNEs often concentrate strategic, long-term R&D in the home country. Another feature of the literature is that R&D internationalisation may also be associated with a separation of R&D and production (Pearce and Papanastassiou 2009). MNEs have various options in the location and organisation of R&D and production which mono-national firms do not have. Research, development and production are not necessarily located in the same country, because MNEs may find it useful to develop products in one country and manufacture in another country where conditions for production seem more favourable. As a consequence, policy measures to promote R&D and product development may only yield a small number of jobs and only provide a weak stimulus to growth when foreign-owned firms decide to produce abroad.

The internationalisation of R&D also has implications for the home country of the multinational firm. As discussed above, a main driver for firms to go abroad with R&D activities is to get access to knowledge not available in the home country. Hence, a first main benefit for the home countries that is noted in the literature is the transfer of results from overseas R&D activities which brings new knowledge back to the home country. Various studies provide evidence for such reverse knowledge transfers (Fors 1997; Feinberg and Gupta 2004; Todo and Shimizutani 2005; Piscitello and Rabbiosi 2006; Rabbiosi 2009). Reverse knowledge transfer can increase overall technological capacities, help to develop new products and foster growth and employment in the home country. R&D activities abroad can therefore strengthen the growth of the parent company in the home country (Rammer and Schmiele 2008). Potential challenges or costs from the internationalisation of R&D for the home country may arise when firms replace domestic R&D and innovation activities with similar activities abroad. This may lead to a 'hollowing out' (Criscuolo and Patel 2003) of domestic innovation capacity, a loss of jobs in R&D, and a downward pressure on wages of R&D personnel in the home country. Despite public discussions on the offshoring of R&D and possible consequences for home country innovation systems, empirical results that confirm such 'hollowing out'-effects are rare. Studies based on patent data give no indication for a substitutive relationship between R&D abroad and home-based R&D activities (D'Agostino et al. 2013).

Data and approach

Based on the experience of the original study and on developments in the field more generally (see also D1, the literature review), the study employs quantitative as well as qualitative techniques to study the dimensions of interest. In line with work in the original study, the current work has compiled core and secondary data to describe and analyse the internationalisation of business R&D expenditures ("BERD Flows"). The core data consists of R&D expenditures of foreign-owned firms, as the inward and outward flows of these investments link together research and innovation decisions between countries.

Data include total R&D expenditures of the business sector (total BERD), R&D expenditures of foreign-owned firms (Inward BERD), R&D expenditures of firms abroad (outward BERD), and the indicators based on these data for the ERA countries. The inward perspective looks at R&D internationalisation from the host country point of view, and reports the R&D expenditures of foreign-owned firms in a particular host country (Inward BERD). Inward BERD data were obtained for odd years from 2005-2013 for most countries. There is also information on the data sources, units of measurement, and remarks on data quality and comparability. Inward, Outward and total R&D expenditures data collected by Eurostat and by the OECD make up the core datasets. These two sources have been further complemented by data available at national statistical offices where appropriate.

The methodology report (see D3) provides a comprehensive account of data choices, categorisation schemes, provisos and detailed description. Moreover, the core and secondary datasets are themselves provided. Data collected are stored in a single relational database, which can be linked with other databases. This storage facility allows for the easy update of the data, of source information as well as of the metadata. For access to the relational dataset, see D4. The relational datasets are accompanied by a number of basic queries and rules to reliably generate a range of indicators. In addition, the data is accompanied by a tool to visualise important relationships in the data are also provided (see the link to Tableau) [2].

The metrics that come out of this work describe key dimensions of interest, not least the mix of business R&D investments by domestic and foreign-owned firms. Using these indicators, the study goes significantly beyond this in two key directions. The first extension is methodological. It is based on the question of how to use the information derived in the study to analyse drivers and impacts of these flows most accurately. The report adapts robust econometric approaches to address known challenges that face formalized analytic approaches in this context. Utilising the official data to analyse what drives the internationalisation of business R&D investments and what effects it has at the country level poses significant challenges (e.g. heteroscedasticity, unobserved heterogeneity, endogeneity).

The earlier study employed a pooled OLS based approach (without time fixed-effects) to calculate factors that 'drive' Inward BERD. The current study moves on to adapt a Cobb-Douglas model that uses another technique (responsiveness scores in a random-coefficient regressions) to provide more reliable estimates of true effect (responsiveness) of individual factors on Inward BERD in a selection of country and sector settings. In formalising the impact of Inward BERD on the domestic economy, the earlier study employed a fixed-effect approach. The current study adopts a different (continuous treatment) model to analyse the effect of MNE's BERD

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[2] *See www.ait.ac.at/internationalisation/ for the embedded version of the data. See also the pilot tables here: https://public.tableau.com/views/BERD_flows/Indicators_Circles?:embed=y&:display_count=yes*

investment on different outcomes (host country labour productivity, domestic BERD and domestic patenting). Both refinements represent a considerable step forward both in terms of the earlier project both also in terms of the current literature.

The second important extension is to utilize secondary qualitative data in conjunction with the standard metrics in order to dig deeper into the question of what drives visible changes in the allocation of R&D investments in specific sector and country contexts. A major contribution of the report is in the form of case studies that complement the description of the metrics with more contextual information from other trusted sources (such as the R&D Scoreboard). This material studies includes:

1. Seven case studies of selected sectors
2. 30 standardized country reports that summarize what is important about R&D internationalisation in the particular ERA countries, in addition to a special work on the US and, within data limitations, China.

In addition, three other case-studies combine the quantitative and qualitative information to study specific topics.

1. Two case-studies utilize the data-resources and econometric approaches to explore two important topics of general policy interest.
    a. the impact of the financial downturn,
    b. the impact of tax policy and other fiscal measures
2. Two other cases look into supplementary data-sources:
    a. Using the Community Innovation Survey (2012) to explore investment and collaboration patterns
    b. Using FT Markets data on FDI Projects to investigate a single source global data to focus on foreign direct investments in R&D as well as design projects.

The aim and organisation of the report

The overarching goal of this work is to better understand the patterns of the internationalisation of business R&D investments in the European context and thus to improve the evidence-base for R&I policy making in Europe. Using the approach introduced above, the contribution of this analytic report can be summed up in the following four points.

1. The report uses the metrics from earlier steps of the study. The aim is to describe and analyse business R&D internationalisation in different (national, cross-border, and sectoral) contexts
2. The report complements this indicator work with extensive case-work. The aim is to provide an empirically based discussion of factors that drive cross-border R&D investments by business enterprises and the effects that they seem to have in these contexts.
3. The report adapts robust econometric approaches to address known challenges that face formalized analytic approaches in this context. The aim is to best utilise the metrics that have been collected to derive robust and comparable results across contexts.
4. And the report draws conclusions that can help the statistical community to improve the production of relevant measures and that can help the policy community to make full use of statistical and allied empirical sources.

This report presents the analysis of the study in a reduced form. It should not be read in isolation. As emphasized, it builds directly on two sets of material and should be seen in relation to these. The first set of material is the work already reported from the study. To sum up, these elements consist of the literature review (D1), the methodological report (D2), as well as the dataset (D3) introduced above. The analysis should be seen in light of this work and the reader is invited to use these resources actively for further information about issues, methodology, or indeed the data themselves3. In addition, this report summarises the extensive analytic work reviewed above. To do this material justice, the report is accompanied by extensive appendices that covers the case-work, the specifications of the econometric models and their results, as well as other ancillary information.

In consolidating the extensive analytic material, this report is organised in the following way.

Chapter 2 introduces inward R&D investments from the host country perspective. It describes the extensive case-studies (corresponding to t4.1 of the Tor), it provides illustrations at the country level and describes tendencies across time.

Chapter 3 follows up to explore how the internationalisation of R&D expenditures links countries together. It presents general cross-country patterns with a focus on Inward BERD (corresponding to t4.2), and it discusses what can be said about the attractiveness of European countries to inward flows from third-countries (particularly the US) in the period (corresponding to t4.4). The position of China is also considered.

Chapter 4 presents the analysis in a sector perspective in light of patterns found at the country-level. The main focus is on the results of seven sector case-studies that were selected to capture sector-level drivers of the headline patterns of the internationalisation of business R&D.

To complement the mixed approaches of the case studies, Chapter 5 presents the formal analysis of factors that can be said to influence inward flows of R&D investments (corresponding to t4.3.) and of outcomes that can be said to grow out of them in the different contexts (corresponding to t4.5).

In light of the work with the data currently publically available, chapter 6 discusses the most urgent data needs for future analysis of inward and outward R&D expenditures (corresponding to t4.6). The chapter discusses limitations and recommends ways to address them. In addition, the case work on other data sources is referred to here. The final chapter presents a discussion of the implications of the analysis to research, technology and innovation policies.

Chapter 2.

European Countries and Inward BERD

Parimal Patel, Georg Zahradnik and Eric Iversen

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In order to better understand the patterns of the internationalisation of business R&D investments in the ERA, this analysis report starts from the perspective of the host country. This chapter describes and analyses business R&D internationalisation in terms of the extent and relative significance of inward R&D investments in different national contexts across the ERA. Drawing on the metrics collected in previous stages of the study, this presentation builds on the 35 case studies that are included in the extended annex. It introduces the core-data and it illustrates what they reveal about business R&D internationalisation at the level of individual countries and more generally in recent years. The chapter provides an analytic basis on which to explore what drives the inward BERD and what consequences it may have for these countries.

Country-based analysis of Inward BERD over time

As introduced above, the core data of the study consists of R&D expenditures of foreign-owned firms in host countries in the European Research Area. This section introduces this data (inward BERD) in the context of individual host countries in ERA. In line with the aim of the study (t4.1), the presentation here reflects the series of country reports based on the core data collected (see D3).

The inward BERD data have been obtained for odd years with important limitations in the data. The presentation is shaped by availability of core-data in the post 2008 period. The important issues are described in the methodology (see D2 and chapter 6). Table 1 introduces the data in terms of the country case-studies. It reports on data availability for the countries in question. 34 country reports have been produced, 29 based on inward BERD data and a further 5 (Cyprus, Greece, Lithuania, Luxembourg, Malta) on the basis of patent statistics. There are 10 non-EU countries without any inward BERD data (no report has been produced).

Table 1 Overview of country-reports

Data Availability	***Countries***
No Data for 14 countries (4 EU and 10 Non-EU)	*Cyprus, Lithuania, Luxembourg, Malta,* Brazil, China, India, Iceland, South Korea, Liechtenstein, Turkey, FYR Macedonia, Montenegro, and Serbia.
Very Poor Data for 9 Countries	Bulgaria, Croatia, Estonia, *Greece*, Ireland, Latvia, Portugal, Romania and Slovenia.
Limited Data for 9 countries (5 EU and 4 Non-EU)	Denmark, Poland, Spain, Sweden, Italy, Israel, Japan, Norway, and Switzerland.
Good Data for 12 Countries (10 EU and 2 Non-EU)	Austria, Belgium, Czech Republic, Finland, France, Germany, Hungary, Netherlands, Slovakia, UK, Canada and USA

Each of the 30 country reports follows a standardized format. In this report, we present four indicators that are standard across the case-studies to describe a single country: The Netherlands. For more information about the individual countries, the reader is directed to the annex as well as to data-resources that accompany the report (the data-set and the Tableau dashboard)[4].

The four standard indicators are:

- Share of inward BERD in total BERD
- Inward BERD by country of origin
- Share of industries in inward BERD
- Share of inward BERD in Total BERD by Sector

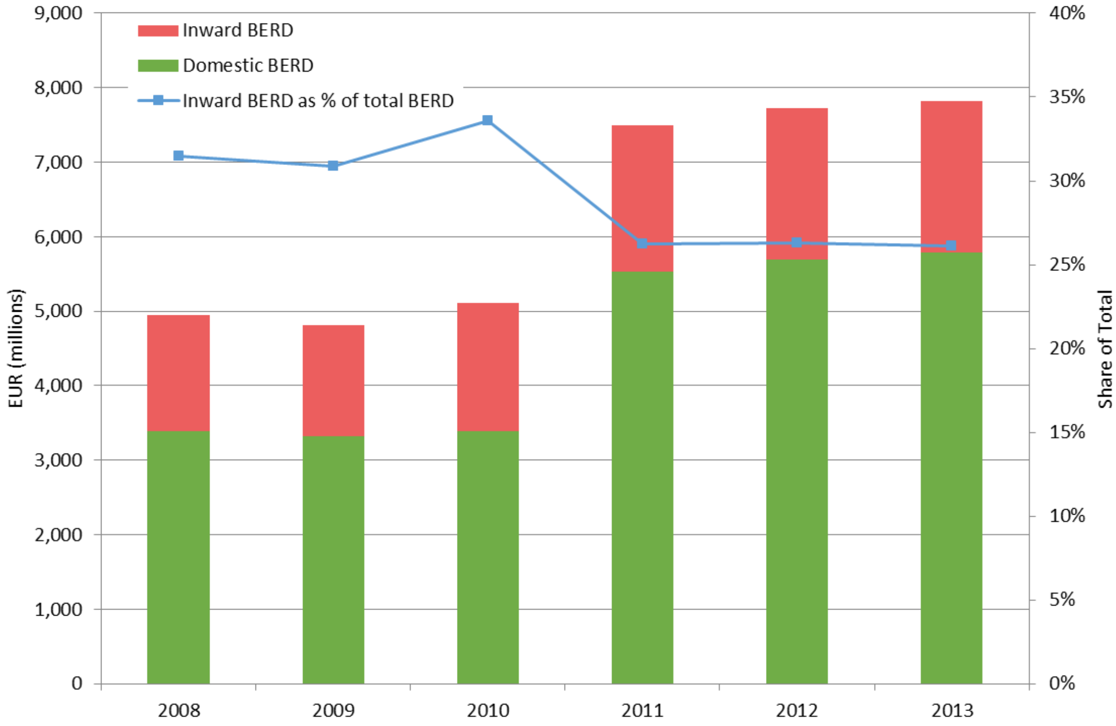
Country-report example: Inward BERD in the Netherlands

As an example we show the charts for each one of these indicators for the Netherlands below. The main conclusions to emerge from this analysis are as follows based on the four standard indicators.

A first conclusion that emerges is that foreign firms are an important component of R&D in the Netherlands, accounting for just under one-third of total BERD from 2008 to 2013. While inward BERD increased by 26% from 2008 to 2011, it has stagnated since then. In the meantime, domestic firms have increased their investments in R&D greatly in the last few years.

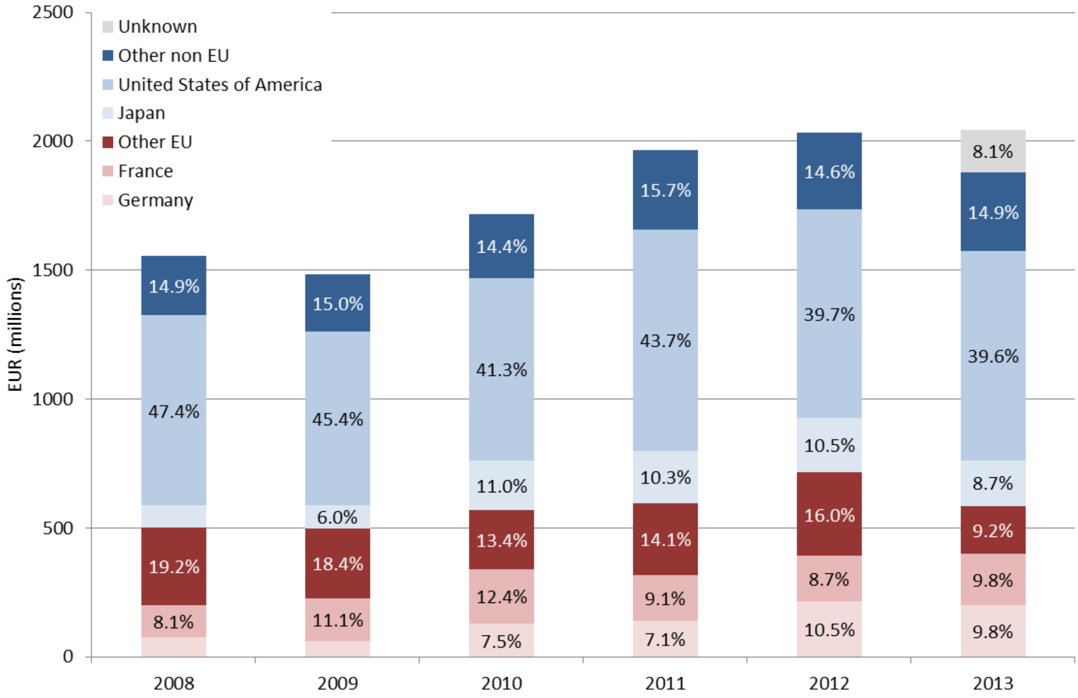
[4] *See www.ait.ac.at/internationalisation/ for the embedded version.*

Figure 1 Trends in the share of Inward R&D in Total BERD (2008-2011)



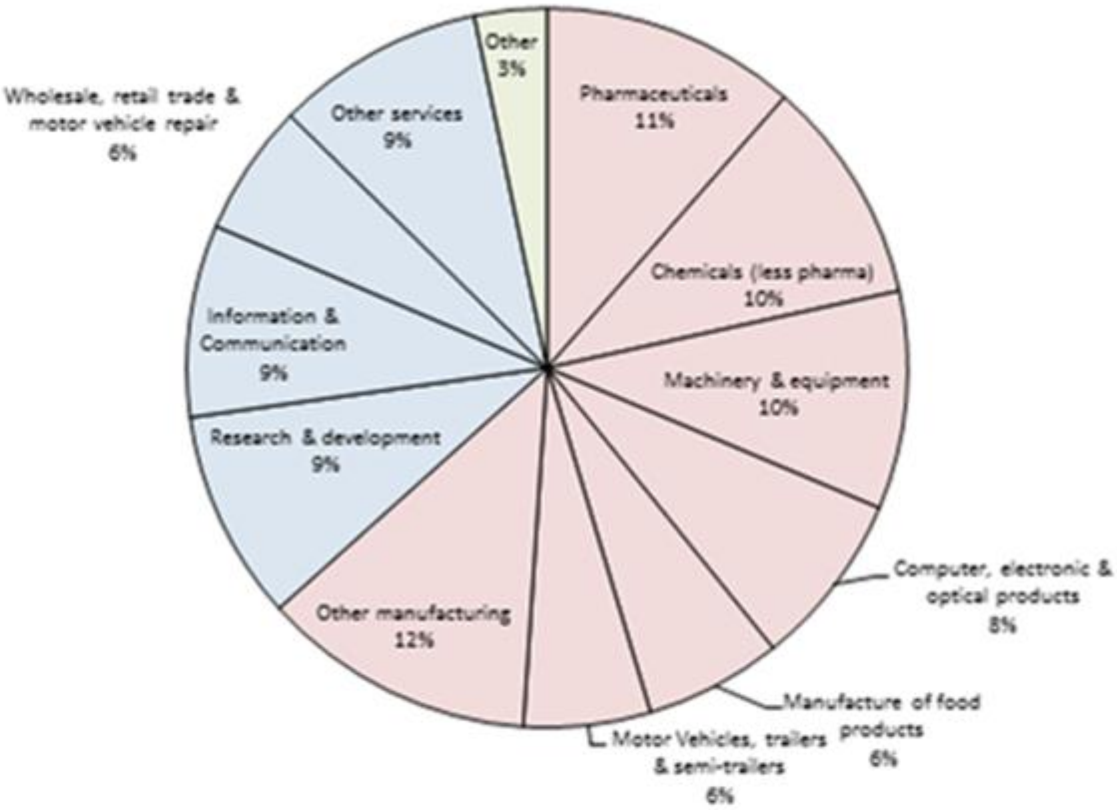
A second conclusion is that there is a high degree of concentration in the country distribution of inward R&D for the Netherlands and this is dominated by non-EU firms. For example, firms headquartered in the USA and Japan account for around half of all inward flows. The former are by far the largest investors with a share of around 40%. Japanese companies have more than doubled their expenditures since 2009. Indian companies have also risen in prominence, spending around €78 million in 2013. Of the EU firms the most prominent are German and French firms. The former has increased their expenditures more than 3-fold since 2009.

Figure 2 Inward BERD by country of origin: 2008 to 2013



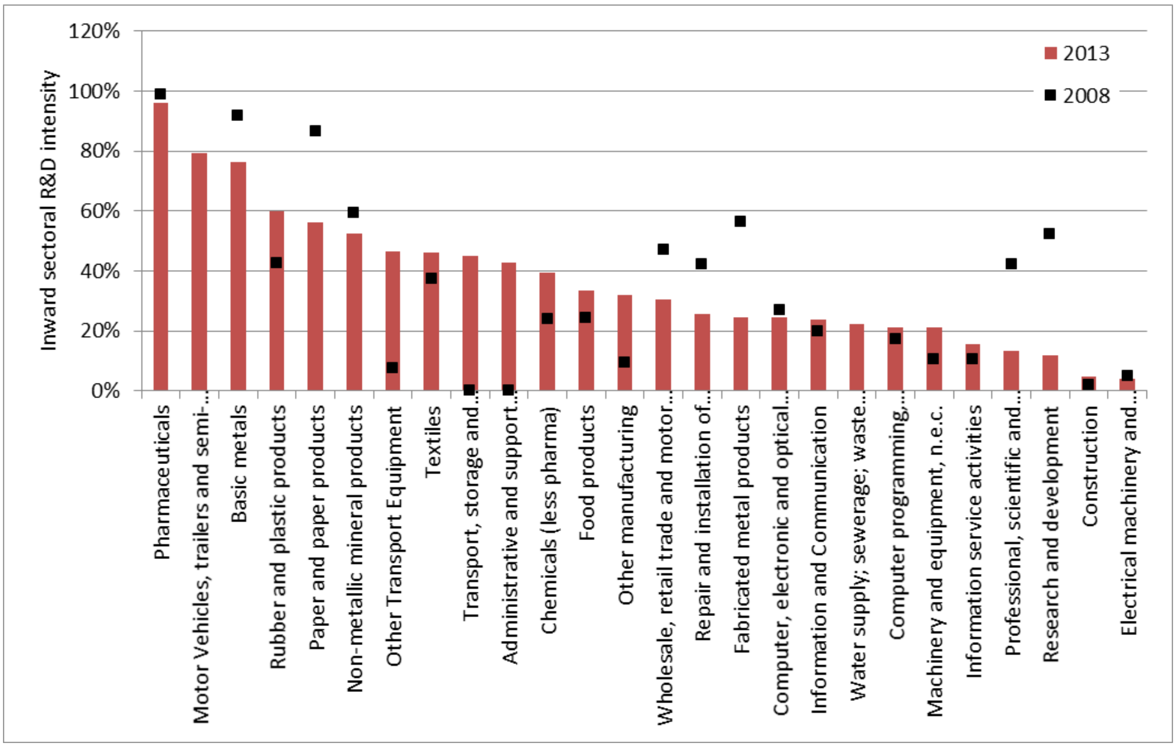
While Manufacturing remains the main focus of inward BERD, a third conclusion is that Service sectors have become relatively more important over time. The most prominent Manufacturing industries are Pharmaceuticals, Chemicals, Machinery and Equipment, and Computer, Electronic and Optical products. Within Services, the majority of foreign firms are concentrated in R&D services, ICT services, and Computer services.

Figure 3 Distribution of Inward BERD across Industries (2013)



A fourth conclusion is that an important trend has been the relative decline of the importance of Pharmaceuticals in inward BERD, going from 28% of the total in 2008 to 11% in 2013. This is also an industry where R&D is dominated by foreign firms. These four figures provide an indicative picture of the case-study material, the standard indicators that make up the core-metrics of the study, and what can be drawn from them. The next section explores conclusions at the more aggregate level.

Figure 4 Share of Inward BERD in Total BERD by Sector: 2008, 2013



Overview of the country reports

In this light, we move on to give a composite overview of the country reports. Table 2 is based on one of the key indicators employed in these reports, namely the share of Inward BERD in total. On the basis of this measure we divide the 24 European countries where we have sufficient data into 3 categories:

- ***High Internationalisation*** where the proportion of foreign firms' R&D exceeds 50%. [5]
- ***Medium Internationalisation*** where the proportion of foreign firms' R&D is between 20% and 50%.
- ***Low Internationalisation*** where the proportion of foreign firms' R&D is less than 20%.

We further categorise countries according to whether the level of internationalisation has *increased* or remained *stable* over time (from 2003 to 2013), by examining the trend in Inward R&D share.

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5 On average over the period 2003 to 2013.

Table 2 Patterns of inward R&D amongst European countries, 2007 to 2013

Level of Internationalisation	*Increasing*	*Stable*
High (Inward Share >50%)	Slovakia, Romania, Hungary, UK and Austria	Ireland, Belgium, Czech Republic
Medium (Inward Share between 20% and 50%)	Poland, Spain, Slovenia, and Bulgaria	Sweden, Germany, Netherlands, Norway, France and Italy
Low (Inward Share < 20%)	Denmark, Finland, Portugal, Estonia, Switzerland	

The results show that a vast majority of European countries (20 out of 24) have a **high** or a **medium** level of foreign penetration. Nine of these have **increasing** levels of internationalisation and 10 are in the **stable** category. Amongst the countries with relatively low levels of foreign R&D are two Scandinavian countries that are amongst the most innovative according to the IUS Scoreboard[6]: Denmark and Finland. Switzerland also falls into this category. On the other hand, 5 out of the 9 countries with high levels of foreign share are described by the IUS Scoreboard as performing well below the EU average. Amongst the large R&D performing countries the UK is an anomaly with very high share of inward R&D in total.

Table 3 gives an indication of the foreign firms that are investing in different European Countries. It shows that American firms are amongst the most important investors in R&D in European countries: in 11 out of the 20 countries listed here, they are either the largest or the second largest. However, their relative importance has decreased in a number of countries. Firms from Germany are also very important in 7 countries. The next section contains a more detailed comparison of these patterns.

6 http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

Table 3 Largest investors in European countries, by nationality (% of Total Inward BERD)

Country	Home Country of the Largest Investing Firms (2013)	Second Largest
Austria	Germany (47% ⇩)	US (15% ⇧)
Belgium	US (33% ⇩)	UK (20% ⇧)
Bulgaria	Germany (31% ⇧)	
Croatia	Netherlands (93%)	
Czech Republic	Germany (46% ⇔)	US (24% ⇧)
Finland	Switzerland (30% ⇧)	US (22% ⇩)
Germany	US (26% ⇩)	Netherlands (19% ⇧)
Hungary	Germany (34% ⇧)	France (15% ⇩)
Ireland Data for 2005 only	US (75%)	
Italy	US (27% ⇔)	Germany (14% ⇧)
Latvia	Denmark (44% ⇧)	Germany (22% ⇩)
Netherlands	US (40% ⇩)	
Norway	US (31% ⇩)	
Poland	US (27% ⇩)	UK (14% ⇧)
Romania	France (64%)	
Slovak Republic	Netherlands (34% ⇔)	France (23% ⇧)
Slovenia Data for 2007 only	Switzerland (71%)	
Spain	France (28% ⇧)	Netherlands (19% ⇩)
Sweden	UK (24% ⇧)	Germany (19% ⇩)
UK	US (40% ⇩)	Non EU (30% ⇧)

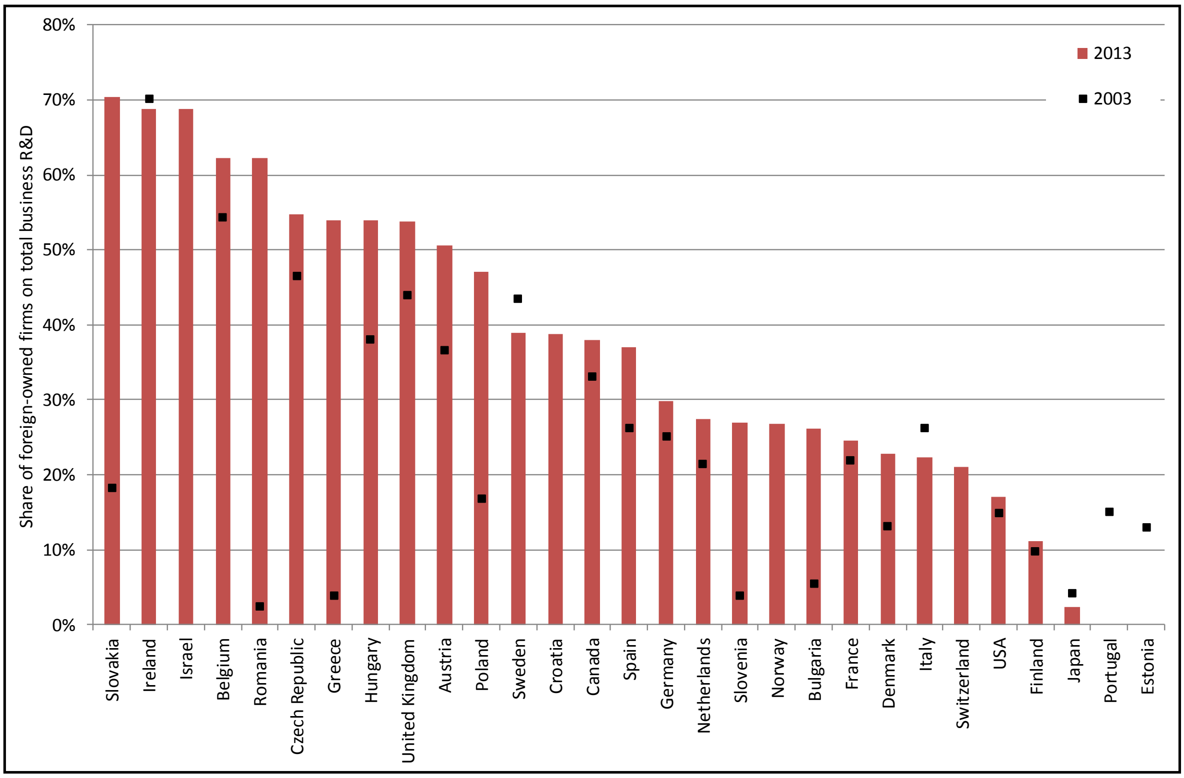
Note: ⇧ Increasing share; ⇩ Decreasing share; ⇔ little change

Inward BERD across countries and over time

This section compares the internationalisation of R&D across countries. We cover both inward and outward BERD as well as absolute BERD for the countries where data is available. The most important indicator employed in this chapter is *overall inward R&D intensity*. This indicator measures the ratio of inward BERD to total BERD (including foreign-owned and domestically owned BERD). It thus shows the ability of a national innovation system to attract inward investments of foreign-owned firms (see chapter 3).

We see in that the internationalisation of R&D is rising in the majority of countries where data is available. Only Ireland, Sweden, Italy and Japan experienced a decrease in the share of inward BERD between 2003 and 2013, while 19 countries show an increase. The internationalisation of R&D, however, emerges only slowly, as we can see from the almost stagnant inward R&D intensities in a number of countries, including large countries such as France or the US. Huge changes between 2003 and 2013 can only be observed in small and medium-sized countries, most notable some central and eastern European countries.

Figure 5 Overall inward R&D intensity (2003 and 2013)



Notes: Bulgaria, Croatia, Germany, Italy, Norway, Poland, Spain, Slovakia only NACE B-F in 2013; Denmark only NACE C and 2007 instead of 2003; Ireland, Japan, Switzerland and US 2012 instead of 2013; Finland 2011 instead of 2013; Hungary 2004 instead of 2003; Greece 1999 instead of 2003 and 2011 instead of 2013 and only NACE B-F; Poland only NACE C in 2003; Israel 2011 instead of 2013; Romania only NACE C and 2004 instead of 2003; data for Portugal in 2013 unreliable; Netherlands 2007 instead of 2003, no data for Estonia for 2013, no data for Croatia, Israel, Norway and Switzerland in 2003

Source: OECD, Eurostat, national statistical offices, own calculations

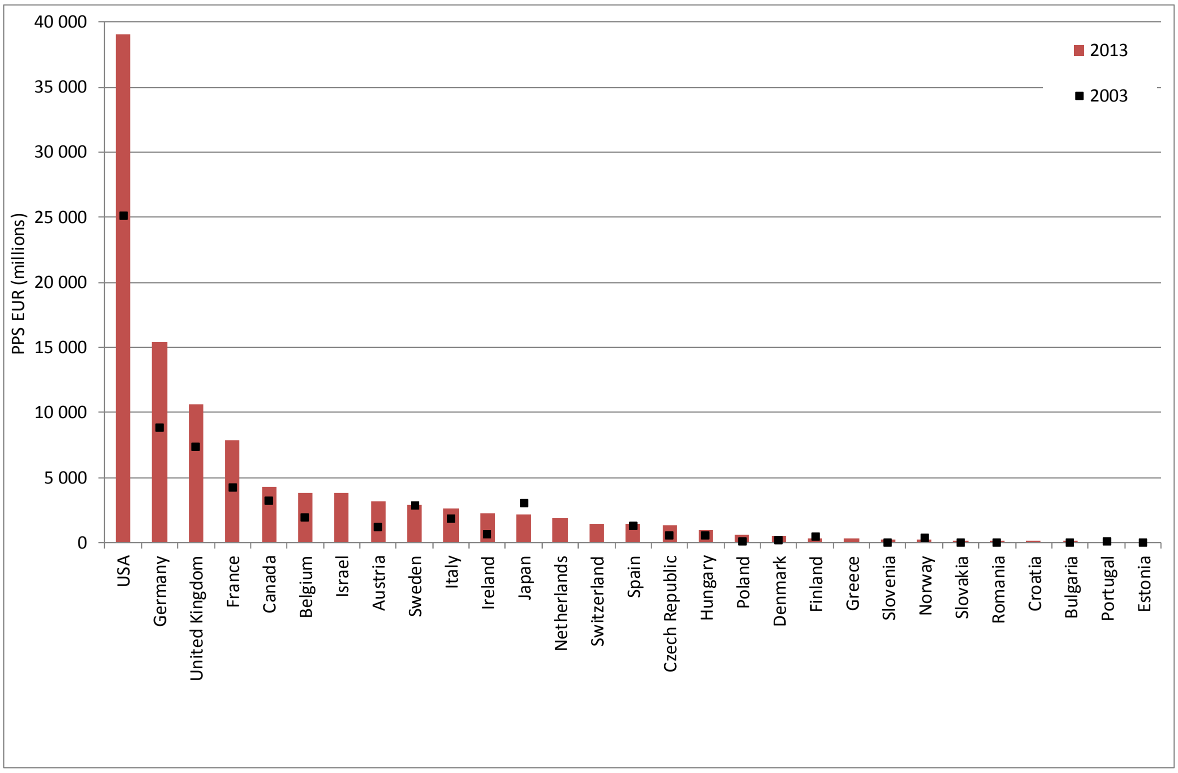
Overall inward R&D intensity is highest in small and medium-sized countries, and these countries are leading the process of R&D internationalisation. That is to say, inward BERD accounts for more than 50% of total BERD in Slovakia, Ireland, Israel, Belgium, Romania, the Czech Republic, Greece, Hungary, the UK and Austria. Large countries such as Germany, Spain, France or the U.S., in contrast, show inward R&D intensities of only 17% to 37% of total BERD.

But there are also important exceptions to this rule. For example, some countries including Switzerland, Demark or Finland show only low levels of R&D internationalisation. At the same time, the United Kingdom is a large country with a very high R&D internationalisation. It is difficult to find a common pattern in the figure, since overall inward R&D intensity seems to be unrelated to most science and technology policy or internationalisation indicators such as the share of aggregate R&D expenditures on GDP, share of persons with tertiary education on the workforce, positions of countries in the Innovation Union Scoreboard, or openness in terms of foreign trade, foreign direct investment or student’s mobility.

In order to get an impression of the magnitude of the process of R&D internationalisation, it is important to have a look not only at relative, but also at absolute inward BERD. Total inward BERD (see Figure 5), is highest in the largest countries, even if these countries have low inward R&D intensities. In comparison to all other countries observed here, the U.S. accounts for a lion’s share of total inward BERD.

In absolute numbers, inward BERD increased in every single country between 2003 and 2013, with the exception of Japan. Ireland, Sweden and Italy reported a decrease in relative terms, but have a rising inward BERD in absolute terms. Again, the EU-13 countries show lowest total inward BERD among the EU-28 countries, whereas the EU-15 countries are ranked highest.

Figure 6: Total Inward BERD (PPS EUR, 2003 and 2013)



Notes: See Figure 5
Source: national statistical offices, own calculations

The importance of inward BERD for different countries can also be judged in relation to overall economic activity of the country, i.e. gross domestic product (GDP). Here, we see that EU-15 countries tend to have higher and stable levels of inward BERD as % of GDP, while EU-13 countries tend to have lower levels but higher growth rates). In 2003 all countries with an inward BERD share of more than 0.5% of GDP were small and medium sized EU-15 countries; in 2013, three EU-13 countries (Czech Republic, Hungary and Slovenia) and two large EU countries (Germany and the United Kingdom) joint this group. In general, total inward BERD as a % of GDP is fairly stable over time for the majority of the countries.

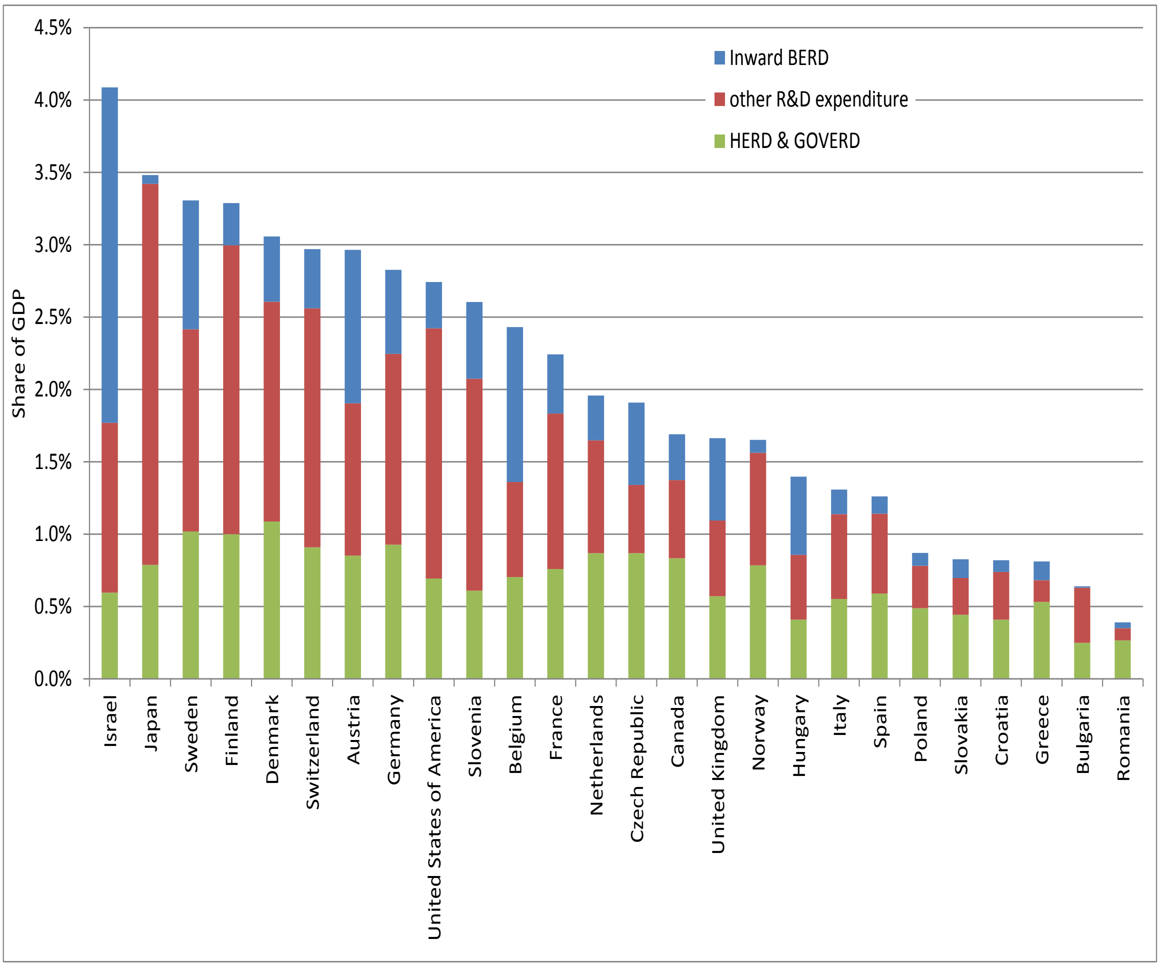
Most non-EU countries - including Canada, Switzerland, the USA and Norway - have medium and stable levels of inward BERD as % of GDP. The highest inward BERD as % of GDP by far is Israel. Israel is also the OECD country with the highest BERD as a % of GDP and third highest inward BERD intensity.

A share of 3% of GDP to be invested in R&D is one of the targets of the Europe 2020 strategy. Foreign-owned firms considerably contribute to this target in some countries, as the following figure shows. Here, total R&D expenditures is divided into inward BERD, higher education R&D expenditures (HERD) and governmental R&D expenditures (GOVERD), and other R&D expenditure.

The share of foreign-owned firms is around 1 percentage point in Austria, Belgium, and Sweden, and around half a percentage point in the Czech Republic, the UK, and Hungary. The figure shows that this is approximately the share of public R&D

expenditures in these countries, so foreign-owned firms are an important driver of knowledge intensity. In contrast, the share of foreign-owned firms is only low in some South- and South-East European countries and does not match public R&D in these countries.

Figure 7: Inward BERD and other national R&D expenditures (% of GDP, 2013)

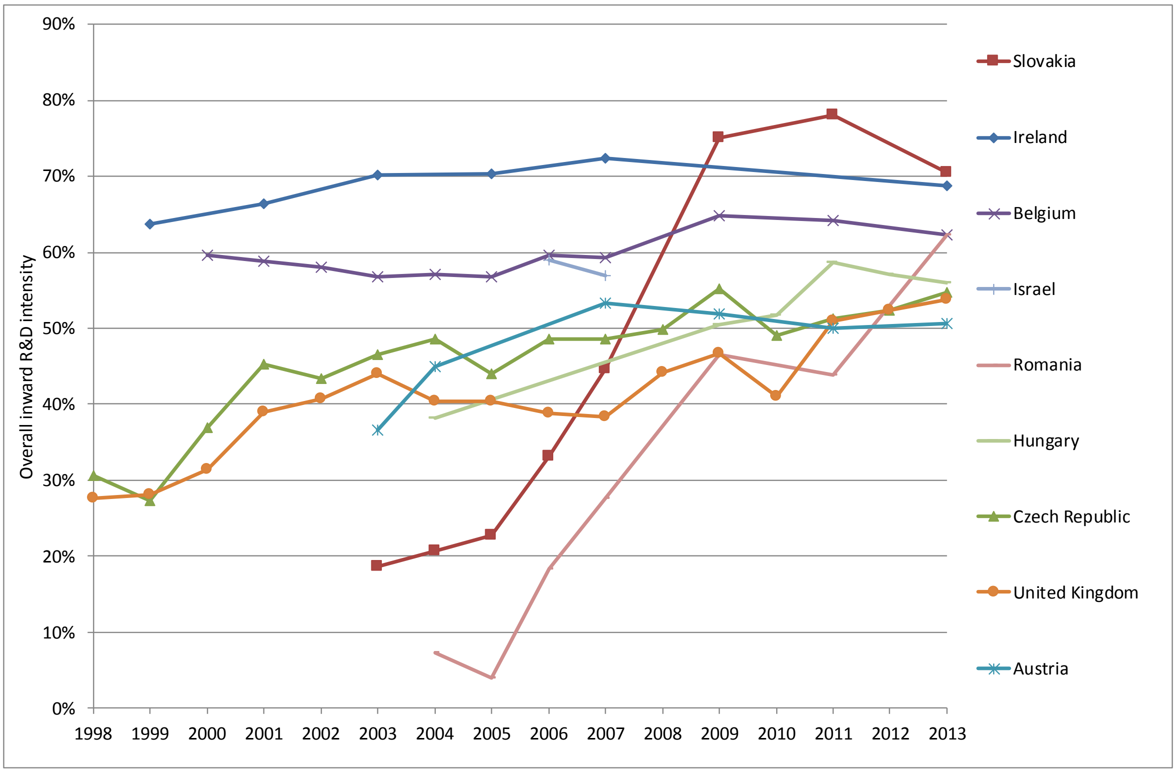


Notes: See Figure 5 for included inward BERD data

Source: OECD, Eurostat, national statistical offices, own calculations

The following figures show the overall inward R&D intensity over time. It is evident that overall inward R&D intensity has been growing in almost all countries over the last decade. A constant and slightly increasing level of inward R&D intensity is observed in most of the high intensity countries (Figure 8) and low intensity countries (Figure 10). A considerable level of volatility in contrast can be found in the medium intensity countries (Figure 9).

Figure 8: Overall inward R&D intensity (1998 to 2013, high intensity countries)

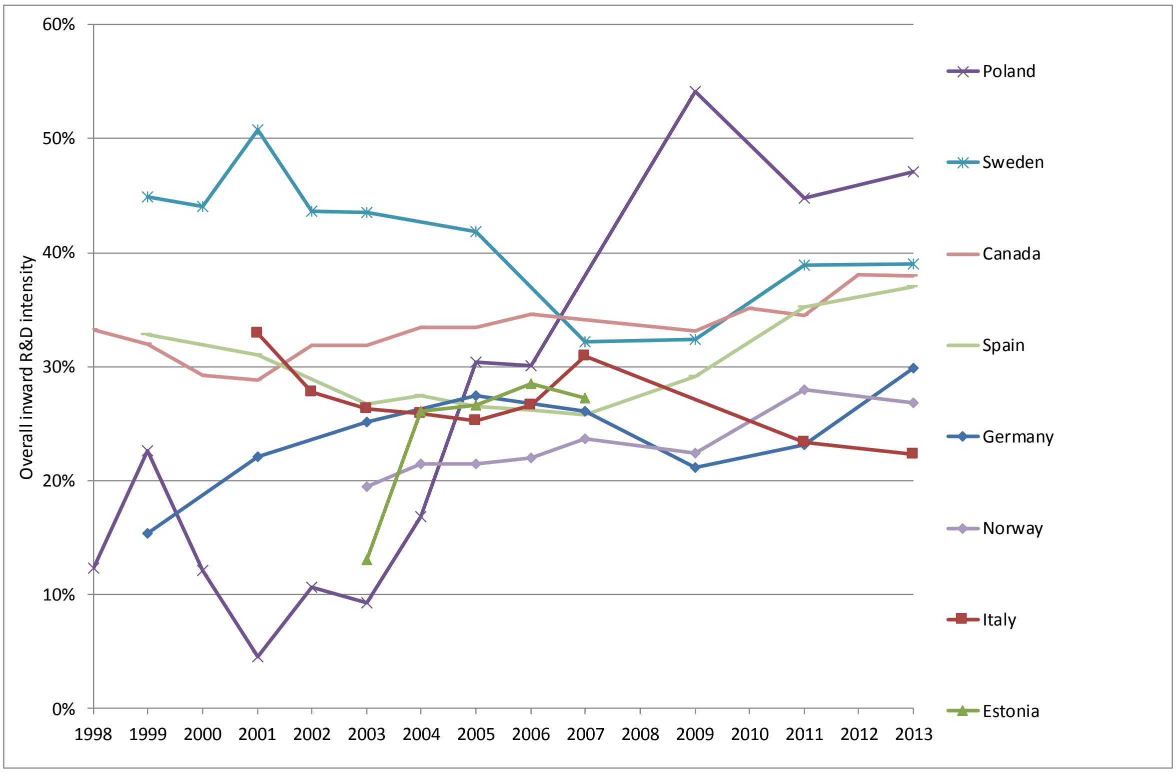


Notes: Slovakia 2013 B-F; Slovakia 2009 NACE C. Romania 2009, 2011 and 2013 NACE C
Source: OECD, Eurostat, national statistical offices, own calculations

Large increases and decreases are mostly found in small countries and EU-13 countries. This might be due to the fact that inward BERD in absolute terms is lower in these countries (see Figure 10). There are only a few foreign-owned affiliates in these countries, and R&D expenditures of an additional foreign-owned subsidiary can strongly affect total inward R&D intensity. This is for example the case in Slovakia, the Czech Republic (Figure 8), as well as in Slovenia or Poland (Figure 9). Especially in the medium intensity countries (Figure 9), a convergence towards an inward R&D intensity level of about 25% to 40% can be observed.

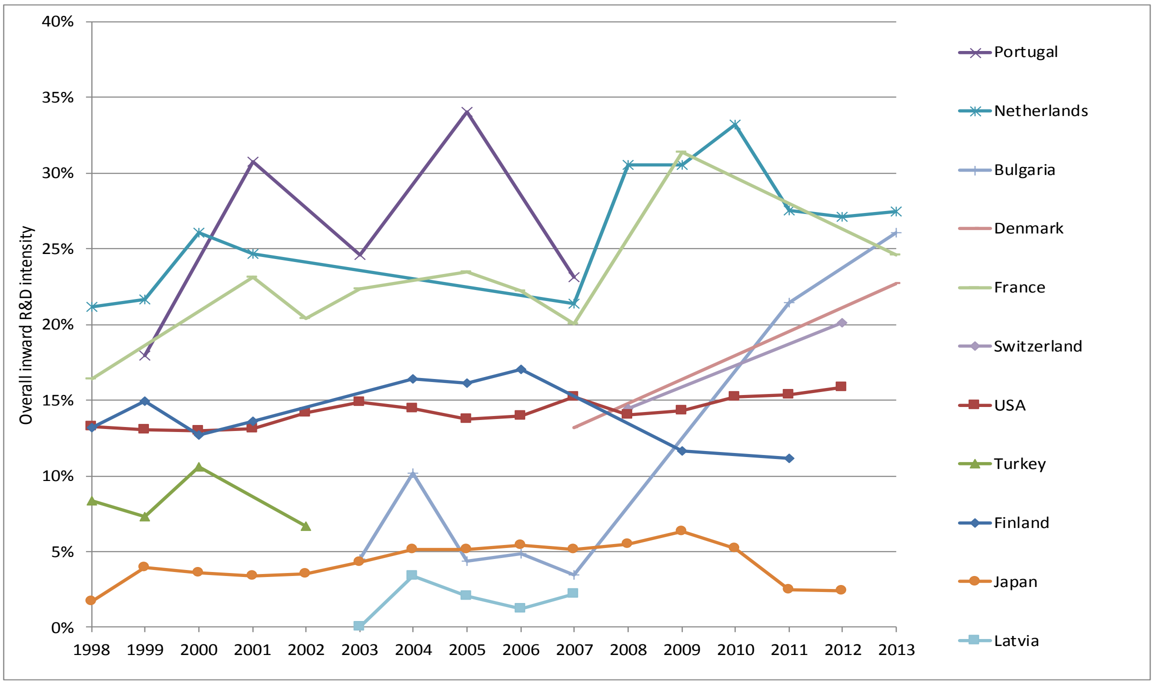
The largest increases of overall inward R&D intensity can be found for the EU-13 countries, examples are Slovakia, Poland or Slovenia. This might be traced back to widely known R&D internationalisation patterns: in most cases, the internationalisation of R&D follows the internationalisation of production. These countries have received huge inflows of foreign direct investment since they joined the European Union, and foreign-owned affiliates in these countries gradually upgrade their portfolio of activities, starting from production and move into product development. This development is certainly an encouraging sign for the quality of the location and for the future development of these countries, although the contributions of foreign-owned firms to overall R&D expenditures are still small, as could be seen in Figure 7.

Figure 9: Overall inward R&D intensity (1998 to 2013, medium intensity countries)



Notes: Croatia NACE B-F, Norway, Poland and Spain 2011 and 2013 NACE B-F
Source: OECD, Eurostat, national statistical offices, own calculations

Figure 10: Overall inward R&D intensity (1998 to 2013, low intensity countries)



Notes: Denmark NACE C; France 2009 NACE C, no data for Turkey and Latvia in recent years
Source: OECD, Eurostat, national statistical offices, own calculations

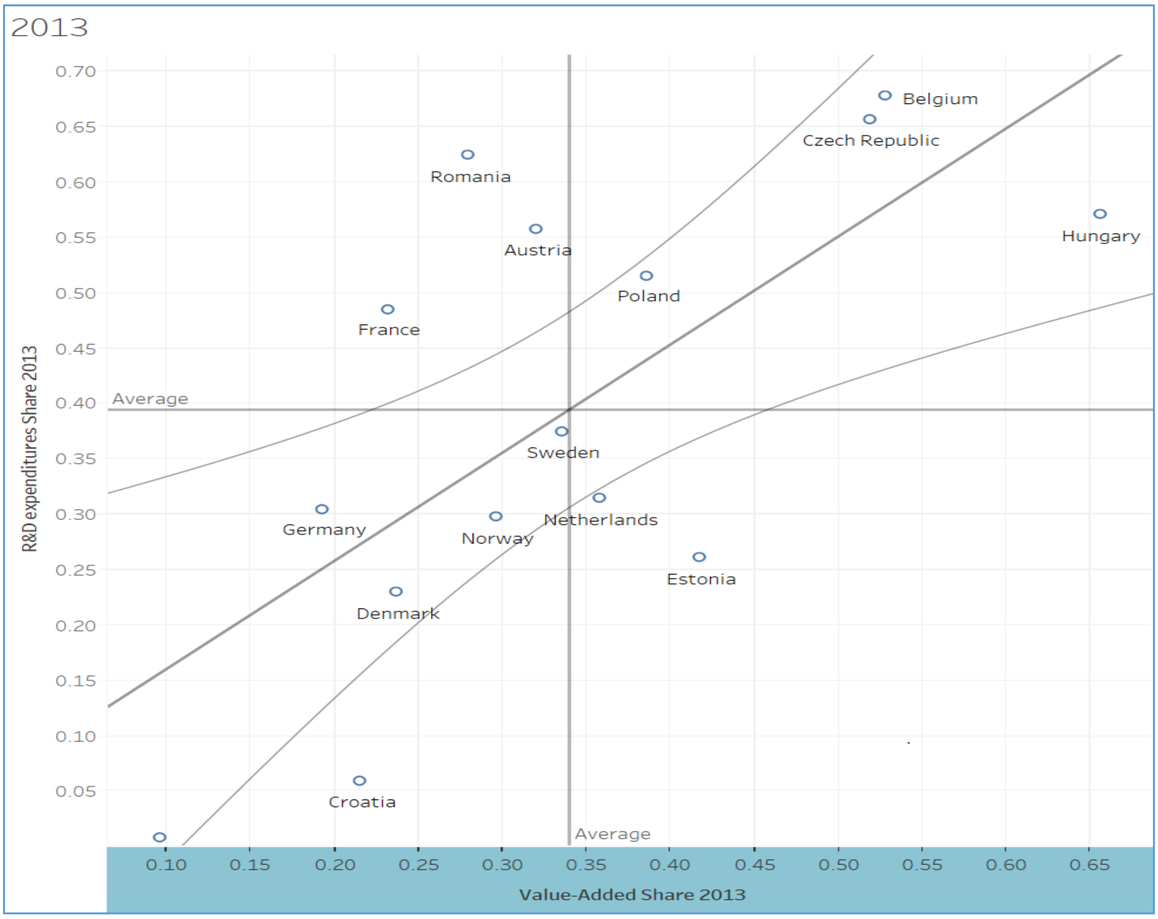
BERD intensity and a relative measure of economic structure

inward BERD intensity (the share of inward BERD on total BERD) can furthermore be related to a measure of how significant the economic activity of foreign-owned firms is in a given country. To do this, this section uses a comparison between the share of value-added of foreign-owned firms on the GDP of the host country.

This relationship helps to contextualise the intensity of inward BERD in different countries (for which we have data) in terms of a common measure of the economic structure of the country. This common measure helps us contextualise the inward BERD discussed in the case studies and to compare any differences that emerge in the internationalisation of business R&D across different country contexts and across time.

Error! Reference source not found. Figure 11 provides a snapshot of this relationship for selected countries using Eurostat data for the share of foreign activity (value added at factor cost)/ gross value added) and BERD intensity (inward BERD/total BERD). It indicates the relative position of countries in terms of the importance of foreign firms in their economies. Countries that lie right of the upright line are those where the value-added of foreign firms is higher than average (around 33 percent for the countries under consideration here). Countries that lie above the horizontal line are those where the relative importance of BERD flows is higher in terms of total BERD carried out in the country.

Figure 11: The intensity of Inward BERD (y-axis) in terms of the value-added of foreign-owned firms (x-axis) for selected countries: 2013



Source: OECD and Eurostat
Tableau:
https://public.tableau.com/profile/publish/Scatterplot_example2011/2009#!/publish-confirm

Based on countries for which we have data for both dimensions, we can substantiate the picture that has emerged so far, namely that foreign-owned firms are among the most active performers of research and development (R&D) in a number of countries. In general, we find the average intensity of inward BERD for these countries at around 40 for both years. However, this intensity increases in a number of cases, notably Romania. In addition, the figure indicates the importance of foreign firms in the national economies (based on value-added).

The diagonal line (with confidence interval) indicates a situation where inward BERD flows most closely reflect the economic structure of the country. All countries which lie close to or on the diagonal are countries where inward BERD flows reflect the economic structure of the country, while those above or below the diagonal indicate countries where foreign firms do more (less) R&D than expected. The implication is that these are cases where there are other factors that can explain the deviance. Such factors may include the research intensity of the sectors of foreign-owned firms in the country or other factors (e.g. access to skilled workforce, market-size, incentives) that explain a higher (lower) attractiveness for foreign firms to carry out R&D in the specific countries. These drivers will be further analysed in Chapter 4 via the sector studies and more formally in Chapter 5 in the econometric exercise.

Chapter 3.

Chapter 3. Country linkages and inward flow from third countries

Bernhard Dachs, Georg Zahradnik, Thomas Scherngell and Parimal Patel

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Countries vary considerably in the degree foreign-owned firms contribute to total R&D expenditures of the business sector. Moreover, there are also major differences between countries in the relative importance of foreign-owned firms from different home countries.

In this chapter we focus on the relative importance of various home countries. Moreover, we consider the question if the internationalisation of R&D in different countries is mainly due to the activities of European firms (intra-Europe internationalisation) or non-European firms, which are mainly US firms. The chapter measures the role of different home countries on overall inward BERD by the share of inward BERD from a particular country on total inward BERD. We distinguish between EU-28 and non EU-28 member countries. Further, Germany and the USA are listed separately, as they are the countries with the largest outward BERD.

Cross-country variations in the share of home countries

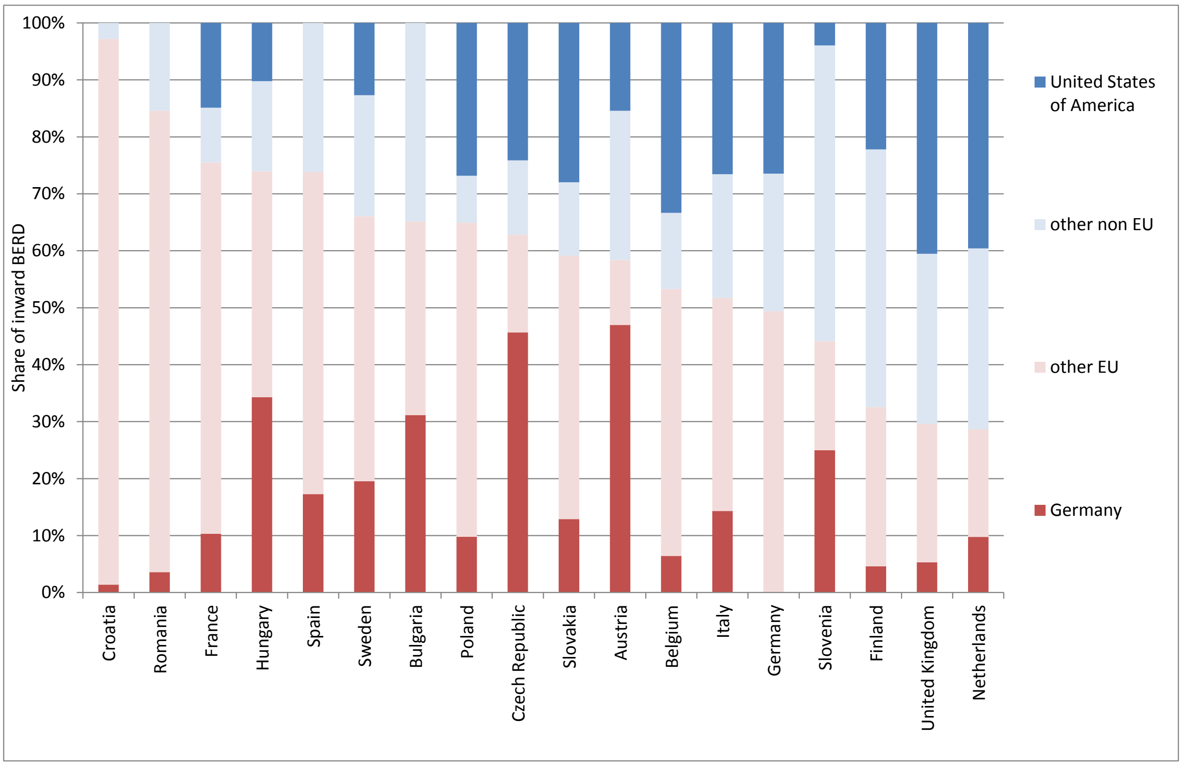
We begin with the relative importance of European countries vis-a-vis the United States as the main sources for inward BERD. In the figure below we have divided total inward BERD into the shares from the US, Germany, other EU and non-EU countries.

We see that the share of Germany is highest in the neighbouring countries Austria and Czech Republic (but not France and Poland). Croatia and Hungary have virtually no inward BERD from non-European firms, while the opposite is true for the UK, the Netherlands or Finland. In the latter countries, the share of non-EU firms on total inward BERD is around 70%. The United Kingdom and the Netherlands in particular can be seen as gateways for non-European firms into the EU, and as a preferred location for EU regional headquarters as we research facilities. It has to be seen if the UK can still serve this role in the future.

France and Spain are two large countries that lie on the other side of the distribution, hosting mainly inward BERD from other EU countries. Between these two extremes, virtually every distribution between European and non-European firms can be observed. Belgium, France and Sweden lie in the middle of this distribution.

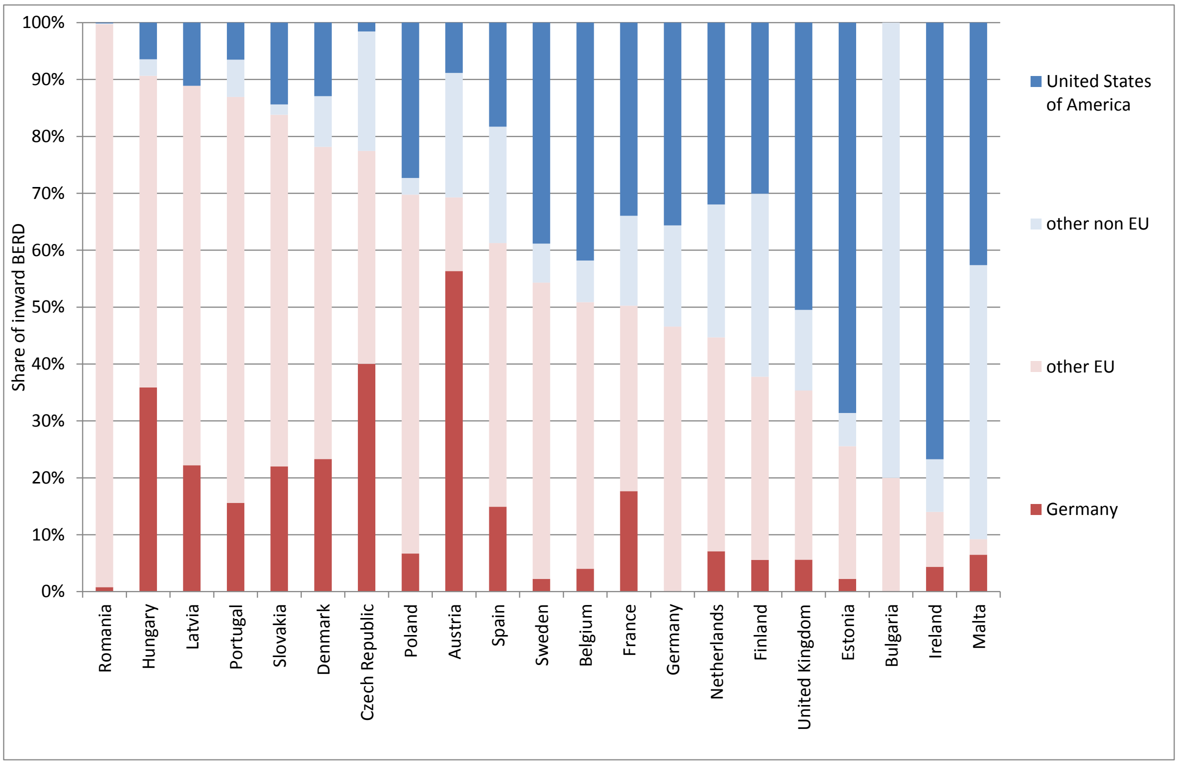
For comparisons, Figure 13 presents similar data for 2007. This figures is also important because it includes some country where no data is available for 2013. We see that in addition to the UK and Ireland, also Malta and Estonia have considerable inflows from outside the EU. In the case of Ireland and Malta, this may be explained by the common language with the US. Compared to 2007, Austria, Spain and France moved to higher shares of intra-EU inward investment, while the Netherlands moved in the other direction.

Figure 12 Inward BERD from the US, Germany, other EU and non-EU countries as a share of inward BERD, 2013



Notes: US included in other non EU in BG, ES, RO and SI; FI 2011
Source: OECD, Eurostat, national statistical offices, own calculations

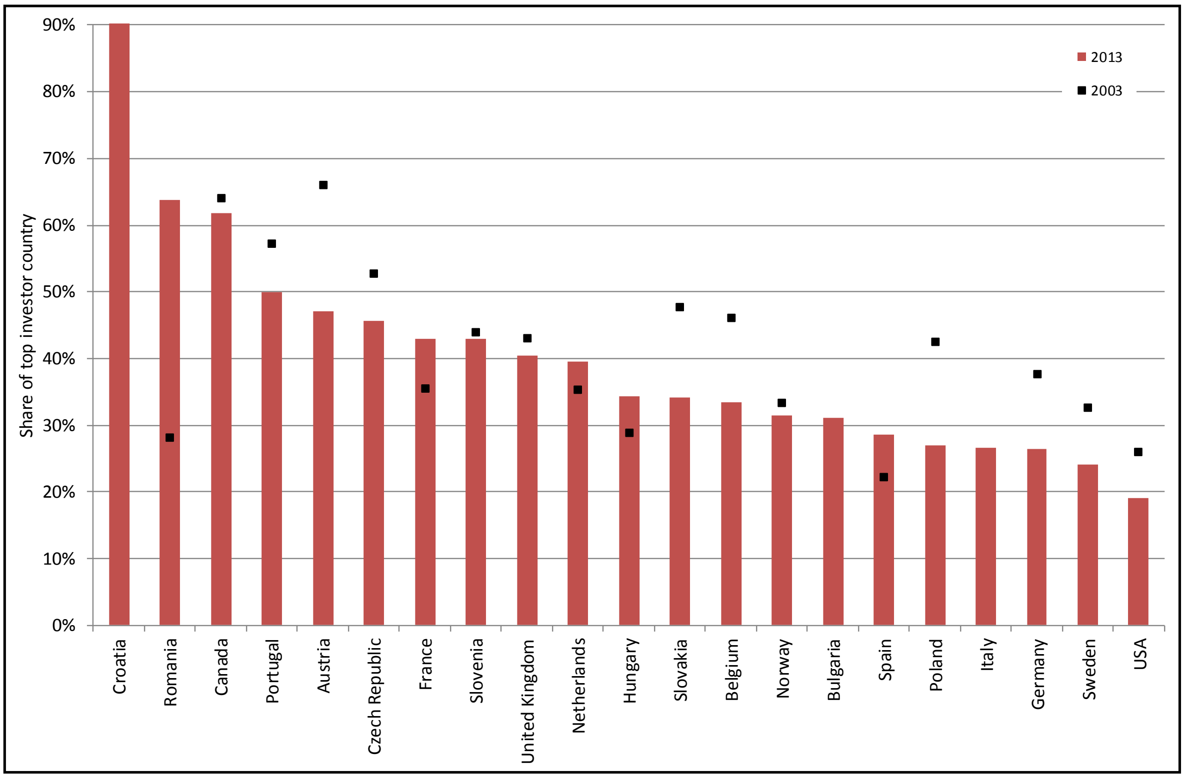
Figure 13: Inward BERD from selected countries as a share of total inward BERD, 2007



Notes: US included in other non EU in Bulgaria, Germany included in other EU in Bulgaria
Source: OECD, Eurostat, national statistical offices, own calculations

Distance and proximity - whether it be socio-cultural or spatial distance - might have an impact the share of the top investor country in total inward BERD as well. We conclude that this is the case for Austria, Hungary and the Czech Republic, where the largest shares of inward BERD come from Germany, the neighbour of two of the three countries. But Canada or Belgium also benefit from inward BERD from a large neighbouring country. Figure 14 shows the share of the top investor country in total inward BERD. There are eight countries with shares of over 50%. This indicates that there are strong relationships between single countries which may have different reasons.

Figure 14: Share of the top investor country in total Inward BERD, 2003 and 2013



Note: Bulgaria, Croatia and Italy missing in 2003.

Source: OECD, Eurostat, national statistical offices, own calculations

Single investment decisions of foreign-owned firms may have a large impact on the national level when the absolute size of inward and total BERD in the country is small. Examples are Bulgaria, Romania, Slovenia or Slovakia. As mentioned above, this is the very reason why these countries also show a high volatility of inward R&D intensities. The case of Ireland is somewhat different, as total inward BERD in Ireland is higher than in the countries mentioned above. Ireland has focussed on attracting inward FDI from the US; this policy has led to considerable increases in FDI inward stocks, above all from the United. The level of inward FDI stock in Ireland can be compared to that of Canada. Furthermore, one determinant, albeit not observable from this figure, might be the technological proximity of two countries. The sector case studies, specifically on computer services, sheds more light on this question.

It is striking that the share of the top investor country declines in the majority of countries between 2003 and 2013. Thus, we assume that the internationalisation of R&D became more diverse, and evolved from regional integration with neighbouring countries to true international integration where dependencies on a single country are declining and the concentration of controlling countries is decreasing. This is what we can also learn from Figure 14 above.

Country Linkages

This section moves on to describe the structure of cross-country linkages using a network analytics perspective. It is worth noting that data available from the current project does not fulfil all requirements for conducting a systematic Social Network Analysis (SNA) due to a significant amount missing data for important countries, such as China. SNA – in contrast to conventional statistical methods usually based on normality assumptions – missing values dramatically bias network-level statistics and inferences (see e.g. Kossinets 2006). However, we can rely on the strong portfolio of

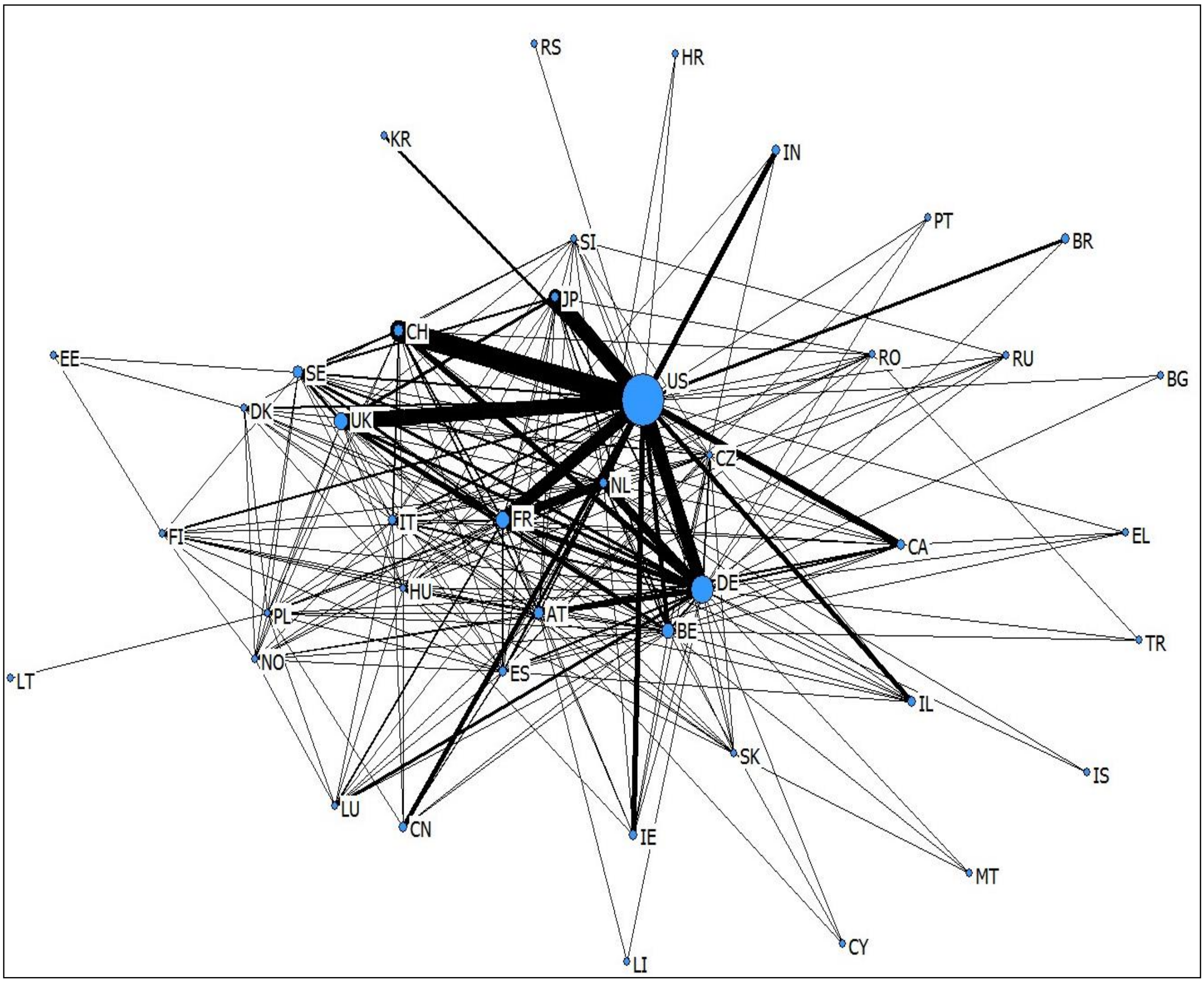
SNA visualisation tools to illustrative and describe the structure of cross-country R&D linkages in an effective way.

For the analysis of country networks, two types network visualisation have recently come into fairly wide use (see e.g. Scherngell 2013). *Spring model inspired visualisations* on the one hand, and *spatial network maps* on the others. Spring-model-inspired visualisations rely on information theoretic techniques, usually employed when focusing on network structures and dynamics, while spatial networks are used to illustrate the spatial distribution of network linkages. Given our focus on global R&D internationalisation, we use the spring-model-inspired approach to illustrate the global cross-country network of R&D investments. The spatial network approach is taken to describe the European distribution of linkages, pointing to integration tendencies in comparison to earlier studies (Scherngell 2014).

Figure 15 focuses on the global perspective. It illustrates the network of R&D investment flows using a standard approach from *spectral graph analysis* so that countries with a relatively higher intensity of bilateral BERD flows between them are positioned nearer to each other. The node-size corresponds to the country´s inward BERD, while the line-size corresponds to the total flows between any two countries.

Although the network becomes more integrated, the US still represents the central hub showing the highest interaction intensity with other countries. Interestingly, the most important partner country in terms of absolute size is now Germany (the UK held this position in earlier studies), followed by UK and Switzerland. The latter is the most important partner of the US relative to the country size. The results from Figure 15 – as in earlier studies – still do not point to the existence of specific groups of countries that are highly integrated with each other, but only loosely related to other countries. Moreover, we may assume that the influence of geographical distance has somewhat decreased; only for some areas of the network countries geographically located nearer to each are also placed nearer to each other in the network visualisation, such as the Scandinavian countries.

Figure 15: Network visualisation of R&D investment flows between countries 2013



Note: Vertex positions were determined using spectral graph analytic methods according to the normalized Laplacian so that countries that are strongly interconnected are positioned nearer to each other (for details see the discussion of the normalized graph Laplacian in, e.g., Higham and Kibble 2004). With these positions, the network was then visualized using UCINet 6.303. Node size corresponds to the weighted degree centrality of a country that is defined as the sum of a country´s inward and outward R&D investment flows, the strength of the lines corresponds to total R&D investment between any two countries.

Comparing the results with those from the previous study, it becomes clear that (i) a more diversified set of countries participates in the network and (ii) that the intensity is higher. In general, the network becomes more integrated globally and somewhat less concentrated on the US. Country-pairs with no US participation become increasingly important, such as those involving France and Netherlands, Germany and Netherlands or Sweden and UK. In comparison to earlier studies, China, Brazil and India enter the network but their role is still underestimated due to data limitations.

Figure 16 complements the network analytic visualisation in Figure 15 by focusing on the spatial structure of the network of inward BERD, in this case limited to European countries. Here, we do not position the nodes according to methods from spectral graph theory, but according to their spatial location, i.e. the capital city is used to position the respective country. Again, node-size corresponds to the sum of a country´s inward BERD, while the line size corresponds to the total flows between any two countries.

The results clearly reveal a clustering of R&D inward BERD in the centre of Europe while the periphery is participating to a lower extent. Germany now appears as the central hub showing a high interaction intensity in particular with the direct spatial neighbours France, Netherlands, Switzerland and Austria. This largely confirms results from earlier studies (Scherngell 2014). However, corresponding to the global picture received, network integration tendencies also become visible for the European case, in particular concerning the participation intensity of Eastern European countries that are much more integrated in the network of 2013. This tightened regional integration also fits with the evidence of the Europe's manufacturing activity is increasingly concentrated in a Central European manufacturing core, centred around Germany with Austria, the Czech Republic, Poland, Slovakia and Hungary as the other members (Stehrer and Stöllinger 2015).

Figure 16**: Patterns of R&D investment flows in Europe 2013**

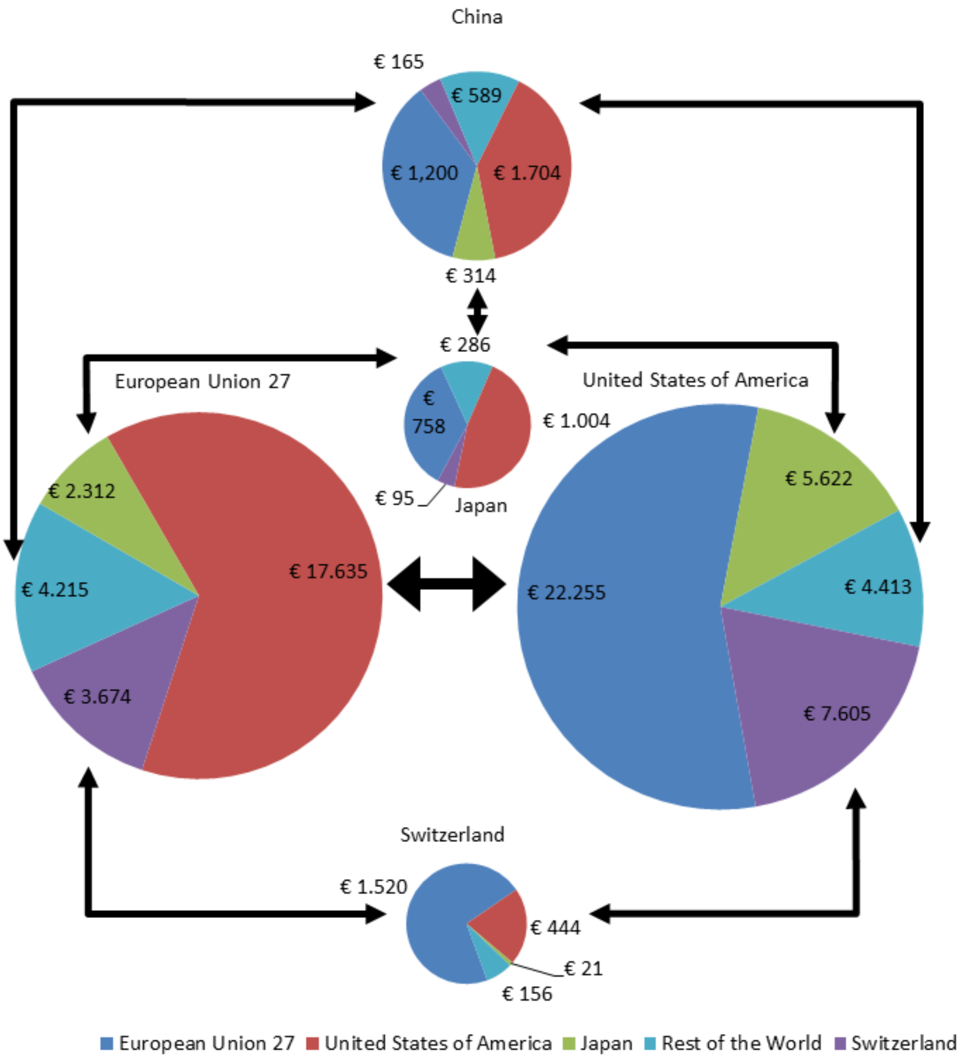
Source: own visualization.

The global perspective

To round off this section on interlinkages, we move from Europe to a global perspective of R&D internationalisation, by focussing on the relations between the EU, the US, Switzerland, Japan and China. To illustrate the issue of global integration of business R&D, Figure 17 summarises the relations between these countries and country groups as measured by inward BERD. The size of each circle represents total inward BERD. Relations between the countries are illustrated with arrows. For the US, EU, Japan, China and Switzerland, inward BERD is split into the shares of US, EU, Japanese, Swiss firms and in the share of firms from the rest of the world.

This figure encapsulates central information about the internationalisation of R&D expenditures. The relations included in the figure cover the lion's share of R&D expenditures of foreign-owned firms worldwide. In 2013, US firms spent around 18 billion EUR on R&D in the European Union. R&D expenditures of EU firms in the US is about 22 billion EUR. Inward BERD from the US towards the EU-28, and vice versa, accounts for more than half of all inward BERD worldwide, if inward BERD between EU member states is excluded. R&D expenditures of Japanese firms in the US (5.6 billion EUR) and the EU (2.3 billion EUR) as well as R&D expenditures of Swiss firms in the EU-28 (3.7 billion EUR), and in the US (4.5 billion EUR) are the most important remaining cross-border links by inward BERD. Inward BERD from countries summarised under "Rest of the World" appears, if at all, almost entirely in the US or the EU-28. The single most important country included in the "Rest of the World" is Canada, accounting for about 0.9 billion EUR in the EU and another 0.4 billion in the US. Total inward BERD in China with about 4.3 billion EUR is significantly smaller than the corresponding inward BERD in the US or the EU.

Figure 17: Inward BERD between the EU, the US, Japan, China and Switzerland (2013, EUR Mio, current prices)



Notes: No country breakdowns for China and Japan are available, country shares based on PCT patent data (average 2011-2013); values for EU exclude service industries in most countries, see notes for *Figure 5*.

Source: OECD, Eurostat, national statistical offices, own calculations

However, there are major gaps in Chinese inward BERD data as no county breakdown is available. PCT patent data on domestic patent inventions owned by foreign organisations suggests that US firms account for about 40% (1.7 billion EUR) and EU firms account for about 36% (1.5 billion EUR) of total inward BERD in China. According to PCT patent data, Swiss and Japanese, both countries play a limited role and likely have together less than 500 million EUR of R&D expenditures in China. Data on inward BERD in India is even less complete and not displayed in the figure. US outward data indicates higher growth rates for inward BERD in India compared to China. Inward BERD from emerging economies including China and India is also included in "Rest of the World" for the EU and the US. While there are some gaps in the data, the magnitude of these investments is still very small. Chinese firms account for about 300 million EUR of inward BERD in the EU as well as in the US, while Indian firms have R&D expenditures of about 1 million EUR each in the EU and the US.

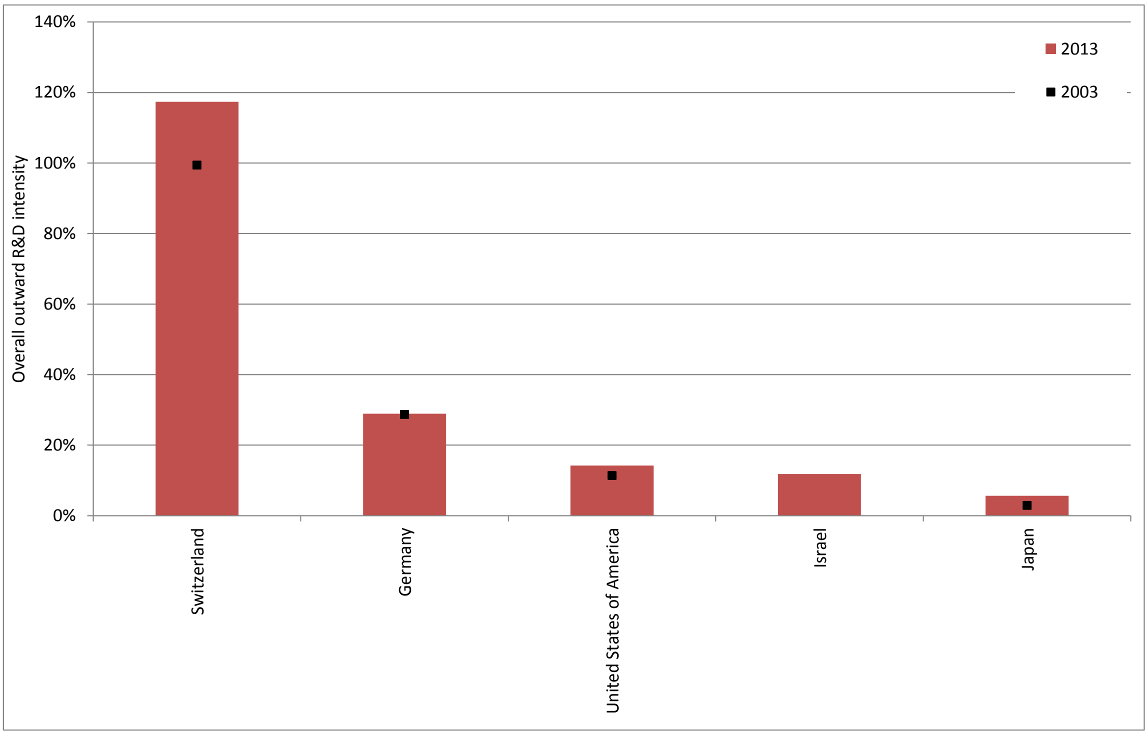
Total inward BERD in China with about 4.3 billion EUR is significantly smaller than the corresponding inward BERD in the US or the EU[7].

Compared with 2007 (cf. Dachs et al, 2012), the shares of different countries and country groups on inward BERD at the global level are surprisingly stable. The big question, however, is the current and future role of China and India. There is no doubt that inward BERD attracted by these countries has increased considerably; we also know that these amounts are only poorly captured in the data so far. Another open question is the size of R&D internationalisation in services, which is increasing fast, but is not well covered by the data. We try to explore these cases with available data below.

Outward BERD across countries over time

This overview of the interlinkages of countries and regions via BERD flows lays the basis for the outward dimension or, in other words, the R&D activities of firms outside of their home countries. There is considerably less outward BERD data available than inward BERD data. Therefore, the cross-country comparison is limited to a small number of countries. Data for France, the United Kingdom, the Netherlands, Spain, as well as all emerging economies are missing.

Figure 18: Overall outward R&D intensity (2003 and 2013)



Notes: Switzerland 2012 instead of 2013; Germany and Israel 2011 instead of 2012, Switzerland 2004 instead of 2003

Source: OECD, Eurostat, national statistical offices, own calculations

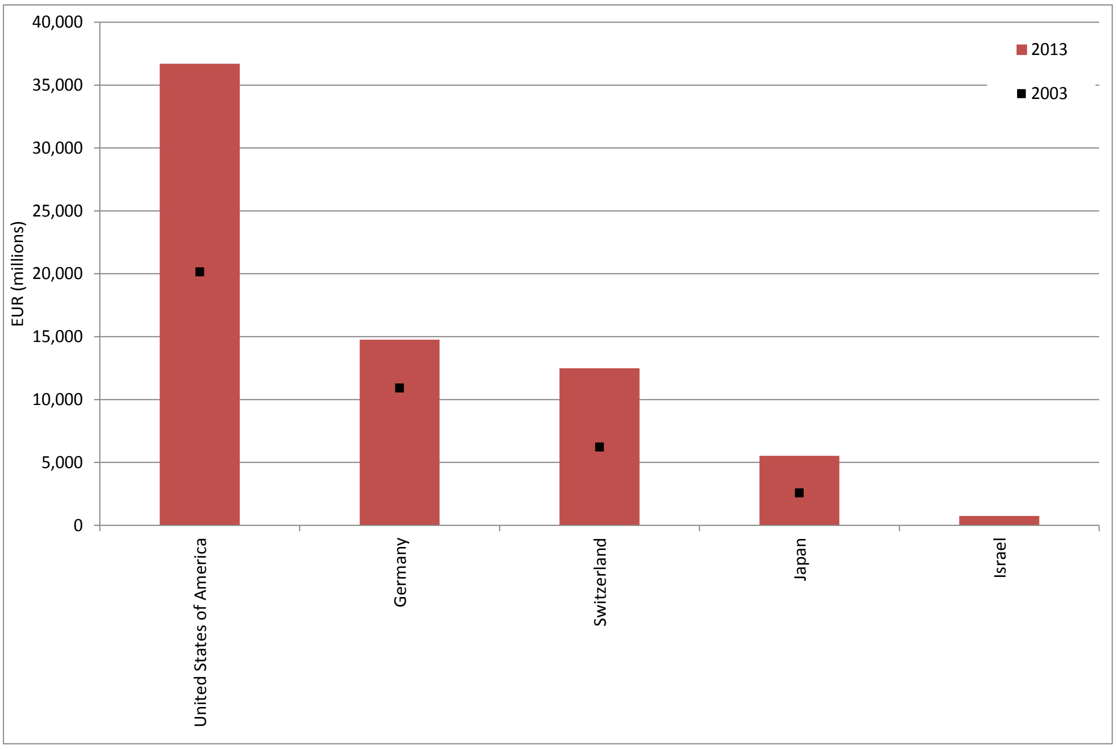
Corresponding to the overall inward R&D intensity, Figure 18 displays overall outward R&D intensity for all countries where recent data is available. This indicator is defined as outward BERD as a share of total national BERD (including domestic and inward BERD) in the Annex (Annex Figure 1) presents the development of overall outward R&D intensity over time for some countries.

[7] It should be noted that, if differences in purchasing power between the EU and China are taken into account total inward BERD in China would be significantly higher (ca. 7 billion PPS EUR) but still well below the EU or US level.

Overall outward R&D intensity has increased in all countries. This indicates that R&D expenditures of domestic firms abroad has increased faster than total national R&D expenditures. Particular attention should be given in the Figure to Switzerland, where outward R&D intensity is almost 120% in 2012 and at or above 100% since - at least - the late 1990s. In other words, R&D expenditures of Swiss firms abroad is higher than total business R&D expenditures in Switzerland. Another country with a large outward R&D intensity is Germany. While no recent data is available for Sweden, data from 2007 (see country report annex) also shows a high outward intensity of almost 50%.

How can we explain the exceptional value of Switzerland? One explanation is the combination of a limited domestic market, a large stock of foreign direct investment abroad and a number of large multinational firms. These firms have a need to delocalize R&D to bring it closer to large foreign markets. Moreover, foreign R&D can augment and complement the domestic knowledge base, provided that knowledge flows sufficiently towards the MNEs' headquarters. Germany and the United States, ranked second and third, are large markets. For these countries, the second argument may be of greater importance; i.e. to use foreign R&D to augment and complement the domestic knowledge base. The level of outward R&D intensity of Germany and the USA is similar to their respective level of inward R&D intensity.

Figure 19: Total outward BERD (EUR, 2003 and 2013)



Notes: Switzerland and US 2012 instead of 2013; Germany and Israel 2011 instead of 2012, Switzerland 2004 instead of 2003

Source: OECD, Eurostat, national statistical offices, own calculations

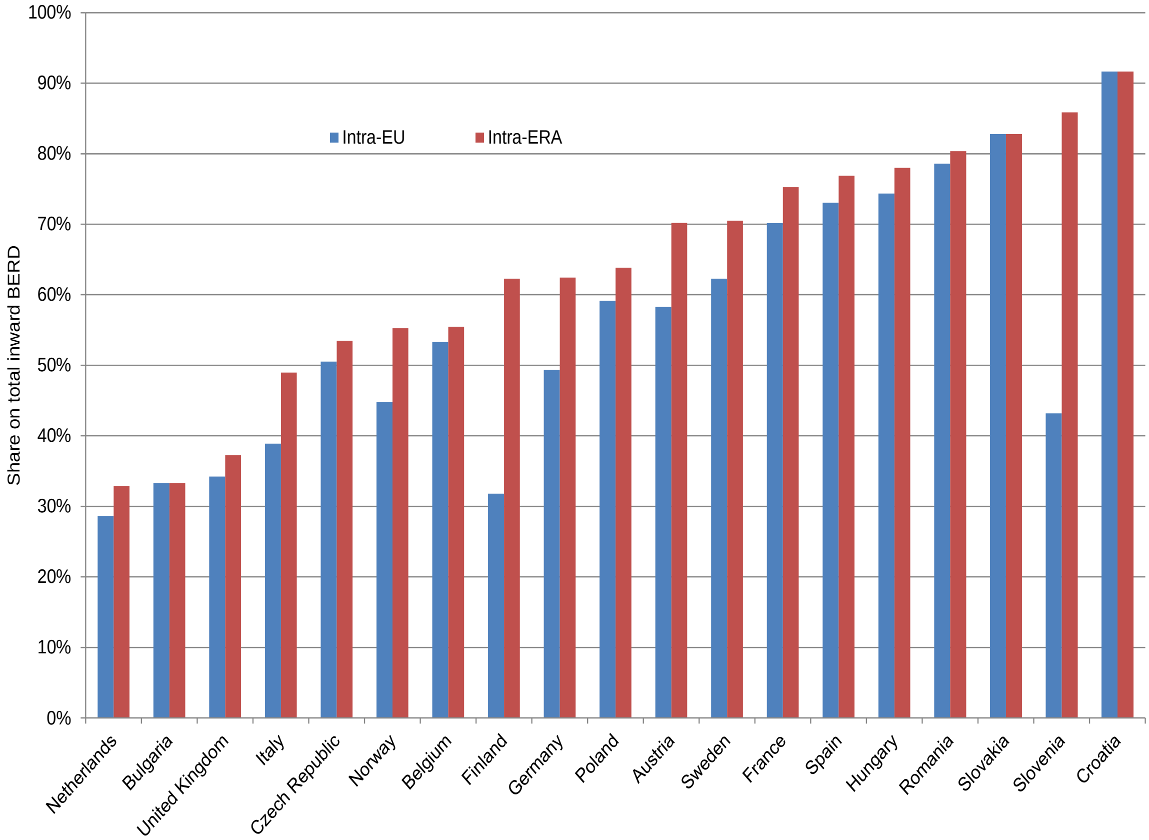
Total outward BERD in absolute terms is depicted in Figure 19 above. It does not come as a surprise that total outward BERD is largest for the United States, as its stock of foreign direct investment abroad is largest of all countries observed here. Switzerland, where outward R&D intensity - in relative terms - is largest (see Figure 10), is ranked third, just before Germany. Total outward BERD has increased significantly in the United States, Germany, Switzerland and Japan since 2003 (Switzerland 2004). Largest increases can be found in the United States; Switzerland showed considerable increases as well.

The attractiveness of the ERA for business R&D activities of non-European companies

R&D activities of firms outside their home countries have created tight connections between European countries and have fostered an integration of national innovation systems in the European Research Area (ERA). However, R&D internationalisation has also strengthened the links between Europe and non-European countries and increased the openness of the European Research Area to North America, Asia and the Pacific. Affiliates of foreign-owned multinationals can act as bridges for international knowledge transfer, and spur knowledge flows between the home and the host country.

At the EU level, around 52% of all inward BERD is from another EU country; if we add the ERA countries, the share of intra-European internationalisation rises to 61%. The following figure wraps up the evidence for R&D activities of European and non-European firms in Europe. It shows the share of firms from EU and ERA countries (most notably Switzerland) on total inward BERD.

Figure 20: Share of foreign-owned firms from the EU (intra-EU) and the European Research Area (intra-ERA) on total Inward BERD for different European countries, 2013



Notes: Croatia, Finland, Germany, Italy, Norway, Spain, Slovakia and the United Kingdom only NACE B-F Source: Eurostat, own calculations

We see that Middle and Eastern European countries, but also Spain and France, have a considerably lower share of R&D by non-European firms than the Netherlands or the UK. The UK and Netherlands are preferred locations for the European headquarters of non-EU firms and therefore also attract a high share of their R&D activities in Europe.

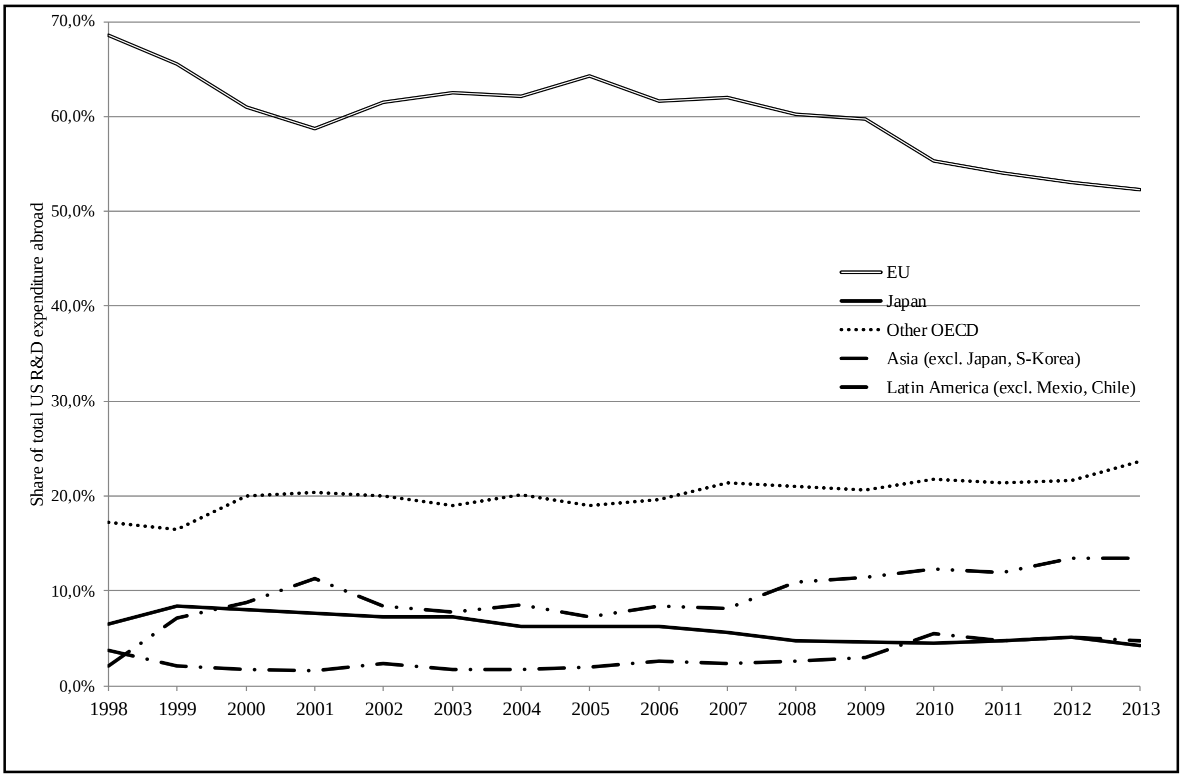
A closer look at the data reveals that most of the R&D activities of non-EU firms in Europe and the European Union can be attributed to US multinationals. The US share on total inward BERD from non-EU countries is 66%, and 81% if we extend the geographical scope to ERA countries. This corresponds to the prominent role of the USA in R&D internationalisation. The US is – by far - the country with the highest inward BERD as well as outward BERD in the world.

Europe - and the member states of the European Union in particular – is still the most important host location for R&D activities of US firms, both in absolute (million USD) as well as in relative terms (share on total US outward BERD). The EU hosts more than half of all US overseas R&D activities, or 25 billion USD of R&D expenditure. In absolute terms, US outward BERD in the EU has more than doubled, from 12 billion USD to 25 billion USD, since the year 2000.

There is, however, an undeniable erosion of the position of the EU. In 1998, the EU enjoyed a share of two thirds of total US outward BERD, a value which could never reached again. Emerging economies such as China and India are quickly gaining importance, both in absolute and relative terms. However, US outward BERD to emerging economies is still way below that to Europe: in 2013, Asia and Latin America together account for 18.3% of total US outward BERD, or 8.9 billion USD.

The share of emerging economies on US outward BERD is also lower than that of 'other', non-EU OECD countries, including Canada, Switzerland, Israel, South Korea and Mexico. This group of countries could gain shares on US outward BERD since 2008. Drivers in this group are Israel and Switzerland in particular.

Figure 21: Shares of different country groups on US outward BERD, 1998-2013.



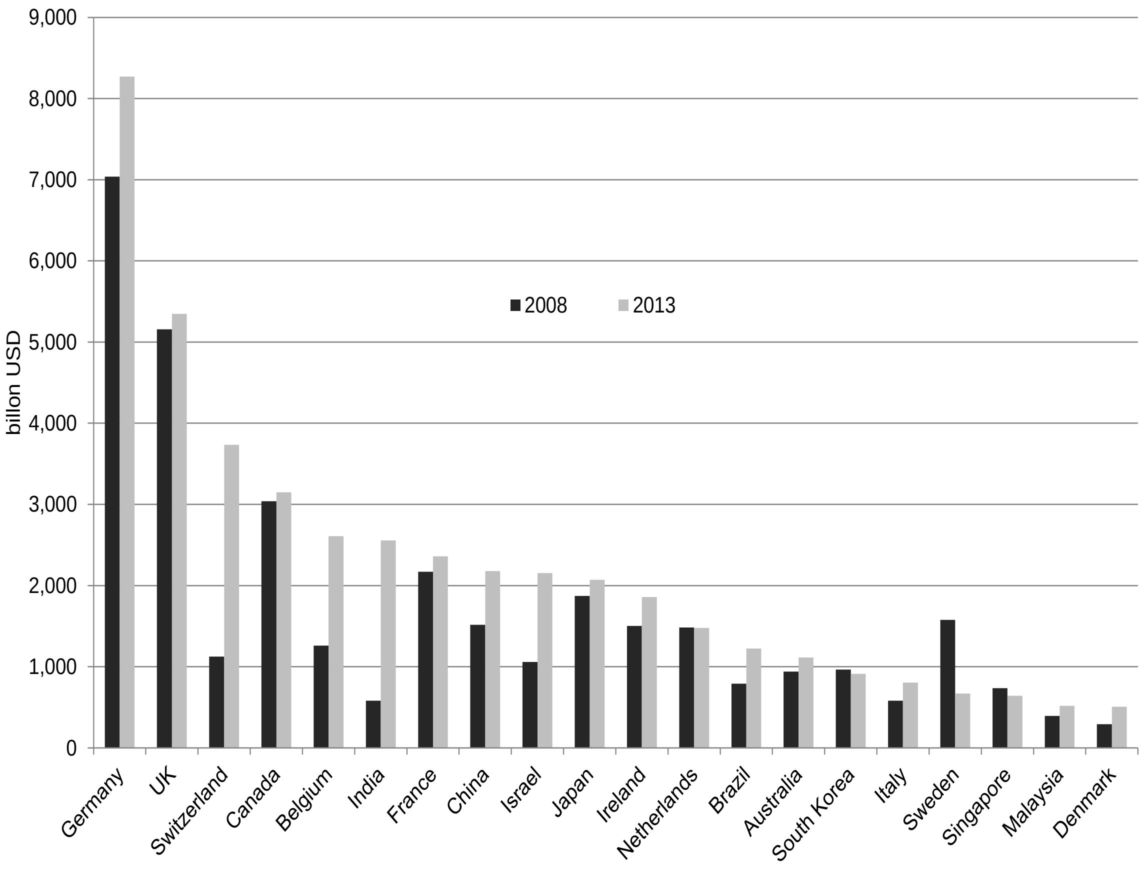
Source: US Department of Commerce, own calculations

A look at the level of individual countries in following figure allows some interesting comparisons of the size of R&D activities of US firms at different locations. Moreover, it reveals a considerable degree of divergence in attractiveness for US outward BERD within Europe.

At the global level, Germany is by far the largest host country for US R&D activities in 2013, followed by the UK, Switzerland, and Canada. Belgium is more important as an

R&D location for US firms than India, while France still attracts more inward BERD than China. Data show that India, China and South Korea are the countries which the highest annual growth of US outward BERD over the period 1998-2013. Growth in all three countries, however, has slowed down in the two shorter periods and is slowest in the most recent period 2008 -2013. Both, India and China, however, still host considerably less US R&D activity than the UK, Germany, or Switzerland. The latter two countries could also increase their share on US outward BERD. The figure clearly shows that 'winners' of US outward BERD are not necessarily emerging economies.

Figure 22: US outward BERD in different countries, 2008 and 2013, billion USD



Source: US Department of Commerce, own calculations

The data clearly indicate that Europe is still attractive for Extra-EU firms, in particular US firms. The rise of China or India has not led to a reduction of US activity in Europe. Moreover, there is evidence that firms from emerging economies are making their first steps into R&D internationalisation by setting up R&D activities in Europe and the US.

Inward BERD from India and China

Data for Europe is patchy due to the lack of a single figure for Chinese or Indian R&D activities in the EU. Notwithstanding, from the data we can see inward BERD by Chinese firms of at least 270 Mio. EUR in 2013, and another 89 Mio EUR by Indian firms. Hot-spots of R&D activities by firms from emerging economies in the EU are Germany and the Netherlands. We highlight these two cases based on what is known

Indian companies have been investing in R&D in the EU since 2006, albeit at a lower level than their Chinese counterparts. The most significant investments are in the Netherlands, between €70 million and €80 million in the last few years. Two other countries also host significant R&D from Indian companies: Belgium and Germany. There are lower level investments in Hungary and Czech Republic.

China is one of the most important players in the R&D world economy and its importance is expected to grow in the near future. China is currently the world's second largest investor in R&D after the US with R&D expenditures of approximately $344 billion in 2014. While Indian investments in Europe began some years ago, those from China are of more recent origin.

The main point to note is that there has been a rapid rise, albeit from a low base in a very short period of time. For example, in the case of Belgium, Chinese companies invested €0.6 million in 2011 which rapidly rose to €37.2 million in 2013. In Germany their expenditures have increased from €8.5 million in 2007 to €102.4 million in 2013. Austria has also seen Chinese investments expanding from €36 million in 2011 to €86 million in 2013.

Chinese R&D activities within the EU in recent years have been dominated by Germany and Austria, which accounted for nearly 70% of total inward BERD in 2013. The former accounts for 38% and the latter 32%. However, readers should note that this is based on the published data, so there is almost certainly more hidden in the confidential data. The other significant investments are in the Netherlands (7.4%) and in Italy (6.4%). In 2011 Norway was also a significant recipient of Chinese investments in 2011. The other countries with smaller investments are Hungary, Italy, Poland and Spain. See also the case study of China in the country report annex.

Chapter 4.

The Sector Perspective

M. Knell, E. Iversen, B. Poti, R. Spallone and B. Dachs

Chapter 4 The sector perspective

M. Knell, E. Iversen, B. Poti, R. Spallone & B. Dachs

The patterns that are observed at the country- and the cross-country levels reflect a range of factors, some of which direct relate to R&D as well as other non-R&D-related factors that are not immediately observable. It is however clear that the internationalisation of business R&D is strongly shaped by the industries or sectors in which it takes place. In this chapter, the core data that was introduced above is analysed at the sectoral level using a range of qualitative sources as well as quantitative analysis. This presentation complements the focus on the country and cross-country level and offers a detailed picture of the relationships between countries and sectors as seen through the lens of R&D internationalisation.

This chapter presents a digest of R&D internationalisation in seven case studies covering the most significant high technology industries based on their based on its R&D intensity. The main objective is to identify some of the key drivers of inward R&D in these industries, and place them within their sectorial context. Based primarily on statistics on total BERD and inward BERD flows (excludes domestic BERD), the study integrates productivity data from the Foreign affiliates statistics (FATS) together with several other indicators to investigate the underlying determinants that explain the observed patterns of R&D internationalisation. Another major data source used in this chapter is the EU Industrial R&D Investment Scoreboard, a database of the largest corporate R&D investors in Europe and world-wide. The patterns observed at the country level reflect a range of factors, some of which relate directly to R&D as well as to other non-R&D-related factors where the relationship are neither direct or immediately observable.

The chapter organized in the following way. We start by summing up some underlying issues underlying the significance of sectors for the internationalisation of R&D. The chapter then presents a comparison of the internationalisation of business R&D in selected industries or sectors. Six manufacturing industries, all with a high or medium-high R&D intensity, plus knowledge intensive business services (KIBS) are included in the analysis. The cases that were selected in consultation with Commission Services are:

- The automotive Industry (NACE 29)
- The electronics industry (NACE 26)
- Software and computer services (NACE 58.2 and 62-63)
- The electrical equipment industry (NACE 27)
- The pharmaceutical industry (NACE 21)
- The Chemical industry (NACE 20)
- Machinery and equipment (NACE 28)The full reports are available in appendix.

Issues

At the sectoral level, foreign ownership and technological intensity of sectors plays an important role in shaping the internationalisation of private sector R&D. Sectors with high shares of inward BERD also tend to be technologically intensive. Sectors also matter because innovation processes differ considerably across industries. These inter-sectoral differences shape innovation behaviour of firms to a considerable degree, including decisions to locate R&D abroad, leading to different degrees of internationalisation at the sectoral level.

The internationalisation of innovation systems (cf. global innovation networks in general[8]) has gone hand in hand with the internationalisation of production systems. Established but changing global innovation systems can be seen both in manufacturing as well as service industries, from automobiles to machinery and equipment, from chemicals to pharmaceuticals, from digital hardware to software and services. The landscape for the internationalisation of business R&D is undergoing a period of comprehensive change. Notably, these changes include shifts in the location of demand, production and innovation, the importance of changing technologies and technological regimes (e.g. green-tech) as well as convergence (e.g. digitisation/IoT), as well as the longer term repercussions of stemming from the US sub-prime credit crisis ('the financial crisis', see chapter 5 for analysis).

The importance of these changes varies in different sectoral contexts. Some observers (Chaminade et al, 2015) point to the importance of the shift in world manufacturing demand more toward emerging markets. This shift is taking place in relative terms in sectors where demand growth is flat in developed markets while demand in emerging markets (notably China) has strengthened. Such shifts can influence the character and complexion of multinational company (MNC) strategies and the location of production, not least global manufacturing. In areas like the automobile sector, MNCs are adapting to a "produce where you sell" strategy to meet local standards, to improve supply chains, to expand local engineering competences, etc (Herrigel et al. 2013). In sectors like the automobile sector, Herrigel, (2014) and other posit a shift from a traditional regime between developed to emerging markets that built on exports and on production-based foreign direction investments to the emergence of "produce where you sell" strategies.

Foreign ownership of domestic production capabilities and inward R&D activity has important implications for the industrial structure. This report shows that there are large differences between sectors in terms of foreign direct investment, and sectors with high shares of inward FDI also tend to be technologically intensive. Sectors with high shares of inward FDI also tend to be technologically intensive. Sectors also matter because innovation processes differ considerably across industries. These inter-sectoral differences shape innovation behaviour of firms to a considerable degree, including decisions to locate R&D abroad, leading to different degrees of internationalisation at the sectoral level. Most R&D activity, whether foreign or domestic, is performed in industries with a high or medium-high R&D intensity. These firms contain certain ownership advantages that allow them to access certain firm specific assets and knowledge capital.

The literature survey indicates four issues that are important for sectoral analysis. The first related to the cognitive capabilities of enterprises and some of the difficulties in articulating this knowledge and transferring between people, or what is called tacitness. A second issue concerns the degree of cumulativeness or the degree future innovation success depends the accumulation of previous knowledge. Cumulativeness tends to be high in enterprises with relatively higher R&D intensity but it can also promote R&D centralisation when strong learning effects lead to increasing returns to scale in R&D or when the R&D process includes economies of scope and effects from cross-fertilisation. Third, some firms are unwilling to internationalise R&D because of the appropriability conditions, or the conditions under which a firm can protect an innovation from imitation or to prevent involuntary knowledge-spillovers. Finally, network externalities, including external relations with suppliers, clients, universities, public administration, etc. build on the availability of complementarities. Some industries, such as biotechnology or pharmaceuticals, have strong linkages to basic science, whereas others, such as the automotive or the electronics industry, are

[8] *See e.g. the EU funded INGINEUS project focused on, 'the evolution of global production networks (GPNs) into global innovation networks (GINs), and the impact this new process of global capitalism has on knowledge intensive activities in the EU'. See http://cordis.europa.eu/project/rcn/90186_en.html*

closely connected to suppliers and customers through international production networks.

Note on complementary data

This section utilizes supplementary data sources that complement the core-data in terms of source, scope and focus. In addition to the R&D Scoreboard and other EU based sources, the analysis here particularly makes use of the fDi Markets database (Financial Times Ltd), which provides information on the number of announced greenfield FDI projects. Announced projects include information about R&D activities, including design, development and testing" that originate (funded) in one country but are carried out in another.

The fDi Markets database provides an alternative, but complementary picture of the internationalization of R&D activity from 2010 to 2015. It differs from the BERD data in its source; its unit is reported projects that are R&D and/or design in focus. In this case study, the numbers are purely counts of R&D-FDI projects.

The presentation here builds on the basic tables generated by the Industrial Research and Innovation Monitoring and Analysis (IRIMA II) project, jointly carried out by the European Commission's Joint Research Centre (JRC) and the Directorate General Research and Innovation. Details on the collection and compilation of the data by FT Markets (https://www.fdimarkets.com/). See also documentation from the IRIMA II project. The presentation is based on full-length case-studies found in the Annex. A second such study involves the Community Innovation Survey (CIS).

R&D internationalisation at the sectoral level

In this light, the following section compares the internationalisation of business R&D in different sectors. Inter-sectoral differences shape innovation behaviour of firms to a considerable degree, including decisions to locate R&D abroad, leading to different degrees of internationalisation at the sectoral level. Individual firms have certain ownership advantages, firm-specific assets, and knowledge capital, which imply that the path of internationalisation can be very different even among enterprises in the same industry. The resulting motives and strategies, together with framework conditions underlying the national, regional and sectoral system of innovation, help to determine the degree of R&D internationalisation of firms.

There are two important constraints in the database: first, the data only allow an analysis of inward BERD, but not of outward BERD. Second, the countries with data available differ across sectors and over time. As a result, only the analysis of the seven largest manufacturing sectors and the service sector as a whole for the last recent year (2013) is feasible at this point and the interpretation of the results should be done carefully.

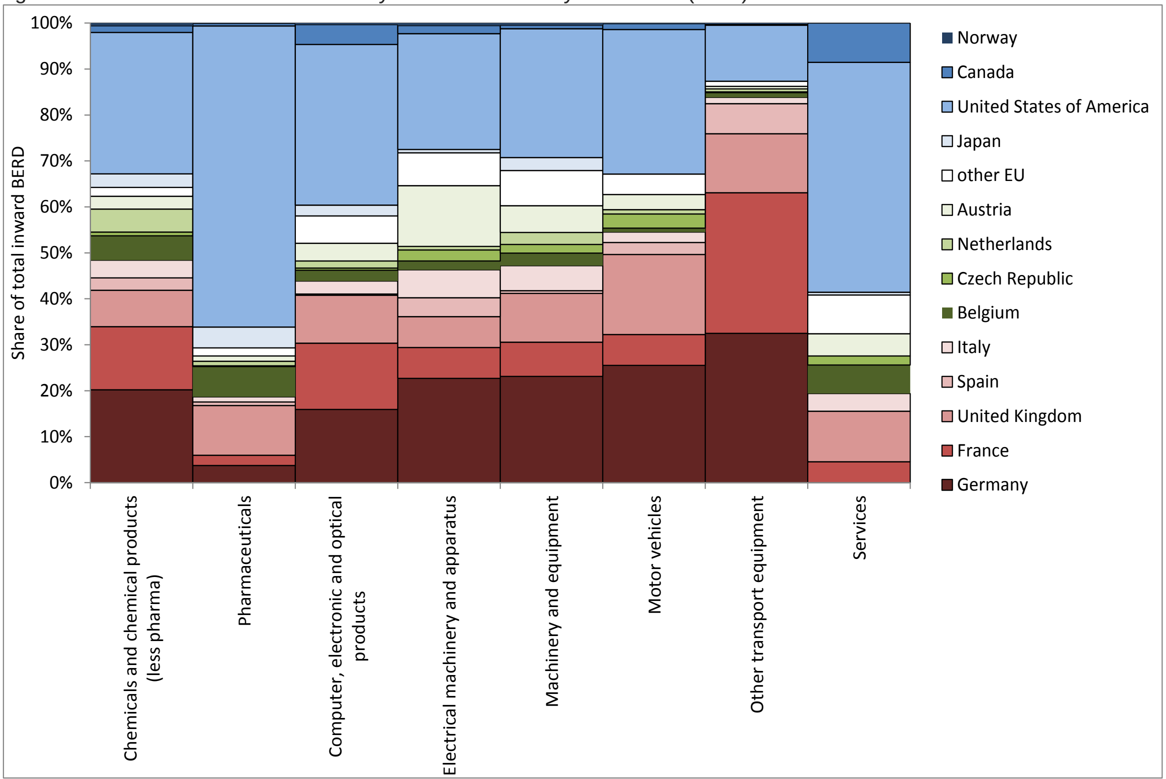
Six manufacturing industries with a high or medium-high R&D intensity were included in the study: chemicals; pharmaceuticals; machinery and equipment; computer, electronic and optical products; electrical machinery and apparatus; and motor vehicles and equipment. Knowledge intensive business services (KIBS) are also included in the chapter as they have a high R&D intensity. This sector was restricted to include only computer programming, information services, software publishing and related activities. The industry should not be considered a service, but an intangible good that is an outcome of R&D activity and subjected to intellectual property rights (Hill, 1999). The seven industries are central to the BERD analysis, each of them attracting between 3.8 billion PPS EUR (chemicals) and 21.7 billion PPS EUR (pharmaceuticals) inward BERD in 2013 worldwide.

Figure 23 provides the share of total inward BERD from a certain country on total inward BERD in the sector considered. All values therefore add up to 100%. In chemicals and chemicals products, the EU attracts about two thirds of total inward BERD, while the remaining third is mostly located in the US. Within the EU, a number of countries account for more than 5% of worldwide sectoral inward BERD, most notable the three largest countries Germany (20%), France (14%) and the UK (8%) but also some medium-sized countries including Belgium and the Netherlands (each 5%).

By contrast, pharmaceuticals, the largest of the manufacturing sectors in terms of inward BERD, is much more concentrated. Besides the US, which play a dominant role as location for inward BERD in pharmaceuticals, only two other countries, the UK and Belgium, account for more than 5% of the total sectoral inward BERD. All other countries of the world together only account for about 17% of total sectoral inward BERD, explaining the high concentration in that sector already mentioned. While inward BERD is highly concentred in pharmaceuticals in a small number of countries, the remaining countries still attract significant absolute amounts due to the massive total amounts of cross-border BERD in this sector. For example, while Germany's share is, at 4%, much smaller than in chemicals, the absolute amount – more than 800 million EUR in 2013 – is still above the corresponding level in chemicals.

The producers, of computers, electronic and optical products attract a total of 9.52 billion PPS EUR inward BERD worldwide, ranking the sector as number three only behind pharmaceuticals and motor vehicles (11.44 billion PPS EUR). Again the US is the single most important country, however, with a share of 35% inward BERD, the cumulative share of the EU is with 58% well above this value. Within the EU more than 2/3 of inward BERD is concentrated in the three large countries Germany (16% of sectoral inward BERD worldwide), France (14%) and the UK (10%). The most important medium-sized country in this sector is Austria, with a share of 4%.

Figure 23: Share of total Inward BERD by destination country and sector[9](2013)



Notes: Germany and Spain not included in Services, shares based on PPS EUR.

Source: OECD, Eurostat, national statistical offices, own calculations

Electrical machinery and apparatus demonstrate a similar picture to computer, electronic and optical products in terms of the relative distribution across countries but

9 Inward BERD in country X in sector Y / total inward BERD in sector Y on a much smaller level in absolute terms. Total sectoral BERD worldwide is only about 2.7 billion PPS EUR.

Machinery and equipment is a sector with a high cumulated share for all EU countries, all EU member countries together attract more than 2/3 thirds of total inward BERD in this sector. While the US plays a much smaller role, with 28% it still accounts for the lion's share of the remaining inward BERD. Inward BERD in this sector is widely distributed across different EU countries. While two of the largest EU economies, Germany and the United Kingdom are ranked two and three worldwide, also smaller economies, including Austria (6%) or the Czech Republic (2%) play a certain role.

Three large countries accounting for about a third of the sectoral inward BERD dominate motor vehicles, the second largest sector in terms of worldwide inward BERD. With about 3 billion PPS Euro of inward BERD in motor vehicles in Germany this is the largest absolute sectoral amount of inward BERD for any country except the US. As a result, Germany's share on total inward BERD is, at 26%, only slightly smaller than the US share of 31%. The third main country is the UK with a share of another 17%, other notable countries are France (7%), Spain, Czech Republic and Austria (each 3%).

Most countries do not include statistics on computer programming and related activities. Statistics are provided by the United Kingdom, but there are no recent figures for France Germany or Italy. Those that do exist indicate the share of inward BERD is very low in the Netherlands and Slovenia, and about half of total BERD in Austria, Belgium and the Czech Republic and about 66% in the UK. It was between 4% and 5% in the USA in 2009 and 2011, but averaged between 1% and 2% when software publishing is included.

In sum, the cross-sectoral comparison of inward BERD reveals that inward BERD in various sectors is still concentrated in a small number of countries. However, we see a trend towards a wider variety of countries involved in the internationalisation of business R&D at the sectoral level. The sheer size of business R&D in the USA strongly influences the results.

Error! Reference source not found. presents Inward BERD by host-country and by ear, from a longer viewpoint that captures the pre and post financial crisis. Most industries observed growth after the economic crisis across the different regions. The most remarkable observation was that inward BERD had more than doubled in east Europe after the economic crisis. The one noteworthy exception was software, where it had doubled in North America, but not in Europe. There was no data for electronics before the crisis as there was no detailed information before 2007, but inward increased fairly strongly across all regions except for Japan where if fell quite dramatically. There are no data for China, where data on R&D expenditure indicate that it has been increasing and in Sweden where data from the post crisis period are not available. The automobile industry appears to have recuperated from its pre-crisis level, but missing data from Sweden. But there appears to be a significant increase in inward BERD in machinery and equipment industry following the economic crisis in almost all industries where there are data. There were few statistics from Eastern and Sothern Europe from the chemical and pharmaceutical industries before the crisis, and there were no statistics for Sweden, which had considerable inward BERD in the past. There may have been some significant cross-border M&A activity that is not being captured here.

Table 4 Inward BERD before and after 2008, from a regional perspective (In Euros).

	Auto	Electronic	Software	Electrical	Pharma	Chemicals	Machinery
				Pre-2008			
Japan	2,799	:	31	152	..	..	19
East Europe	193	:	51	58	22	8	59
North America	2,798	:	408	354	8,772	1,191	1,415
Nordic Countries	829	:	117	266	1,224	253	179
South Europe	330	:	159	120	13	3	388
West Europe	3,908	:	1,234	1,219	5,725	1,773	2,172
				Post-2008			
Japan	:	491	..	54	1,450	132	119
East Europe	397	84	76	129	163	34	127
North America	2,406	3,575	838	577	12,187	1,218	1,922
Nordic Countries	27	272	..	192	57	163	460
West Europe	5,258	4,074	1,632	1,586	4,817	1,893	3,078

Source: BERD flows database

The following sections will focus in on seven sectors. The presentations in these sectors reflect more contextual analysis which drew on outside sources. The combination of qualitative and quantitative analysis for each sector can be found in the sector report annex.

R&D internationalisation in the automotive industry

The automotive industry, including motor vehicles and its subsectors (NACE 29), is classified as a medium-high technology industry based on its R&D intensity. It is a highly internationalized industry with a strong inflow of foreign direct investment within Europe and from Western Europe (EU-15) to Eastern and Central Europe (EU-13). The automotive industry is one of the most important sectors in terms of total R&D expenditures (UNCTAD 2005, ACEA 2010), but its R&D was less internationalized than any other industrial sector. It is generally considered to be an example of predominantly demand-driven R&D internationalization strategies because automobiles require regional and national adaptation of products to satisfy customers' preferences, road and climatic conditions, and governmental regulations in foreign markets (UNCTAD 2005). Automotive R&D activity remained concentrated in Germany over this period, but there were significant investments in Austria, France, Italy, Spain, Sweden, and the UK.

Very large transnational firms dominate BERD activity within the automotive industry (Eurostat R&D Survey). Large transnational firms tend to be efficiency seekers in the industry, mostly depending on R&D facilities of the parent enterprise. This sector alone accounted for about one-quarter of all European R&D activities in 2014. Volkswagen alone spent more than €13.1 Billion Euros on R&D activities, the most of any global transnational enterprise. The majority of this money was spent on efficiency-increasing technologies (across the entire Group). In the period 2010 to 2014 R&D activity doubled in both Fiat Chrysler (Netherlands)[10] and Volkswagen (Germany). Tata Motors (India, ranked 49)) experienced 860% growth from 2010 to 2014, the fastest growth of any top global 100 R&D firm. The Tata Group is a large multinational conglomerate from India that includes Jaguar Land Rover, as well most of its R&D facilities, which are located in the UK.

[10] The R&D Industrial scoreboard 2016 attributes FIAT to Italy rather than the Netherlands.

Table 5 Top 10 Global enterprises producing motor vehicles

World Rank	Name	Country/Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil.)
1	VOLKSWAGEN	Germany	13,120.0	6.5	17.7	202,458.0
9	TOYOTA	Japan	6,858.4	3.7	5.3	185,940.4
11	GENERAL	US	6,095.0	4.7	-3.9	128,431.7
13	FORD	US	5,683.2	4.8	6.5	118,669.7
14	DAIMLER	Germany	5,650.0	4.4	-1.5	129,872.0
17	ROBERT BOSCH	Germany	5,042.0	10.3	3.1	48,951.0
20	HONDA	Japan	4,576.6	5.0	6.9	90,996.0
21	BMW	Germany	4,566.0	5.7	12.4	80,401.0
30	FIAT CHRYSLER	Netherlands	3,665.0	3.8	15.6	96,090.0
34	NISSAN	Japan	3,455.7	4.4	5.4	77,662.8

Notes: BERD growth is the 3-year annual average growth

Source: EU R&D scoreboard 2015. *Industry classification based on* The Industry Classification Benchmark (ICB) *and roughly corresponds to NACE.*

Germany is the most important player within Europe, but it relies on extensive networks that extend beyond Germany's borders, including to the United States and Japan. German enterprises account for almost two-thirds of European BERD over the past 16 years, which more than doubled in size over this period. These enterprises made up a little bit less than half of the total inward BERD over the same period, indicating that there were substantial flows of FDI in R&D to other countries in this period. Geography plays a role in inward R&D activities close to the German border. Global R&D intensity of the Automotive industry was 4.4% in 2014, whereas Europe was above average at 5.5%, and the US and Japan slightly below at 4% and 4.1% respectively. Geographic concentration of automobiles & Parts with domestic and world R&D shares of 26.2% and 47.3% respectively. Overall R&D specialization (share of R&D investment) was 27 in Europe, whereas it was 29% in Japan and 7% in the US and 10% in China.

European total BERD accounts for approximately one-third of total global BERD in the automotive industry and Germany accounts for more than two-thirds the BERD activity. While Germany contributes the most BERD in Europe, its share of funding from abroad (inward BERD) is generally below 15%. Historically, the proportion of R&D activity by large transnational firms undertaken outside their home countries has been quite small, which explains why the three largest countries (Germany, Japan and the United States) with BERD activity in the automotive industry observed shares that were generally below 15%. The data also show that inward BERD into the automotive industry accounted for just under half of total R&D spending in the sector. Austria, Belgium, the Czech Republic, Hungary, Poland, Romania, and Spain were in the 40% to 50% range. There is considerable variation in the UK statistics, but it appears to around the 50% range. Several small countries, including Austria the Czech Republic and Poland exceeded 90%.

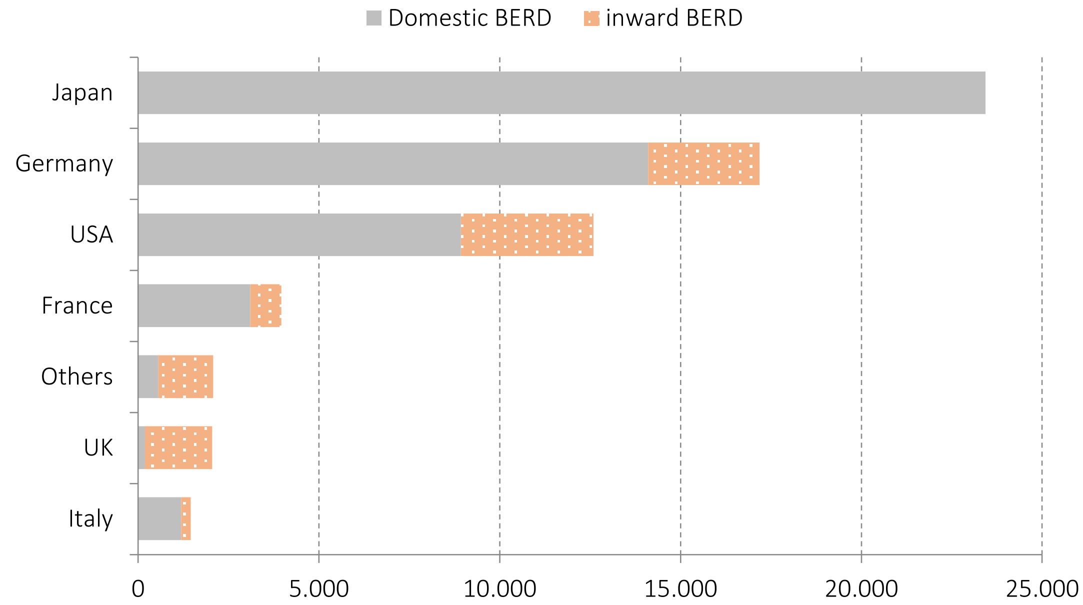
Table 6 Inward BERD as a percentage of total BERD in the automotive industry

		2007		2009		2011		2013
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	*401*	86.0%	*369*	91.3%	*407*	90.7%	*463*	88.8%
Belgium	*123*	75.6%	*84*	73.8%	*113*	70.8%	*148*	72.3%
Canada		..	*158*	62.0%	..	..	*124*	46.8%
Czech Rep.	*290*	44.1%	*134*	89.6%	*162*	92.6%	*250*	95.2%
France		..	*1,658*	18.0%	*4,705*	19.4%	*3,959*	21.6%
Germany	*13,519*	14.9%	*13,821*	15.8%	*16,312*	12.6%	*17,187*	17.9%
Hungary	*50*	..	*61*	..	*70*	71.4%	*103*	75.7%
Italy	*966*	..	*993*	..	*1,298*	16.5%	*1,453*	18.2%
Japan	*15,008*	..	*18,840*	..	*24,606*	..	*23,435*	..
Netherlands	*139*	..	*124*	..	*284*	41.9%	*292*	39.7%
Norway	*40*	..	*30*	..	*27*	48.1%	*30*	63.3%
Poland	*27*	85.2%	*80*	97.5%	*44*	86.4%	*130*	93.1%
Portugal	*46*	65.2%	*63*	..	*35*	..	*24*	..
Romania	*35*	..	*43*	79.1%	*52*	78.8%	*42*	95.2%
Slovakia	*0*	..	*20*	..	*24*	..	*85*	51.8%
Slovenia	*7*	..	*33*	..	*105*	..	*80*	16.3%
Spain	*254*	79.9%	*348*	48.9%	*357*	81.8%	*328*	82.6%
Sweden	*1,627*	47.8%	..	..	*1,053*	..	..	..
UK	*1,134*	..	*1,083*	87.8%	*1,493*	85.6%	*2,053*	90.7%
USA	*11,699*	15.2%	*8,171*	14.0%	*8,402*	25.9%	*12,596*	29.1%

Source: BERD flows database

Error! Reference source not found. corroborates the relative importance of inward lowing R&D to the overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process. For example, Volkswagen, Daimler, Robert Bosch and BMW are among the top 5 European firms producing automobiles and all of them have their headquarters located in Germany. These firms may also have subsidiaries or joint ventures located in other countries, such as Austria, or may carry out assembly in countries such as the Czech Republic. The parent firm will be expected to carry out R&D abroad, which explains why size of the sector differs widely in these countries, as does the total R&D intensity. Italy also has production facilities, but it depends a great deal on the R&D facilities in the Detroit area (Fiat Chrysler).

Figure 24 Table 5 BERD flows in the automotive sector, 2013



Own calculation based on BERD flows database.

Note: Data for Japan is from 2011.

The figure also indicates the general increase in total R&D in the European auto industry in 2013. The financial crisis of 2008 may of also had an impact on the growth of BERD in this industry. Both Germany and Japan show a general growth trend from 2007 to 2013 in total BERD. The most dramatic shift is in the consistent reduction in the US in total R&D in the sector from 2007. Here it is noted that the US total R&D in the US sector and the share of inward R&D both expand dramatically in the latest data (2013). Data for the UK appears unreliable as inward BERD sometimes exceeds total BERD, and the share jumps around by wide margins every two years.

Foreign ownership plays a central role in the automotive industry as total BERD is distinguished from inward BERD (see table A3). Apparent labour productivity of total BERD appears higher in countries such as France, Germany, Italy and the UK where virtually all of the parent firms reside and productivity tends to be higher in firms with inward BERD. A similar pattern is observed for BERD intensity and the share of R&D employment, but as expected BERD intensity is higher in the three countries. Although not the highest in terms of BERD intensity, the UK observes the highest apparent labour productivity. Finally, it should be noted that BERD intensity had increased in Austria and Slovenia. Results appear mixed as to whether any significant catching up took place over the last decade.

There has been considerable activity in merger and acquisition activity in the automotive industry from 2007 to 2014, but it was relatively small when compared with total value of greenfield FDI activity and greenfield FDI projects. Volkswagen engaged in 266 projects totalling €43.3 billion and where involved in 3 cross-border M&A deals (out of a total of 12 deals totalling €20.7 billion) (p.40). By contrast, Toyota engaged in 282 projects totalling €27 billion but where involved in only 2 cross-border M&A deals (out of a total of 7 deals totalling €1.3 billion). Robert Bosch engaged in 191 projects totalling €7.5 billion and where involved in 14 cross-border M&A deals (out of a total of 32 deals totalling €5.7 billion). General Motors engaged in 158 projects totalling €32.3 billion but where involved in only 1 cross-border M&A deal (out of a total of 3 deals totalling €4.7 billion). One larger firm that not in the top 10 (yet) is Tata motors, which were engaged in 5 M&A deals worth over €1.5 billion, including 3 that were cross-border. Fiat Chrysler Automobiles and BMW had large projects but do not report figures publically as they want to conceal their business strategy.

Table 28 summarizes the number of announced greenfield R&D FDI projects, including design, development and testing, by source and destination, from the beginning of 2010 to the end of 2015 for the automotive industry. It presents the data by source (originating) country (or region) by row and the destination (receiving) country (region) by column. There were almost 370 cross-border R&D projects, representing the most significant countries involved in automotive production, from 2010 to 2015. Germany alone supported 95 R&D-FDI projects that were anticipated to be carried out in another country, including East Europe, China, India and the United States. The major players in the auto industry are Germany, the US and Japan, which confirms the inward BERD statistics. There were many greenfield R&D-FDI projects between the major players over the 6-year period. The data also highlights the important role that China, India, Brazil as well as the Visegrád countries (namely the Czech Republic, Hungary, Poland and Slovakia) play as destinations for R&D-FDI projects.

Table 7 Number of announced greenfield R&D FDI projects, by source and destination, in the Automotive industry, 2010-2015.

	Germany	Visegrád[11]	France	UK	USA	Japan	South Korea	China	India	Brazil	Other	Total
Germany	0	15	3	4	13	1	3	22	13	3	18	95
Visegrád	2	0	0	2	1	1	0	1	0	0	1	8
France	1	6	0	0	2	1	0	6	4	2	5	27
UK	2	1	0	0	0	0	0	2	0	0	1	6
USA	8	6	0	5	0	1	3	21	8	3	21	76
Japan	5	1	1	1	21	0	2	10	6	4	17	68
South Korea	2	0	0	0	1	0	0	3	3	1	1	11
China	2	1	0	4	4	0	0	0	0	2	6	19
India	0	0	0	9	4	0	1	1	0	0	2	17
Brazil	0	0	0	0	0	0	0	0	0	0	0	0
Other	5	0	0	3	6	1	1	9	3	1	13	42
Total	27	30	4	28	52	5	10	75	37	16	85	369

Own calculation based on based on information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com)

The industry is currently undergoing fundamental changes, driven in part by R&D activity. R&D activity is mainly (and increasingly) driven by stricter standards on vehicle emissions and fuel consumption. Many innovations are related to the electrification of powertrains and battery technology. And rapid technical change is driving the consolidation of automotive suppliers, which now account for half of all R&D spending in the global supply chain. Increasing use of ICT technologies that come from different subsystems of the supply chain and fully autonomous (driverless) vehicles is currently driving future trends.

In summary:

- The share of BERD performed abroad has remained relatively stable in the European Union since 2005. Internationalisation of automotive R&D has focused on development, while research remains concentrated near the home bases of lead firms.
- The main European player in the automotive industry is Germany, but Italy, France, Sweden and the United Kingdom also engage in R&D activity that involves firms that are not headquartered in Germany. More than 85% of the

[11] The Visegrad countries include Czech Republic, Hungary, Poland and Slovakia

value added in automobiles is produced in Germany; about 75% in both Italy and France; and less than 50% in Sweden and the UK.

- The level of economic development explains large national differences in the R&D intensity. However, there is no clear pattern of R&D activity in terms of the difference between the R&D intensity of national BERD and the R&D intensity of inward BERD.
- Labour productivity (both in terms of value added and production output) appears to be higher in the countries with inward FDI, except for France, Germany and Italy where it appears higher in the domestic economy.
- Countries close to Germany reveal a faster growth of inward BERD. The Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia experienced high growth, although from a very low level. Production remains strong in these countries, but there is little indication that any significant R&D activities will be located in these countries in the near future.

R&D internationalisation in the electronics industry

The electronics industry, including the manufacture of computer, electronic and optical products (NACE 26), is classified as a high technology industry based on its R&D intensity. But the industry contains many different activities, many of which may not contain much R&D activity. Apple is one example as they design and make computer chips based on Intel chips, but they are also are a retailer of consumer electronic products. This becomes readily apparent when the sales figures of Apple are compared with the BERD figures. There are some important differences in the Industry Classification Benchmark (ICB) system and the Statistical classification of economic activities in the European Community (NACE). The Institute for Prospective Technological Studies (IPTS) uses the former to compile the EU R&D Scoreboard and Eurostat uses the latter to compile the BERD statistics. The main difference is that consumer electronics are identified separately from electronic office equipment and are considered to be electrical goods. Hence enterprises such as Samsung are classified as electrical equipment when a large share of the goods produced there could be classified as electronic products, such as their smart phones and smart televisions.

Industrial R&D is highly concentrated in the computer, electronic and optical products industry, and is much higher in the US and East Asian firms than in the European firms. US-based firms do more than 60% of global R&D in the industry. Large transnational firms tend to be strategic asset seekers in the industry, often setting up R&D facilities within a cluster of enterprises with the aim of enhancing the technological assets of the parent company. The largest cluster is found in Silicon Valley, where many computer and electronic enterprises have located. Technology sourcing has also been an important driver of inward BERD flows. Large transnational firms dominate BERD activity within the industry (Eurostat R&D Survey). Six of the top seven transnational firms were located in the United States. Ericsson was the largest European enterprise. Of the top 10 firms, Apple and Qualcomm showed high R&D growth (22.6% and 18.4% respectively), whereas all European firms showed negative growth, with Nokia declining by 11% on average 3-year compound annual growth rate.

Table 8 Top 10 Global enterprises in technology hardware and equipment

World Rank	Name	Country	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
4	INTEL	US	9,502.5	20.6	8.3	46,017.6
16	CISCO SYSTEMS	US	5,112.4	12.6	4.7	40,491.7
18	APPLE	US	4,975.7	3.3	22.6	150,560.0
23	QUALCOMM	US	4,511.2	20.7	18.4	21,816.1
28	ERICSSON	Sweden	3,856.7	15.9	-1.8	24,271.6
39	EMC	US	2,915.7	14.5	7.3	20,130.1
40	HEWLETT-PACKARD	US	2,839.1	3.1	-1.2	91,799.6
41	NOKIA	Finland	2,718.0	17.9	-11.0	15,190.0
54	ALCATEL-LUCENT	France	2,250.0	16.5	-1.9	13,615.0
58	CANON	Japan	2,109.5	8.3	-0.2	25,447.4

Source: EU R&D scoreboard 2015.

Notes: BERD growth is the 3-year compound annual growth rate. *Industry classification based on* The Industry Classification Benchmark (ICB) *and roughly corresponds to NACE 26.* Technology hardware and equipment *includes computer hardware, electronic office equipment, semiconductors, and telecommunications equipment, but not electronic equipment.*

Germany is the most important player within Europe, but the industry is dwarfed by the United States, Japan and Korea. These three countries make up about 80% of total BERD in the database. China and India will add to total global BERD. German enterprises account for between 5% and 6% of total BERD and about 25% to 30% of European BERD, but are not among the top 10 global enterprises in the industry. Overall, Europe has one-third as many enterprises in the computer, electronic and optical products industry, and a corresponding low level of investment, especially in semiconductors. Nevertheless, it was the third largest industry in Europe with 50 of the top 1000 enterprises accounting for more than €15 billion in investment. And there were some world leaders among the European Enterprises, such as ASML in the Netherlands who have an 80% global market share in precision lithography, and ARM in the UK who have a 95% market share in making semiconductor chips for smart phones and 80% share in digital cameras. Generally, R&D intensity in Europe compares quite favourably with US firms.

Table 9 Inward BERD as a percentage of total BERD in computer, electronic and optical products

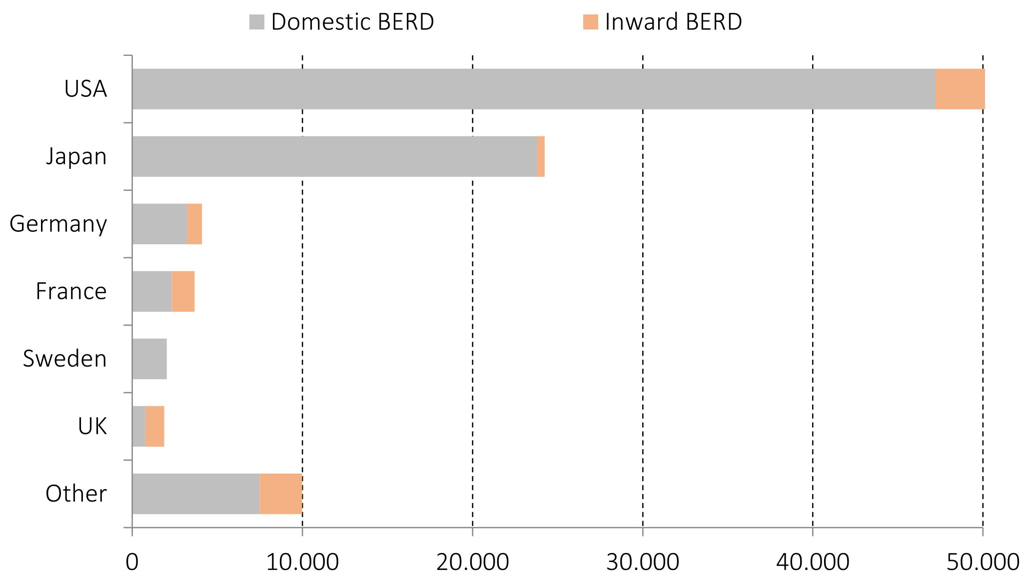
	Total	2009 Inward Share	Total	2011 Inward Share	Total	2013 Inward Share
Austria	527	67.4%	524	66.4%	616	64.4%
Belgium	453	50.8%	425	51.5%	478	52.3%
Canada	1,608	20.0%	1,777	18.4%	1,728	28.4%
Czech Rep.	50	52.0%	47	40.4%	59	50.8%
Denmark	351	:	326	:	386	24.6%
Finland	2,635	5.5%	2,510	4.2%	1,781	5.0%
France	3,373	27.9%	3,193	:	3,669	37.1%
Germany	5,815	14.1%	6,563	20.6%	7,342	21.8%
Greece	:	:	23	:	15	:
Hungary	56	:	66	69.7%	55	78.2%
Ireland	155	:	153	:	103	:
Italy	1,272	:	1,444	21.3%	1,296	20.8%
Japan	24,215	:	28,321	1.7%	24,232	1.7%
Netherlands	796	17.0%	1,152	12.9%	1,306	12.3%
Norway	215	:	214	21.0%	209	25.8%
Poland	21	9.5%	32	6.3%	35	11.4%
Portugal	21	:	26	:	24	:
Romania	5	50.0%	5	8.3%	15	:
Slovakia	1	:	3	33.3%	4	25.0%
Slovenia	39	:	118	6.8%	80	8.3%
Spain	241	16.6%	208	11.5%	176	13.1%
Sweden	1,751	:	2,105	:	2,026	:
Switzerland	:	:	:	:	1,678	35.2%
UK	1,093	:	1,126	50.9%	1,879	58.5%
USA	40,461	7.7%	45,046	6.8%	50,602	6.7%

Source: BERD flows database.

European total BERD accounts for about 20% of total BERD in in computer, electronic and optical products and Germany accounts between 25% and 30% of this. While Germany contributes the most BERD in Europe, its share of funding from abroad (inward BERD) is ranged between 15% and 22%. Historically, the proportion of R&D activity by large transnational firms undertaken outside their home countries has been quite small, which explains why the three largest countries (Germany, Japan and the United States) with BERD activity in the automotive industry observed shares that were generally below 8%. However, Finland shows the share of inward BERD to be very low, perhaps because of NOKIA and several countries in eastern Europe appear to have a low share of inward BERD but the total amount of BERD is very low. The relatively low share of inward BERD in the electronics and electrical industries (compared with chemicals and pharmaceuticals) partly reflects the strong presence of Japanese firms in that industry. The data also show that inward BERD into the electronics industry varied considerably across the sector. Germany, France and Finland were the largest BERD performers, followed by Sweden (Ericsson), Italy, Netherlands and the UK.

Figure 2 also corroborates the relative importance of inward flowing R&D to the overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process. The top 6 out of 7 enterprises had American headquarters, including Intel, Cisco Systems, Apple, Qualcomm, EMC and Hewlett-Packard. Only Ericsson, Nokia and Alcatel-Lucent were had their headquarters in Europe. These firms have subsidiaries or joint ventures located in European countries, such as Apple in Ireland (most Apple products are assembled in China by the Foxconn Technology Group, based in Taiwan). The parent firm will be expected to carry out R&D abroad, which explains why size of the sector differs widely in these countries, as does the total R&D intensity.

Figure 25 BERD flows in the electronics industry, 2013



Own calculation based on BERD flows database.

Note: Data for Japan is from 2011.

The figure also indicates the general increase in total R&D from 2009. Many countries in Europe show a general growth trend from 2007 to 2013 in total BERD. There was strong growth observed in the US and Japan between 2009 and 2011, but there was a large decline observed in Japan in 2013. The shares appear relatively consistent across observations, except for the UK where the share of inward BERD jumped dramatically in 2013.

Foreign ownership plays a central role in the electronics industry as total BERD is distinguished from inward BERD (see table A3). Apparent labour productivity of inward BERD appears consistently higher in the larger countries such as France, Germany, Italy and the UK. A similar pattern is observed for BERD intensity and the share of R&D employment. Ireland has the highest apparent labour productivity, perhaps because of the strong presence of Apple, but it could also be due to transfer pricing. Several small countries show the opposite trend, where total labour productivity is higher in the domestic industry. Results appear mixed as to whether any significant catching up took place over the last decade.

The technology hardware and electronic equipment industries appear to engage more in investment in new assets (greenfield FDI) than rely on mergers and acquisitions (M&As). These firms are strategic asset seekers and are looking to benefit from local R&D resources, often with the active participation of local enterprises (for example Huawei). There has been comparatively little merger and acquisition activity in technology hardware and electronic equipment industries from 2007 to 2014. Intel engaged in 69 projects totalling €8 billion but where involved in 18 cross-border M&A deals (out of a total of 37 deals totalling €8.2 billion) (p.40). By contrast, Apple engaged in 35 projects totalling €4.1 billion including 12 cross-border M&A deals, but engaged in only 20 greenfield investments totalling €300 million. The telecommunications industry was mainly involved in cross boarder M&As: Nokia engaged in 19 projects totalling €7 billion and where involved in 16 cross-border M&A deals and Ericsson engaged in 33 projects totalling €4.7 billion, of which 31 involved cross-border M&As.

Table 10 summarizes the number of announced greenfield R&D FDI projects, including design, development and testing, by source and destination, from the beginning of 2010 to the end of 2015 for the automotive industry. It presents the data by source (originating) country (or region) by row and the destination (receiving) country (region) by column. The table contains more than 2000 cross-border R&D projects, or more than half of the half of the projects included in this case study. This example includes electronic and electrical hardware and complementary software (NACE 26, 27 and NACE 62-63), which is one of the strengths of US technology. US enterprises initiated almost 900 international projects around the world, without any clear preference for location. Still, it is noticeable that the US initiated 60 projects in Ireland and 83 in East Europe, whereas Ireland initiated only three projects in the US and the whole of East Europe initiated two projects in the US. A similar trend though not as pronounced occurs between the US and East Asia and India and even to a much lower degree between Europe and Asia. These data indicate that there is a transfer of ideas and knowledge between countries in West Europe and the United States, but a more direct flow from the US to countries below the technology frontier.

Table 10 Number of announced greenfield R&D FDI projects, by source and destination, in the ICT sector, 2010-2015

	USA	Germany	France	UK	Ireland	India	E Asia	E Europe	Other	Total
USA	0	24	32	93	60	203	127	83	273	895
Germany	21	0	1	9	7	17	20	16	39	130
France	14	1	0	10	2	11	17	9	42	106
UK	29	6	2	0	6	15	12	21	76	167
Ireland	3	0	1	3	0	2	3	5	9	26
E Europe	2	4	0	0	0	1	1	3	4	15
India	21	5	0	8	7	0	10	4	26	81
E Asia	37	17	2	10	4	16	60	8	45	199
Other	56	25	16	31	5	36	47	41	137	394
Total	183	82	54	164	91	301	297	190	651	2013

Own calculation based on based on information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com)

Europe adopted an electronics strategy covering micro and nano-electronics in May 2013. The computer, electronic and optical products industries drive rapid technical change and provide key-enabling technologies. This has led to consolidation of the industry, but it also appears to be encouraging new greenfield investment. The industry continues to pack more transistors onto an integrated circuit, it tends to drive further investment with each new generation of chips. Nano-electronics (semiconductor components and highly miniaturised electronics) and Photonics (conversion of sunlight into electricity, photodiodes, LEDs and lasers) are driving investment in the most radical new technologies.

In summary:

- The share of BERD performed abroad has remained relatively stable within Europe since 2008, with some modest gains in France, Germany and the Netherlands. While research remains concentrated near the home bases of lead firms, internationalisation has focused more on production facilities abroad, particularly in east Asia.

- There is no main player in the European computer, electronic and optical products industry as several companies have headquarters in Europe. Germany, Italy, France, Italy, the Netherlands, Sweden and the United Kingdom have research programmes in Europe. Europe depends heavily on the USA and east Asia, which means that research networks will play an important role in transferring technology and fostering innovation
- The level of economic development explains large national differences in the R&D intensity, especially in the computer, electronic and optical products industry. Here the relatively backward countries contribute relatively low-value added activities to the global value chain. There is some indication that technological upgrading is taking place in east Asia and there may be significant catching-up taking place in eastern Europe though from a low level. Apparent labour productivity more than doubled between 2009 and 2013 in Bulgaria, Czech Republic, and Slovakia (and possibility Slovenia).
- Labour productivity (both in terms of value added and production output) appears to be higher in the countries with inward FDI, except for new small countries where it appears higher in the domestic economy.

R&D internationalisation in the software and computer services.

Computer programming, information services, software publishing and related activities (NACE 58.2 and 62-63) are classified as Knowledge Intensive Business Services (KIBS) based on its R&D intensity and R&D growth. Certain clarifications are important for this service industry. Because of significant changes made to the Statistical classification of economic activities in the European Community in revision 2, software and related activities were reorganized into Section J: information and communication. Previously (NACE 1.1) it was organized into NACE 72 (part of Section K) as computer and related activities. As a consequence, software publishing (NACE 58.2) is not included in computer programming, etc., but it is included in the EU R&D scoreboard. Software publishing makes up about two-thirds of the software and computer services in the United States, and it makes up almost 90% of total BERD in the global economy. Germany is missing from the story because the data are confidential, but R&D scoreboard shows that one firm describes more than 80% of total BERD in this industry.

The idea that service production is different from manufacturing date back to at least the time of Adam Smith. Smith believed that services "generally perish in the very instant of their performance", but it was also suggested by Marx and later by Hill that services can also affect the physical or mental condition of the consumer. Economists had long considered services as a residual (Clark, 1940) or as a 'tertiary' sector (Fischer, 1939), and they can also describe them as a particular group of industries (as outputs) or as a group of occupations (as labour inputs). By contrast, Hill (1977; 2015) defined a service as "a change in the condition of a person, or of a good belonging to some economic unit, which is brought about as the result of the activity of some other economic unit, with the prior agreement of the former person or economic unit." In manufacturing the process of production and the output of that process are distinct events, whereas for services the process of production is often confused for the output. In other words, the consumption of a service must take place simultaneously with its production, which will then influence the physical or mental condition of the consumer.

Knowledge-based services are heterogeneous and more complex then the services described by Smith. Hill (1999) suggests that software should not be considered a service, but an intangible good that is an outcome of R&D activity and subjected to intellectual property rights. This fuzzy distinction may explain Baumol (1985; 2002) reasoning that software production could be classified as an asymptotically stagnant impersonal service because it is both progressive (increasing returns) and the stagnant (constant returns) at the same time. Horn (2000) also makes the suggestion that productivity growth in software creation has been rising rapidly, though not as quickly as computer hardware. There are not only scale economies created by spreading fixed and sunk costs over time, but increasing returns may appear in the development and production of new software, often reliant on existing knowledge and existent coding. Software production can lead to radical improvements in productivity (software engineering), but new technological opportunities have been met by growing (often intermediate) demand, mainly in the creation of custom software (Peneder et al. 2003). The fuzzy distinction may also explain some of the challenges presented in measuring BERD intensity and BERD growth in the software industry.

There is considerable variation across the different enterprises in the industry, but R&D intensity tends to be very high in this industry, sometimes surpassing 50% as in the case of Facebook. Software and computer services have observed fairly high growth over the past two decades, and it appears that Inward BERD is also growing rapidly, but there is a problem in getting sufficient statistics. Besides being a key driver in economic growth, another striking feature of KIBS is their role in the internationalisation of R&D. The industry contains several large enterprises with subsidiaries located a many different countries. It also has many complementary subsidiaries in computer, electronic and optical products industry (NACE 26) involved in software production.

A few very large companies mainly located in the United States and China drive R&D growth rate in Software & Computer Services. Rapid growth and technical change is driving the software industry in the US, but there are several firms in Europe who are potential leading innovators. US-based firms account for almost two-thirds of total BERD in this industry (the Eurostat R&D Survey estimates that US companies account for 77% of Global R&D), as it has led the way in the development of software/internet companies such as Google, Facebook, Twitter, Linkedin, eBay and Amazon. Six out of the top enterprises had American headquarters, including Microsoft, Google, Oracle, IBM, Facebook, and Yahoo! Germany and the United Kingdom are the most important players in Europe, but the industry is dwarfed in comparison with the United States. Data from the OECD indicates that Europe makes up no more than 20% of BERD total from 2009 to 2013. SAP is by far the most important player in Germany (and Europe), accounting for more than 80% of total BERD in this industry (European R&D Scoreboard). European total BERD accounts for about 45% of total BERD in computer programming, information services and related activities, of which about half of this amount is attributed to Germany, UK and France. There is very few statistics on inward BERD for Europe, but those that do exist indicate the share of inward BERD is very low in the Netherlands and Slovenia, and about half of total BERD in Austria, Belgium and the Czech Republic and about 66% in the UK. The share was between 4% and 5% in the United States in 2009 and 2011, but it perhaps averaged between 1% and 2% when NACE 58.2 is included.

Eight of the top ten enterprises experiencing the fastest in growth in R&D activity between 2013 and 2015 were located in the United States. King Digital Entertainment (Ireland) had the highest BERD growth averaging more than 110% per year over the three-year period. Facebook observed the highest growth of BERD among the top 10, averaging more than 50% per year over the three-year period. Companies based in the US increased their R&D investment by about 13%, performing better than enterprises in Europe and Japan. There is a significant gap for the EU vis-à-vis the US in terms of number of companies and R&D investment in software. Nevertheless, the

Scoreboard also shows a number of world-beating EU companies of substantial size in these sectors, as well as a significant number of high-performance companies showing the potential to further climb-up in the ranking of world top R&D investors. Many software companies located in China showed double digit R&D growth, such as Baidu (69.9%) and Tencent (52.2%) in 2015.

Table 11 Top 10 Global enterprises in software and computer services

World Rank	Name	Country	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
3	MICROSOFT	US	9,921.7	12.9	5.1	77,077.6
6	GOOGLE	US	8,098.2	14.9	15.3	54,362.1
22	ORACLE	US	4,549.9	14.5	4.4	31,485.0
25	IBM	US	4,335.7	5.7	1.4	76,429.4
50	SAP	Germany	2,307.0	13.1	5.6	17,560.0
55	FACEBOOK	US	2,195.9	21.4	53.9	10,267.7
84	FUJITSU	Japan	1,384.1	4.3	-2.4	32,452.0
116	YAHOO!	US	1,064.3	28.0	-1.7	3,803.7
131	BAIDU	China	939.7	14.2	43.9	6,602.7
132	TENCENT	China	934.4	8.8	23.9	10,624.7

Notes: BERD growth is the 3-year compound annual growth rate. *Industry classification based on* The Industry Classification Benchmark (ICB) *and roughly corresponds to NACE*. Software and Computer Services includes computer services, internet and software.

Source: EU R&D scoreboard 2015.

Germany and the United Kingdom are the most important players in Europe, but the industry is dwarfed in comparison with the United States. Data from the OECD indicates that Europe makes up no more than 20% of BERD total from 2009 to 2013. SAP is by far the most important player in Germany (and Europe), accounting for more than 80% of total BERD in this industry (European R&D Scoreboard). The UK appears to be of a similar size, mainly because there are many smaller software firms. As already mentioned, King Digital Entertainment had the highest BERD growth, showing up in tenth place of the European top ten.

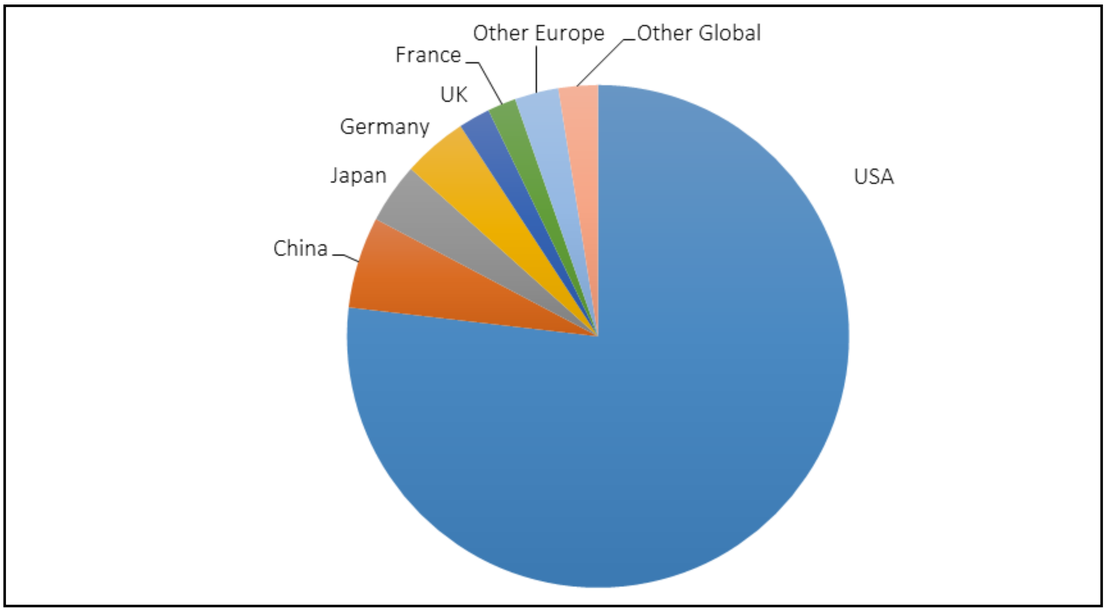
Table 12 Top 10 European enterprises in software and computer services.

EU Rank	Name	Country	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
15	SAP	Germany	2,307.0	13.1	6.0	17,560.0
60	AMADEUS	Spain	568.4	16.6	16.3	3,417.7
68	UBISOFT ENTERTAINMENT	France	445.6	30.4	7.9	1,463.8
73	DASSAULT SYSTEMES	France	409.7	17.9	7.6	2,294.3
116	AMDOCS	UK	212.4	7.2	5.1	2,935.2
124	YANDEX	Netherlands	201.2	27.1	31.2	743.3
129	INDRA SISTEMAS	Spain	195.1	6.6	1.0	2,937.9
146	SQUARE ENIX	UK	173.0	129.3	20.5	133.8
151	SAGE	UK	168.7	10.0	-7.5	1,680.0
167	KING DIGITAL ENTERTAINMENT	Ireland	152.3	8.2	146.3	1,861.7

Notes: See previous note.
Source: EU R&D scoreboard 2015.

European total BERD accounts for about 45% of total BERD in computer programming, information services and related activities, of which about half of this amount is attributed to Germany, UK and France. There is very few statistics on inward BERD for Europe, but those that do exist indicate the share of inward BERD is very low in the Netherlands and Slovenia, and about half of total BERD in Austria, Belgium and the Czech Republic and about 66% in the UK. It was between 4% and 5% in the United States in 2009 and 2011, but it perhaps averaged between 1% and 2% when NACE 58.2 is included. By contrast, it has increased from 13% in Canada in 2009 to over 28% in 2013, and it was over 71% in 2011 in Israel.

Figure 26 Software & Computer Services in the top 2,500 ranked by R&D.



Source: 2015 EU R&D Scoreboard: World - 2500 companies ranked by R&D.

Table 13 also corroborates the relative importance of inward flowing R&D to the overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process. The table also indicates the general increase in total R&D from 2009. Many countries in Europe show a general growth trend from 2011 to 2013 in total BERD and total BERD in both the United States and Europe. The shares appear relatively consistent across observations, except for the UK where the share of inward BERD is relatively high for its size.

Table 13 Inward BERD as a percentage of total BERD in software and computer services

		2007		2009		2011		2013
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	255	35.7%	166	24.7%	274	47.4%	352	53.7%
Belgium	264	31.8%	236	36.9%	324	39.2%	422	46.4%
Canada	:	:	787	13.1%	1,167	21.1%	1,002	28.4%
Czech Rep.	103	43.7%	121	47.9%	171	45.0%	194	47.4%
France	:	:	:	:	:	:	2,027	21.7%
Germany	:	:	:	:	:	:	3,170	13.7%
Israel	:	:	:	:	1,915	71.1%	:	:
Italy	390	55.9%	277	:	290	:	859	:
Netherlands	275	:	624	9.8%	1,381	7.7%	1,376	10.4%
Slovenia	6	:	19	:	52	:	36	11.1%
UK	1,464	66.5%	1,328	:	1,773	:	2,379	65.7%
USA	24,838	1.1%	10,966	3.8%	12,603	5.3%	:	:
USA*	:	:	*29,889*	1.0%	*32,693*	1.5%	*38,436*	*1.6%*

Notes: Germany includes total information and communications; USA* includes software publishing.

Source: BERD flows database.

Software and computer services account for just over half of R&D investment in key enabling technologies (KETs). The development of better software, including software supporting artificial intelligence defines the industry. Software development has become increasingly important for high performance computing, building data value, social computing, internet-based applications, embedded systems, human-oriented computing, enterprise applications and the generation of software-intensive systems.
In summary:

- Industrial R&D is highly concentrated in software and computer services, and is much higher in the US and East Asia than in Europe.
- Germany and the United Kingdom are the most important players in Europe, but the industry is dwarfed in comparison with the United States.
- There is a significant gap for the EU vis-à-vis the US in terms of number of companies and R&D investment in software.
- Six out of the top enterprises have American headquarters, including Microsoft, Google, Oracle, IBM, Facebook, and Yahoo! Three of the top 10 enterprises had their headquarters in Asia, including Fujitsu in Japan and Baidu and Tencent in China. Only SAP had their headquarters in Europe.
- Inward flowing R&D makes up a significant share of overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process.
- Apparent labour productivity appears higher in virtually all of the foreign affiliates when compared with their domestic counterparts.

R&D internationalisation in the electrical equipment industry

The electrical equipment industry (NACE 27) is classified as a medium-high technology industry based on its R&D intensity. Some multinational firms such as Samsung could easily be classified in computer, electronic and optical products (NACE 26), especially when you consider their smart phones, smart televisions and other related products that BERD intensity in Samsung is approximately twice that of Apple. Robert Bosch, for example, could be classified in electrical equipment, but its core activity is automotive. There are some important differences in the Industry Classification

Benchmark (ICB) system and the Statistical classification of economic activities in the European Community (NACE). The Institute for Prospective Technological Studies (IPTS) uses the former to compile the EU R&D Scoreboard and Eurostat uses the latter to compile the BERD statistics. The main difference is that consumer electronics are identified separately from electronic office equipment and are considered to be electrical goods.

Industrial R&D is highly concentrated in the electrical equipment industry. European firms account for about half of global R&D in the industry, not including China or Taiwan. And despite the high growth of R&D activity by Samsung, Asian R&D activity declined quite precipitously in Japan from more than half of global R&D activity at the time of the millennium to 21% of global R&D activity, excluding China and Japan. The industry is very heterogeneous, where large transnational firms tend behave as strategic asset seekers, but they can be market seekers or efficiency seekers depending on the strategic objectives of the enterprise. R&D internationalization strategies tend to be demand-driven as consumer electronic and electrical products often require regional and national adaptation of products to satisfy customers' preferences. Many of the firms are considered to be d Global R&D intensity electrical equipment industry averaged 4.5%, which is somewhat higher than that of the US and Japan, but the dispersion of R&D intensity is quite large in Europe. Both Siemens and Phillips have an R&D intensity that is above the 5% threshold generally used to identify a high tech industry. Samsung, as well as Toshiba and Fuji Film, are above the threshold, but Samsung has highest R&D activity in the world, second only to Volkswagen. One important caveat is that there about 400 enterprises in China and Taiwan in the top 2500 companies with R&D activity, whereas there are about 600 enterprises in the whole of Europe, which indicates there can be some interesting dynamics between Europe and Asia.

Table 14 Top 10 Global enterprises producing consumer electronic and electrical equipment.

World Rank	Name	Country/Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
2	SAMSUNG ELECTRONICS	South Korea	12,187.0	7.9	13.1	154,500.
24	SIEMENS	Germany	4,377.0	6.1	2.1	71,920.0
33	GENERAL ELECTRIC	US	3,486.5	2.8	1.1	122,386.
47	TOSHIBA	Japan	2,407.9	5.3	1.0	45,442.3
51	HITACHI	Japan	2,285.9	3.4	-5.2	66,737.2
70	PHILIPS	Netherlands	1,693.0	7.9	2.4	21,391.0
75	HONEYWELL	US	1,558.4	4.7	0.1	33,198.2
94	HON HAI PRECISION	Taiwan	1,269.9	1.2	4.5	109,520.
95	MITSUBISHI ELECTRIC	Japan	1,226.4	4.2	1.6	29,515.0
112	FUJIFILM	Japan	1,100.2	6.5	-1.8	17,018.0

Notes: BERD growth is the 3-year compound annual growth rate. Industry classification based on The Industry Classification Benchmark (ICB) and roughly corresponds to NACE 27. Electronic and electrical equipment includes consumer electronics contained in NACE 26.
Source: EU R&D scoreboard 2015.

France, Germany, Netherlands and the UK are the key players within Europe. These three countries make up about 60% total European BERD. German enterprises account for just over 30% of European BERD, but only Siemens appears on the top 10 list. It is the fourth largest industry in terms of sectoral distribution in Europe and the sixth largest industry globally. And there were some world leaders among the European Enterprises, such as ASML in the Netherlands who have an 80% global market share in precision lithography, and ARM in the UK who have a 95% market share in making semiconductor chips for smart phones and 80% share in digital cameras. Generally, R&D intensity in Europe compares quite favourably with US firms.

European total BERD accounts for approximately 60% of total global BERD in the electrical equipment. While Germany traditionally contributes the most BERD in Europe, its share of funding from abroad (inward BERD) is usually very low. Historically, the proportion of R&D activity by large transnational firms undertaken outside their home countries has been quite small, which explains why the three largest countries (Germany, Japan and the United States) with BERD activity in the electrical industry observed shares that were generally below 15%. In Japan the share is very low, barely exceeding 3%, in the US it is slightly higher, ranging between 16% and 18%, but in Germany it swings between 30% and 50%. With the exception of Nordic countries and Slovenia, the share of inward BERD is generally above 50%.

Table 2 also corroborates the relative importance of inward flowing R&D to the overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process. Six of the top ten firms in this industry and located in Asia, only two are located in Europe: Siemens and Phillips. The table also indicates the general increase in total R&D in the European auto industry in 2007, 2009, and 2013. The financial crisis of 2008 may of also had an impact on the growth of BERD in this industry. Both Germany and the US show a general growth trend, whereas Japan shows a rapid decline from 2007 to 2013 in total BERD. Data for the UK appears unreliable as inward BERD sometimes exceeds total BERD, and the share jumps around by wide margins every two years.

The rapid decline of Japan in the manufacture of electrical equipment likely reflects the factors influencing the technology upgrading and catch-up of East Asia. Many of the firms are involved in final assembly and hence in relatively low value added activities, but they can move op the technological ladder and produce more advanced equipment and more complex products. Companies based in China and South Korea appears to be catching-up quickly. There is evidence that European firms, such as Siemens and Philips, have invested heavily in Korea. Moreover, Samsung Electronics has at least 16 R&D centres located abroad, including in China, India, the UK and the US. Its global R&D network develops new technologies in digital media, telecommunications, digital appliances and semiconductors and it carries out joint R&D projects through strategic alliances with Sony, IBM, Hewlett-Packard and Microsoft.

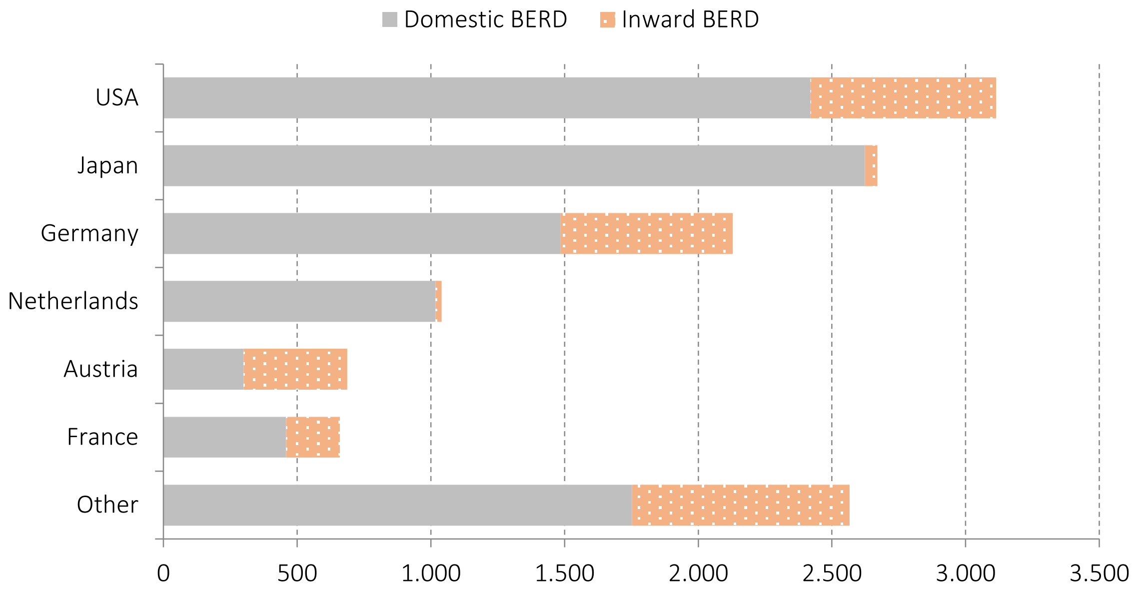
Table 15 Inward BERD as a percentage of total BERD in electrical machinery and apparatus

	2007		2009		2011		2013	
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	647	74.5%	826	71.4%	736	59.9%	688	56.5%
Belgium	128	74.2%	197	86.3%	222	64.0%	137	41.6%
Canada		:	103	54.4%	105	42.9%	102	54.9%
Czech Rep.	38	39.5%	40	67.5%	66	59.1%	72	61.1%
Denmark	67	6.0%	52	:	79	:	67	14.9%
Finland	147	59.2%	212	68.4%	260	67.3%	300	:
France		:	838	20.3%	649	:	660	30.5%
Germany	1,343	30.6%	1,333	29.6%	1,602	53.1%	2,130	30.3%
Hungary	16	93.8%	21	:	22	81.8%	28	82.1%
Ireland	112	:	17	:	13	:	34	:
Italy	205	:	381	:	461	36.9%	483	34.2%
Japan	6,698	3.3%	2,629	:	3,120	1.7%	2,670	:
Netherlands	67	:	1,114	2.3%	962	2.2%	1,040	2.1%
Norway	77	22.1%	46	:	48	35.4%	60	38.3%
Poland	29	37.9%	32	20.8%	52	80.8%	78	62.8%
Portugal	12	58.3%	27	:	44	:	35	:
Romania	15	:	6	20.8%	17	11.8%	5	16.7%
Slovakia	3	66.7%	6	66.7%	18	38.9%	12	33.3%
Slovenia	24	8.3%	42	:	201	24.9%	174	46.0%
Spain	170	:	211	22.3%	195	42.1%	190	53.2%
Sweden	180	23.9%	214	:	268	:	329	:
UK	285	83.2%	154	:	175	57.7%	460	43.5%
USA	1,976	16.4%	2,390	17.1%	2,583	18.2%	3,114	22.3%

Source: BERD flows database.

Foreign ownership plays a central role in the electrical equipment industry as total BERD is distinguished from inward BERD (see Table A3). Apparent labour productivity of inward BERD appears higher than for total BERD for Europe as a whole. This includes Germany, Italy and the UK, but the results tend in the opposite direction in France and the Netherlands. Labour productivity also appears to have risen in the east European catching-up economies across all three periods, but the larger west European countries experienced mixed results from 2011 to 2013. The Nordic countries were an exception to this trend with labour productivity growth continuing in the third period. The share of BERD also tended to increase over the three periods, but the share of R&D employment does not rise in all countries in the third period. Although not the highest in terms of BERD intensity, Norway observes the highest apparent labour productivity. There appears to have been some significant catching up that took place over the last decade.

Figure 27 BERD flows in electrical machinery, 2013



Own calculation based on BERD flows database.

Note: Data for Japan is from 2011.

The electrical equipment industries are diverse as to whether they invest in new assets (greenfield FDI) or rely on mergers and acquisitions (M&As). It appears that more established firms in Europe and the US are more market seekers, whereas Asian firms, and in particular Samsung, are like strategic asset seekers and are looking to benefit from local R&D resources, often with the active participation of local enterprises. General Electric is one of the largest firms involved in M&As. Between 2007 to 2014 General Electric was involved in 275 different FDI projects, of which 30 were M&As valued at €20.5 billion, and 16 of these were cross border. In Japan, Hitachi was involved in 143 FDI projects, of which 27 were M&As valued at just under €10 billion, and 8 of these were cross border. By contrast, Samsung Electronics were involved in 59 FDI projects, 24 M&As, of which 12 were cross border, but the total value of the M&A was just over €1 billion, whereas the total value of Greenfield FDI exceeded €16 billion.

Europe is considered to be highly competitive and on the technology frontier in machinery and equipment. Upstream and downstream linkages are essential to the innovativeness of the industry, just as maintaining a stable, predictable, and coherent regulatory environment that embraces 'smart' principles. There appears to be a convergence of electronics, electrical and mechanical technologies going on in Europe. Technical change appears is rapid in precision machining and specific high-speed processing technologies. There also appears to be an increasing use of ICT technologies (especially software) that come from different subsystems of the supply chain.

The study shows:

- The R&D growth of the EU based companies of the Machinery & Equipment had declined by more than 4% in 2005; Companies based in US have had a low growth of less than 1%, while companies based in Japan a growth rate exceeding 12%.
- Five European firms are among the top R&D performers: EXagon (Sweden) Wartsilia (Finland); Class (Germany) Kone(Finland) and Weir (UK).
- The Eastern European countries have experienced the most important increase of inward BERD in the recent years. In particular, Hungary (180%) and Czech

Republic (125%) are the two success stories in the “machinery and equipment” sector.

- Among the top European economies, Germany has recorded the highest increase in R&D inward investments of MNE’s (35%), with an even higher increase from the pre-crisis level to 2013 (106%)
- United States is the first hosting Country of foreign investments in R&D, even if in recent years the international dimension of R&D activities has decreased from 19 to 17 percentage points.

R&D internationalization in pharmaceuticals

The pharmaceutical industry, including basic pharmaceutical products and pharmaceutical preparations (NACE 21), is a technologically concentrated industry. It is among the highest R&D intensive sectors (OECD, 2011), where knowledge generation plays a key role in a context of global competition. Almost one-quarter of the top 100 enterprises are engaged in pharmaceutical R&D related activities and about 60% of the total global BERD is attributed to the United States, excluding Switzerland or East Asia. Some of the enterprises focus purely on pharmaceuticals while others specialized in medical technologies (Johnson & Johnson) or chemistry (Bayer). Others are involved in substantial patenting activity in biotechnology (Roche). Germany is the most important player within Europe, making up about a third of EU BERD, with Belgium the second largest BERD. Novartis and Roche are the two largest firms in pharmaceuticals, both of which are located in Switzerland. The industry is fairly internationalised, with the larger countries such as the United States and Germany having between one-quarter and one-third inward BERD, and some smaller countries such as Austria and Belgium approaching a 90% share of inward BERD. Belgium experienced the greatest growth of inward BERD; increasing by 64% from 2008 to 2013.

Table 16 shows the top 10 global enterprises in pharmaceuticals and biotechnology. Switzerland is the only OECD countries for which the amount of outward investment in R&D is higher than inward. Most of this outward BERD is directed to US. Most of the top 100 companies showing a significant increase in R&D activity in the last two years are in Pharmaceuticals and Biotechnology. R&D increased by 21.3% in enterprises where biotechnology predominated, whereas it increased by only 4.8% in traditional pharmaceutical enterprises.

Table 16 Top 10 Global enterprises in pharmaceuticals and biotechnology

World Rank	Name	Country/Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
5	NOVARTIS	Switzerland	8,217.6	16.7	2.5	49,084.1
7	ROCHE	Switzerland	7,422.1	18.8	2.5	39,523.1
8	JOHNSON &	US	6,996.1	11.4	2.7	61,223.1
10	PFIZER	US	6,844.6	16.8	-8.1	40,857.4
12	MERCK US	US	6,056.3	17.4	-1.9	34,788.7
19	SANOFI	France	4,812.0	14.2	-0.3	33,770.0
26	ASTRAZENECA	UK	4,164.4	19.4	-2.2	21,493.3
27	GLAXOSMITHKLINE	UK	4,002.0	13.5	-2.4	29,575.6
29	BAYER	Germany	3,689.0	8.7	2.3	42,239.0
32	AMGEN	US	3,498.9	21.2	8.8	16,525.0

Notes: BERD growth is the 3-year compound annual growth rate.
Source: EU R&D scoreboard 2015.

The US has the highest degrees of internationalization in health related innovations (pharmaceuticals and biotech), in terms patent inventors located outside the world region. The distribution of patents filed by the world's top R&D investors is a good proxy for the location of companies' innovation activities. Growth of R&D investment in pharmaceuticals and biotech enterprises was 10.7% in the US and 6.5% the EU in 2014 (R&D Scoreboard, 2015). By contrast, pharmaceutical enterprises based in Japan had declined by 1%, (although it had increased by almost 10% 2013).

R&D intensity in biotechnology was 18% in Europe vis-à-vis 23% in US and in pharmaceutical is 13,1% in Europe vis-à-vis 15% in US. Bio-pharma and health equipment sectors shows a significant gap for the EU vis-à-vis the US in terms of R&D investment, even if there are a number of winning EU companies of substantial size in these sectors, the problem is that they are too few. One of these winning EU companies is Novo Nordisk, a Danish multinational pharmaceutical company, with production facilities in eight countries and affiliates or offices in 75 countries. Novo Nordisk is the world leader in treatments for diabetes, the world's fastest growing major disease, with around 50% global market share.

The US dominates the EU in number of companies (6 times more numerous), R&D investment (11 times larger) and larger average R&D intensity per company in the biotechnology sector, which is also a source of innovation for pharmaceutical products. A particular strength of the US lies in large biotech companies, such as Amgen, Gilead Sciences, Biogen, Celgene and Regeneron, which have grown fast through the early adoption of biotech and all have blockbuster drugs on the market). Most of them are now sufficiently large that they are unlikely to be acquired by pharmaceutical companies.

Table 17 Inward BERD as a percentage of total BERD in the pharmaceutical industry

	2007 Total	2007 Inward Share	2009 Total	2009 Inward Share	2011 Total	2011 Inward Share	2013 Total	2013 Inward Share
Austria	280	93.2%	193	91.7%	170	88.2%	285	92.6%
Belgium	1,249	76.5%	1,145	83.4%	1,428	89.2%	1,944	81.4%
Canada		:	423	58.6%	368	60.3%	372	40.1%
Czech Rep.	40	87.5%	45	86.7%	44	59.1%	38	68.4%
Denmark	:	:	879	:	894	:	1,110	:
Finland	:	:	109	23.9%	117	32.5%	120	:
France		:	854	76.7%	839	:	805	66.0%
Germany	3,312	52.7%	3,896	21.9%	4,070	26.2%	4,075	21.0%
Greece		:		:	60	:	59	:
Hungary	166	:	189	:	193	52.3%	202	51.5%
Ireland	147	:	240	:	127	:	165	:
Italy	474	:	534	:	578	52.4%	544	45.4%
Japan	7,752	:	9,158	:	11,084	13.1%	11,083	:
Netherlands	471	:	816	49.1%	700	45.9%	488	48.0%
Norway	63	:	52	:	92	:	49	49.0%
Poland	34	:	37	45.9%	41	48.8%	52	55.8%
Portugal	62	21.0%	68	1.5%	87	:	85	:
Romania	16	:	2	20.8%	9	55.6%	9	55.6%
Slovakia	7	:		:	13	:	2	104.2%
Slovenia	111	:	135	:	299	:	322	:
Spain	617	:	664	37.2%	636	25.6%	568	26.6%
Sweden	1,102	81.9%	595	:	858	:	805	:
Switzerland	:	:	:	:	:	:	3,086	6.6%
UK		:	1840	41.5%	4850	47.1%	4,805	54.0%
USA	34,749	30.1%	32,217	32.4%	33,009	33.4%	39,474	36.7%

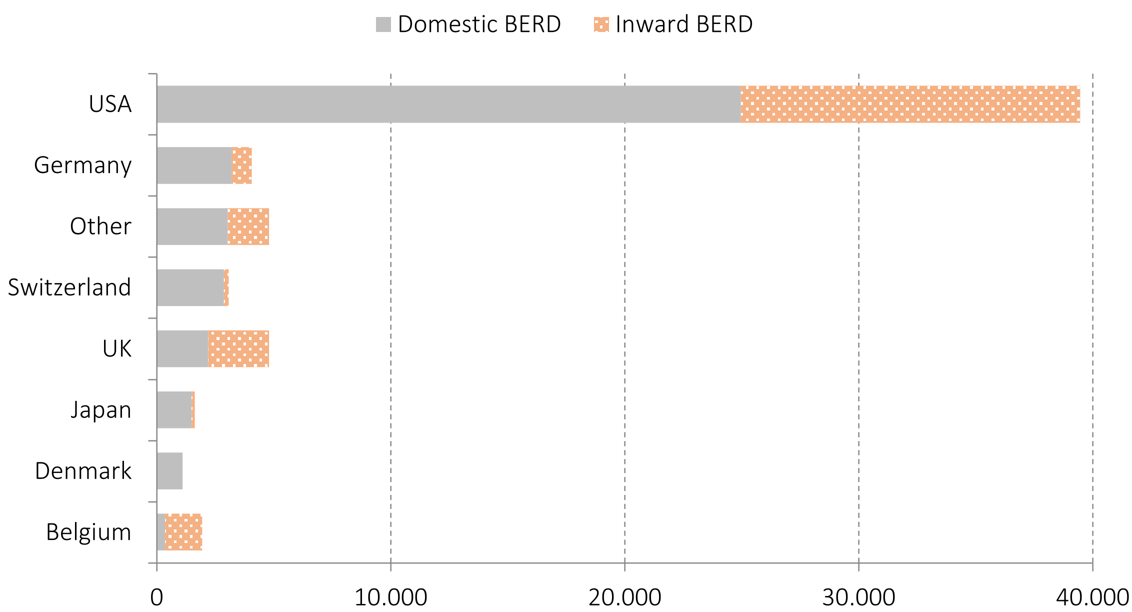
Note: Switzerland is for 2012.

Source: BERD flows database.

Table 17 shows inward BERD as a percentage of total BERD in the pharmaceutical industry. The pharmaceutical industries of United States, Belgium and Czech Republic are the only that have experienced an increase of the inward investments in R&D. However, these three Countries show different patterns in the evolution of their total BERD investments and in the level of internationalization. In Czech Republic the growth of inward BERD investments is not continuous over time, and it seems to be run aground in the last years. This fact has implied a decrease in the inward share of the total BERD investments. From 2011 both total and inward BERD start a falling trend. Conversely, Belgium shows an important increase of total BERD and a parallel increasing internationalization of R&D activities in the Pharmaceutical sector. United States, instead, shows divergent patterns between inward share and total BERD investments. While the former decreases, from 2007 to 2011, the latter increases (from 30% to 33.4%). Conversely, in all the other observed Countries we can see an opposite tendency. Germany records the most pronounced decrease of inward investments in R&D. The increase of 23% is entirely ascribable to an increase of domestic R&D. Figure XX summarizes BERD flows in pharmaceuticals in 2013.

Belgium experienced the largest increase of both Domestic and Inward BERD; this last grew of 64% after 2008. The pharmaceuticals industry is the biggest R&D investor in Belgium, followed directly by the chemicals industry. Approximately 9,000 people are employed in companies' R&D departments of whom half are highly-qualified researchers. Because Belgium has been playing a pioneering role in life sciences for decades on end, the industry is well represented by organizations that uphold its interests. More than 200 life sciences companies are active in Belgium. Major corporations and a vast network of small and medium-sized companies (therapeutics, diagnostics, service and technology providers) specialize in all areas of biopharmaceutical fundamental & clinical research and manufacturing. The life sciences industry in Belgium has resulted in a rich landscape of innovative suppliers and support services. These experienced players specialize in a wide range of services, from services for clinical testing over state-of-the-art product development and lab equipment suppliers to life sciences patent bureaus and specialized logistics players. Together they form an indispensable link in the sustainable success of the life sciences industry in the region. The decrease in R&D investments of MNE'S was much more pronounced in some Countries, as for example in Germany where it has been of approximately 42%.

Figure 28 20 BERD flows in the pharmaceuticals industry, 2013



Note: Data for Japan is from 2011 and data for Switzerland is from 2012.
Own calculation based on BERD flows database.

In Europe the pharmaceutical and biotech companies computed among the top European 1000 R&D investors are 105 (R&D Scoreboard, 2014) mostly present in UK (30), France (17) and Germany (17). Their R&D investment grew in the last three years, respectively 0,4% (UK), 3,9% (France) and 2,3% (Germany). In terms of performance the European pharmaceutical and biotech companies show the highest labor productivity (averaged and compared to the other sectors): €158.7 thousands value added per employee. Important differences between R&D intensity (R&D/Value added) and productivity (Value added per employee) are anyway present among the main companies in this sector: from R&D intensity of UCB 48% (Belgium) to 20% of Novo Nordisk (Denmark) and 19% of Bayer (Germany) and from labor productivity of Novo Nordisk €207.1 thousands (Denmark) to €62,6 thousands of Actavis (Ireland).

The global pharmaceutical industry is expected to experience moderate growth over the next five years, marked by a rebound in US pharmaceutical growth and strong, but slower growth from emerging markets. Led by the US and "Pharmerging", to denote the most promising emerging markets, the global pharmaceutical activity is projected to increase at a compound annual growth rate of 4–7% to 2018 (estimates from IMS Health). The US and Pharmerging markets are expected to account for more than 60% of sales and 80% of sales growth to 2018. Growth in the five major markets of the European Union (France, Germany, Italy, Spain, and the United Kingdom) is mixed, with a growth rate through 2018 of 2–5% each for Germany and Italy, better growth of 4–7% for the UK, but negative to minimal growth for France and Spain. The pharmaceutical markets of China, Brazil, and India are expected to increase at a 9-12% and of 7-10% in Russia.

The rebound of US market in 2014 was attributable to several factors: a lessening of generic-drug use due to fewer patent expires in 2014, comparative to recent years, as well as the strong performance of new drugs. Among developed markets, growth prospects are strongest for innovative products and specialty medicine, while they will also begin to have greater impact in “Pharmerging” markets. Moreover, biologics’ share of the global pharmaceutical market, which increased from 13% in 2004 to 21% in 2014, will continue to grow.

Global mergers and acquisitions accounted for some large changes in R&D in the last ten years. In terms of total value of the deals, pharmaceuticals companies dominate the ranking of M&As over the past eight years (Pfizer, Merck, Roche and Novartis). In the pharmaceutical sector, many companies access specialized R&D by acquiring smaller biotech companies via M&A to diversify their portfolio of biopharmaceutical innovations or to acquire a promising pipeline drug. Seven enterprises accounted for most of the M&A activity: Pfizer with €65 billion (including 4 cross-border projects); Merck US with €48 billion (including 1 cross-border project); Roache with €46 billion (including 22 cross-border projects); Novartis with €31 billion (including 7 cross-border projects); Sanofil Aventis with €18.4 billion (including 14 cross-border projects); Glaxo-Smith-Klein with €15 billion (including 15 cross-border projects); and Bayer with €12.4 billion (including 2 cross-border projects).

Table 18 Number of announced greenfield R&D FDI projects, by source and destination, in the chemical and pharmaceutical industries, 2010-2015

	USA	*Germany*	*UK*	*Switzerland*	*Other EU*	*India*	*E Asia*	*Other*	*Total*
USA	0	10	21	2	31	20	73	44	201
Germany	16	0	0	2	19	7	31	28	103
UK	9	3	0	0	10	3	9	7	41
Switzerland	9	5	3	0	9	11	15	14	66
Other EU	21	8	9	1	21	8	23	23	114
India	5	1	1	0	3	0	0	3	13
E Asia	8	2	4	0	8	7	18	9	56
Other	5	2	2	0	4	1	1	5	20
Total	73	31	40	5	105	57	170	133	614

Own calculation based on based on information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com)

Table 18 summarizes the number of announced greenfield R&D FDI projects, including design, development and testing, by source and destination, from the beginning of 2010 to the end of 2015 for both the chemical and pharmaceutical industries. It presents the data by source (originating) country (or region) by row and the destination (receiving) country (region) by column. The table contains more than 600 cross-border R&D projects, representing almost a third off all projects in the industry. This example shows that Europe supports more than half of all R&D-FDI projects, if Switzerland is included. The US supports about half of all projects in Asia. In this example east Asia (mainly China) and the developing countries are the main destination countries.

The US appears to be the most attractive region of the world for the R&D investment for health related sectors, especially biopharma. Large cross-border mergers and acquisitions are not uncommon, as well as firms looking to acquire smaller biotech enterprises to further diversify their portfolio of biopharmaceutical innovations or to acquire a promising pipeline drug. Technical change and technological learning is most frequently found in medicines, therapies, diagnostics, and vaccines. Genomics (genome sequencing, gene editing), monoclonal antibodies (the basis of many new drugs), drugs capable of fighting antibiotic-resistant infections, anti-viral drugs (for HIV, HepC etc.), regenerative medicine (stem cells etc.) and cancer immunotherapy are driving investment in the most radical new technologies.

In summary:

- The pharma sector recovered in 2014 from the 2013 sluggish performance in both the US and the EU: the R&D investment performance of pharma and biotech companies is better in 2014 both in the US (10.7%) and the EU (6.5%), than in 2013 (0.4% and 0.9% respectively).
- The pharmaceutical and biotech companies computed among the top European 1000 R&D investors are 105 (R&D Scoreboard, 2014) mostly present in UK (30), France (17) and Germany (17). Their R&D investment grew in the last three years, respectively 0,4% (UK), 3,9% (France) and 2,3% (Germany)
- In the "Pharmaceuticals & Biotechnology" sector, companies operating in biotechnology increased R&D by 21.3% whereas the traditional pharmaceutical companies increased it by 4.8%.
- Companies in these sectors still dominate the top places in the world ranking of R&D industrial investors. Most of the top 100 companies showing a relevant R&D increase in the last two years are in the Pharmaceuticals & Biotechnology industry. Pfizer (US) in 2014 climbed to the 10th place from the 15th one; Bayer improved 20 places (now ranked 29th).
- Switzerland, with its strong characterization in pharmaceutical industry, is the only OECD countries for which the amount of outward investment in R&D is higher than inward. The largest part of this outward BERD is directed to US.
- In some case the big changes in R&D over the last ten years are the result of mergers & acquisitions policies (M&As). In fact, in terms of total value of the deals, pharmaceuticals companies dominate the ranking of M&As (Pfizer, Merck, Roche and Novartis).

R&D internationalisation in the chemical industry (NACE 20)

The chemical industry (NACE 20) generally has a medium-high R&D intensity. R&D spending in the chemical industry has been rather flat over the past years, except the USA and perhaps in emerging markets. Japanese companies tend to show higher R&D intensity than the EU and the US in Chemicals. BASF (Germany) has the largest R&D activity measured by R&D expenditure, followed by three large American firms: Dupont, Monsanto and Dow Chemicals. European firms account for about one-third of BERD in chemicals, of which almost half is attributed to Germany, with the Netherlands and France with much smaller investments. The inward share of BERD ranges between 20% and 25% in Germany and the Netherlands, but it is much higher in France. Among the 608 European top R&D companies, the R&D of chemicals represents 3% and it had a decrease between 2014 and 2015 of less than one percent while in the same industry the R&D of the top US 829 companies grew by just over one percent (Scoreboard 2015).

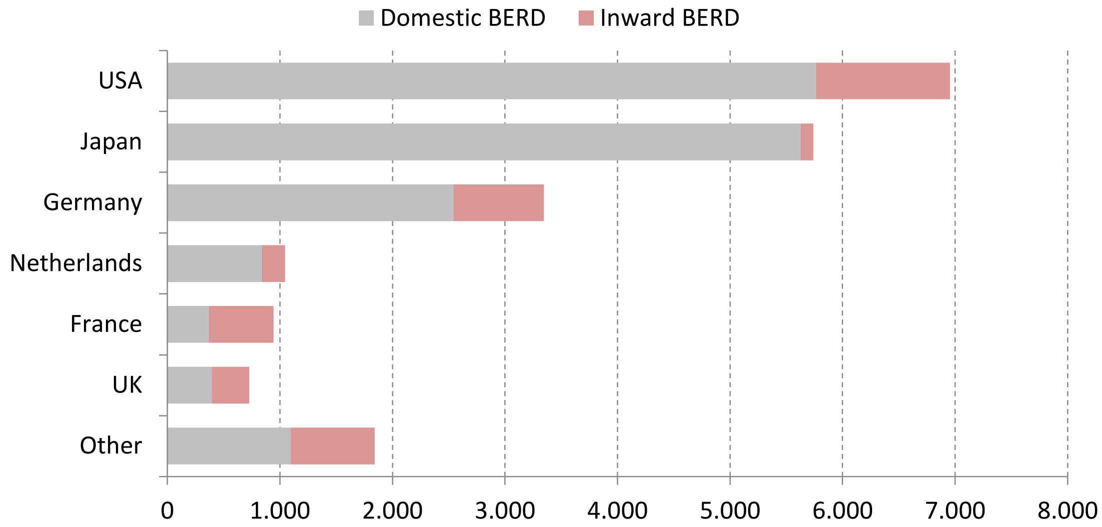
Table 19 Top 10 Global enterprises in the chemical industry

World Rank	Name	Country/Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
64	BASF	**Germany**	1,846.0	2.5	3.9	74,326.0
68	DUPONT	**US**	1,702.5	5.9	3.3	28,750.5
81	MONSANTO	**US**	1,413.4	10.8	3.4	13,059.0
85	DOW CHEMICAL	**US**	1,356.6	2.8	2.0	47,909.5
100	SYNGENTA	**Switzerland**	1,177.8	9.4	6.9	12,465.2
121	SUMITOMO CHEMICAL	**Japan**	1,009.9	6.2	4.9	16,226.6
138	MITSUBISHI CHEMICAL	**Japan**	902.7	3.6	-1.0	24,962.8
212	ASAHI KASEI	**Japan**	515.7	3.8	2.4	13,561.9
258	SAUDI BASIC	**Saudi Arabia**	409.5	1.0	26.2	41,319.5
260	EVONIK INDUSTRIES	**Germany**	408.0	3.2	3.5	12,917.0

Notes: BERD growth is the 3-year compound annual growth rate.
Source: EU R&D scoreboard 2015.

R&D investments of MNE's operating in the chemical sector generally increased over time. The US experienced an upward trend, whereas Europe had experienced mixed results. Belgium, UK, Norway, and Austria were the most internationalized countries producing chemicals. Both domestic and inward BERD increased in Austria from 2007 to 2013, but the inward share decreased from 73% in 2011 to 61% in 2013. By contrast, Germany experienced an increase of inward investments but experienced a decrease of domestic R&D investments.

Figure 29 BERD flows in chemicals, 2013



Note: Data for Japan is from 2011.
Own calculation based on BERD flows database.

Table 20 Inward BERD as a percentage of total BERD in the chemical industry

		2007		2009		2011		2013
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	142	71.1%	172	75.6%	215	73.0%	189	61.4%
Belgium	387	69.3%	277	63.5%	350	64.9%	307	72.3%
Canada		:	186	41.9%	220	65.0%	129	50.8%
Czech Rep.	25	16.7%	34	20.8%	41	43.9%	43	48.8%
Denmark	:	:	208	:	239	:	270	23.7%
Finland	:	:	115	47.8%	129	50.4%	128	:
France		:	1,031	39.1%	833	:	944	61.1%
Germany	3,148	17.4%	3,198	12.5%	3,297	19.1%	3,347	24.1%
Greece		:		:	16	:	13	:
Hungary	11	:	13	:	12	58.3%	14	21.4%
Ireland	173	:	31	:	50	:	50	:
Italy	366	:	338	:	339	41.6%	364	40.7%
Japan	5,098	:	5,794	:	6,706	2.0%	5,799	:
Netherlands	820	:	1,668	11.3%	1,108	19.5%	1,046	19.8%
Norway	117	78.6%		:		:	:	:
Poland	15	:	16	31.3%	31	19.4%	:	:
Portugal	16	18.8%	19	:	18	:	24	:
Romania	4	:	15	:	22	:	1	:
Slovakia	3	:	3	33.3%	4	:	5	8.3%
Slovenia	13	:	14	:	53	1.9%	38	10.5%
Spain	242	:	238	23.9%	242	30.2%	239	39.3%
UK		:	693	42.5%	794	59.8%	727	45.7%
USA	5,615	20.5%	6,017	18.2%	6,735	16.0%	6,956	17.1%

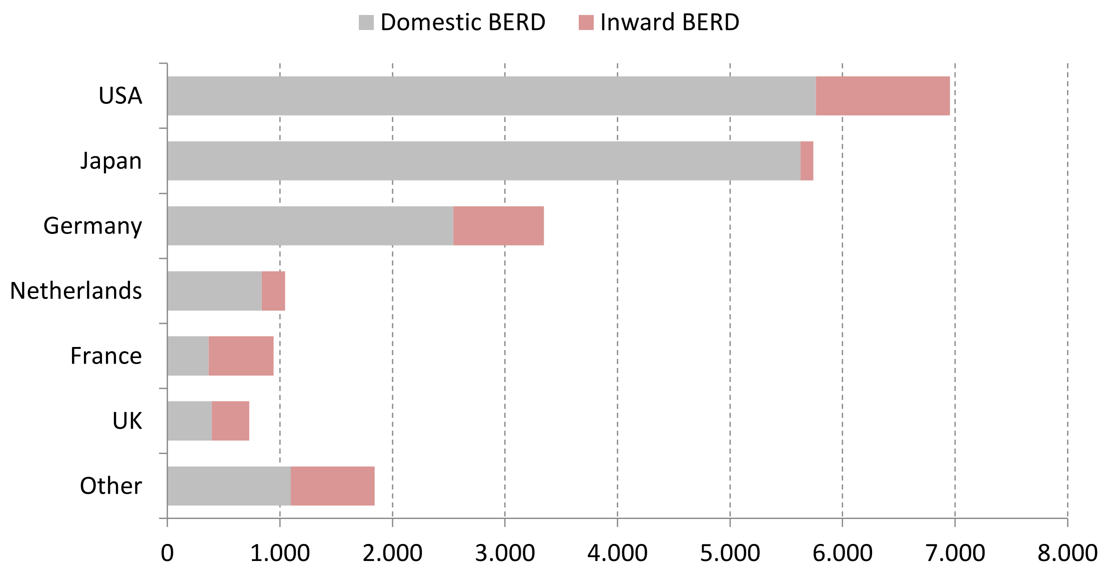
Source: BERD flows database.

European enterprises have been increasingly focusing on the high- tech and high-margin specialty and fine chemicals segments. Companies that make basic chemicals and plastics can suffer for the competition from shale-gas-fuelled production in US.

The European industry is seriously looking at reducing its raw material dependency on oil. BASF, for example, is researching into the production of succinic acid from biomass. Yet, the EU contribution to the world chemical sales dropped from 30,9% in 2004 to 17,0% in 2014 (European Chemical Industry Council, 2015).

The US, Japan and Germany had the highest share of patenting activity, followed by countries are France, Korea, China, India, UK. Academic and non-academic institutions (such as Max Planck Society; Fraunhofer Society) support this large patent activity through R&D activity in chemistry sector. The industry is characterized by increasing international competition; pressure to increase resource efficiency; and a complex regulatory environment that drives R&D and innovation. It is also undergoing rapid structural change and patent intensive relative to the key enabling technologies. Research into new catalysts and the development of industrial (white) biotechnology (industrial processing and production of chemicals and related materials) are driving investment in the most radical new technologies.

Figure 30 BERD flows in the chemicals industrry, 2013



Note: Data for Japan is from 2011.
Own calculation based on BERD flows database.

In summary:

- R&D of Chemicals represents 3% of the activity among the 608 top R&D companies in Europe. and has decreased between 2014 and 2015 by -0,8%; in the same industry the R&D of the top US companies grew of 1,3% (EU Industrial R&D Investment Scoreboard 2015).
- Among the top R&D investors, the US companies from Chemicals sector are DuPont, Monsanto and Dow Chemicals, following BASF (Germany). European countries with the highest number of chemical companies among the 1000 top R&D investors are Germany (13); United Kingdom (11), Belgium (3); Finland (3); Sweden (3).
- In terms patent registrations (by total share) in the industry, Germany holds the third place worldwide (17%) after USA and Japan; it is followed by France, Korea, China, India, UK.
- The Czech Republic is the country where, in the aftermath of the economic crisis, there has been the highest increase of the inward BERD in the chemical industry.

- The Belgian chemicals industry is one of the most diversified and integrated chemical clusters in the world. 13 of the top 20 chemical companies have production sites in Belgium and the country is the world-leader in terms of sales per capita.
- The migration of petrochemical and basic chemical industries out of Europe - mainly in the Middle East, but increasingly also in China— in the past decade has led to an important changes in the European chemical industry.

R&D internationalisation in machinery and equipment

The machinery and equipment industry (NACE 28) is a medium-high R&D intensity sector. It is a highly diversified sector, with the largest companies having very different production profiles that include the manufacture of basic power and hand tools, hardware, small-scale machinery and other industrial components. Volvo (Sweden) had the highest BERD in this industry, averaging 2.5% annual growth from 2013 to 2015, whereas Caterpillar (US) experienced an average decline of 3.8%. European total BERD accounts for more than 40% of total global BERD in the machinery and equipment industry. Germany accounts for more than one-third of the European BERD activity, followed by the Netherlands, Italy and France. But these data do not include South Korea, Switzerland or the most recent figures for the United States. The average R&D intensity of European firms was higher than in US firms (3.2% vs. 2.9%), but many firms experienced negative growth in recent years. Among the European countries, Belgium has the most internationalized R&D activities, followed by Denmark and Hungary. Conversely, Netherlands has the most "closed" R&D activities for the machinery and equipment sector. Germany was fairly open given its size.

Table 21 Top 10 Global enterprises producing machinery and equipment

World Rank	Name	Country/Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
61	VOLVO	Sweden	1,921.2	6.4	2.5	30,123.2
66	CATERPILLAR	US	1,758.5	3.9	-3.8	45,452.6
93	ABB	Switzerland	1,277.5	3.9	2.1	32,806.2
97	DEERE	US	1,195.9	4.0	6.4	29,706.7
133	CNH INDUSTRIAL	The Netherlands	924.1	3.4	8.0	27,145.2
169	CRRC CHINA	China	689.7	4.3	7.0	15,872.8
181	CUMMINS	US	607.0	3.8	4.1	15,831.5
205	ISUZU S	Japan	529.9	4.1	4.2	12,831.7
224	KOMATSU	Japan	482.8	3.6	5.5	13,509.2
238	LIEBHERR-INTERNATIONAL	Switzerland	446.0	5.1	-1.1	8,823.0

Source: EU R&D scoreboard 2015.

Notes: BERD growth is the 3-year compound annual growth rate.

EU enterprises generally had a R&D intensity slightly above that observed in the US (3.2% vs. 2.9%). But EU enterprises experienced a decline in BERD activity of more than 4% in 2014, whereas US enterprises experienced R&D growth of less than one percent while companies based in Japan recorded an average growth rate exceeding 12%. Of the leading European enterprises, The Volvo Group is one of the world's leading manufacturers of trucks, buses, construction equipment and marine and industrial engines. ABB (Switzerland) is a global-leader in power and automation technologies, including instrumentation, automation and optimization of industrial processes as well as industrial robots, modular manufacturing systems and service.

Table 22 Inward BERD as a percentage of total BERD in machinery and equipment

	2007		2009		2011		2013	
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	553	49.7%	545	48.1%	680	55.7%	890	50.1%
Belgium	254	62.2%	193	67.9%	240	69.2%	303	70.3%
Canada		:	399	20.3%	452	:	466	14.4%
Czech Rep.	101	43.6%	86	51.2%	119	47.1%	165	54.5%
Denmark	191	30.9%	622	:	689	:	454	70.3%
Finland	370	27.3%	349	28.9%	399	23.3%	504	:
France		:	932	53.6%	1,026	:	1,035	56.2%
Germany	4,763	18.5%	4,498	13.6%	4,902	30.0%	5,388	31.9%
Greece		:		:	7	:	7	:
Hungary	31	64.5%	14	:	39	66.7%	54	77.8%
Ireland	43	:	48	:	30	:	4	:
Italy	911	37.1%	1,080	:	1,168	28.3%	1,372	28.1%
Japan	7,256	0.1%	8,381	:	9,888	1.2%	9,622	:
Netherlands	580	:	1,030	6.5%	1,632	13.2%	1,910	10.5%
Norway	236	13.6%	90	:	117	28.2%	160	31.9%
Poland	42	26.2%	29	31.0%	42	26.2%	52	42.3%
Portugal	28	42.9%	15	:	16	:	19	:
Romania	14	:	6	16.7%	2	20.8%	5	16.7%
Slovakia	8	20.8%	6	33.3%	13	69.2%	14	71.4%
Slovenia	27	33.3%	15	53.3%	81	29.6%	39	25.6%
Spain	335	18.8%	244	11.5%	224	17.0%	218	18.3%
Sweden	792	51.3%	534	:	668	:	739	:
Switzerland	:	:	:	:	:	:	1559	18.5%
UK	1,506	55.4%	1,000	61.3%	1,118	66.8%	1,039	67.4%
USA	7,198	19.7%	6,551	26.0%	10,567	17.3%	12,650	21.2%

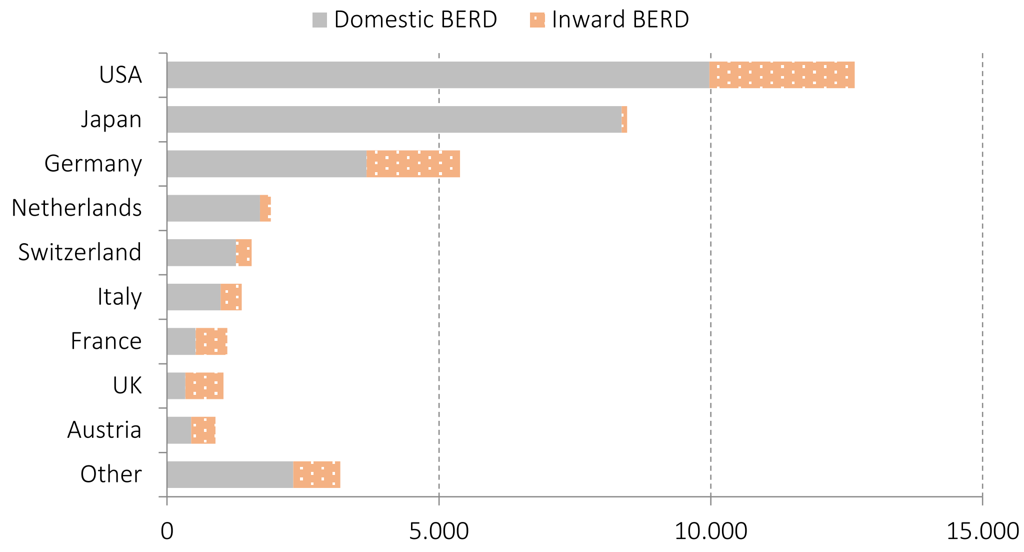
Note: Switzerland is for 2012.

Source: BERD flows database.

The United States, followed by Japan and Germany, had the highest about of BERD in the machinery and equipment sector, but as expected had the lowest share of inward BERD in the industry. Yet, Germany had a relatively high percentage share of inward BERD that was higher than found in German industry. Indeed, The Netherlands had very little inward R&D activity, relying much more on domestic R&D. Belgium had the most internationalized R&D activities, followed by Denmark and Hungary. France and Italy have both experienced an increase in total and inward BERD, however, for Italy the percentage of inward over total BERD has decreased from 2007 (37%) to 2013 (28%). Germany experienced the highest growth in R&D inward investments (35%), with an even higher increase from the pre-crisis level (106%). Table 2 shows Inward BERD as a percentage of total BERD in machinery and equipment, and Figure 2 shows BERD flows in machinery and equipment for 2013.

Both total and inward R&D activity doubled in Hungary and Czech Republic. In the first case there has been an increase of foreign investments of approximately 180%, while in the second case an increase of 125%. The growth seems to be continuous over time in both countries.

Figure 31 BERD flows in machinery and equipment, 2013



Own calculation based on BERD flows database.

Table 23 summarizes the number of announced greenfield R&D FDI projects, including design, development and testing, by source and destination, from the beginning of 2010 to the end of 2015 for the machinery and equipment industry. It presents the data by source (originating) country (or region) by row and the destination (receiving) country (region) by column. The table contains more than 350 cross-border R&D projects. This example also shows the US to be an important player having supported 100 projects and being the destination to 45 projects. The data complements the inward BERD statistics by illustrating that Europe is a good location as both source and destination R&D-FDI projects.

Table 23 Number of announced greenfield R&D FDI projects, by source and destination, in the machinery and equipment industries, 2010-2015

	USA	*Germany*	*UK*	*Other EU*	*E Asia*	*India*	*Other*	Total
USA	0	10	16	14	29	8	23	100
Germany	4	0	3	11	13	9	7	47
UK	4	2	0	2	2	3	3	16
Other EU	19	8	9	18	25	13	16	108
E Asia	13	10	14	5	8	5	9	64
India	1	2	0	1	0	0	1	5
Other	4	3	2	2	0	0	1	12
Total	45	35	44	53	77	38	60	352

Own calculation based on based on information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com)

Europe is considered to be highly competitive and on the technology frontier in machinery and equipment. Upstream and downstream linkages are essential to the innovativeness of the industry, just as maintaining a stable, predictable, and coherent regulatory environment that embraces 'smart' principles. There appears to be a convergence of electronics, electrical and mechanical technologies going on in Europe.

Technical change appears is rapid in precision machining and specific high-speed processing technologies. There also appears to be an increasing use of ICT technologies (especially software) that come from different subsystems of the supply chain.

In summary:

- Companies based in US experienced a low growth rate of less than 1% in R&D activity, while companies based in Japan a growth rate exceeding 12%.
- Five European firms are among the top R&D performers: EXagon (Sweden) Wartsilia (Finland); Class (Germany) Kone (Finland) and Weir (UK).
- Middle and Eastern European countries have experienced the most important increase of inward BERD in the recent years. In particular, Hungary (180%) and Czech Republic (125%) are the two success stories in the "machinery and equipment" sector.
- Among the top European economies, Germany has recorded the highest increase in R&D inward investments of MNE's (35%), with an even higher increase from the pre-crisis level to 2013 (106%)
- The USA is the major host country for foreign investments in R&D, even if in recent years the international dimension of R&D activities has decreased from 19 to 17 percentage points.

Chapter 5.

Drivers and effects of inward BERD

Giovanni Cerulli, Raffaele Spallone, and Bianca Poti

Chapter 5 Drivers and effects of inward BERD

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This chapter develops and presents formal analysis of what factors can be said to drive inward BERD and what effects can be said to stem from the flow of these investments. In this respect it complements the composite presentation of the previous chapters at the country and the sectoral levels. The chapter is structured as follows. This chapter first develops and presents a formalized analysis of the factors driving (the 'determinants') the business R&D investment abroad through two kinds of analysis: a multivariate regression analysis (a log log OLS without fixed effects) and a random coefficient regression (Rscore). Using a reader friendly presentation of the model, we explain the advantages of the Rscore approach over other more standard approaches (e.g. fixed effect regressions). The details of the approaches used is found in the annex (see Annex Table 1). In short, the Rscore gives a measure of the reaction of inward BERD to a series of factors; the distribution of these levels of responsiveness provides evidence of how differently inward flows of business R&D react to each factor in different contexts.

We go on to use the approach in relation to two specific analytic topics. The first involves the financial crisis of 2008-2009 ('economic crisis') on inward BERD. Here we test the response of inward BERD in terms of the degree to which each driver demonstrates significant change between the pre- and post-crisis period. We use univariate models to explain the different types of results yielded by the multivariate and the univariate analysis (direct casual effect in the first case and total, direct and indirect effects, in the second case). The second specific topic focuses on the effects of fiscal or tax policy. In particular, the focus is on relevant policy incentives for attracting business R&D, which have increased particularly in European countries. We showcase these two topics to demonstrate how the empirical material of the project can be used to study specific issues using the data. These two excursions are more experimental given the limitations of the data. They represent a complement of the work on the determinants in the first section and on effects in the next.

The last section deals with the impact that inward business R&D investments has on several measures of performance of the host countries: labour productivity, domestic business R&D and innovation. We use a counterfactual approach and a continuous treatment model, which allows us to study the effect of different "doses" of inward BERD (the so called 'treatment') on each of the three outcomes, for the overall sample and for other two groups of countries, EU 15 and EU 13.

5.1. Drivers of inward BERD

In this section we address the question about the factors that affect inward BERD flows in different country contexts. The point of departure for this analysis is two basic motives for firms to internationalise their R&D activities identified in the literature (cf. Kuemmerle 1999; Kumar 2001; le Bas and Sierra 2002; von Zedtwitz and Gassmann 2002; Narula and Zanfei 2005). First, overseas R&D activities of enterprises focus on adapting existing products to local needs and supporting local production for the host markets ("asset-exploiting" strategy). The internationalisation of R&D is therefore a by-product of the internationalisation of production and sales and R&D activity evolves out of other economic activity of foreign-owned firms (Birkinshaw et al. 1998). High incomes and a large local market can therefore act as a major incentive for enterprises to start R&D activities in a particular country. Second, enterprises wish to create new knowledge and technologies abroad, which is facilitated by excellent knowledge infrastructure and the presence of knowledge-spillovers from universities, clusters and enterprises in the host country ("asset-augmenting" strategy).

Here, a suitable approach is multivariate regression analysis, which is capable of simultaneously revealing the association between various explanatory variables and inward BERD. In this case, we regressed inward BERD on several explanatory factors, that reflect economic conditions and the innovation system of the host country. Regression analysis on the drivers of R&D internationalisation was also part of the 2012 project (Dachs et al., 2012) and we have re-run the regression analysis with new data in this project.

Methodology

Panel econometric techniques allow us to control for (unobserved) country and industry characteristics that were introduced in the previous chapters. But the use of fixed effect models in the presence of a very large heterogeneity of data (as in our case, since our units of analysis are sector, country and time dependent) serves to multiply the heterogeneity, thus inducing a low significance of variables. When applying a fixed effect model, we found an adjusted R square (which is a test of the specification of the model) that was lower than with a baseline (simple OLS) model.

Another concern was the performance across time. The time-lag variables didn't yield good results, primarily because it drastically reduced the number of observations, thus compromising the efficiency of the estimators. Moreover, even if time-lags are introduced in the panel model, there is the possibility that the errors are auto-correlated between years. Finally, the use of time lags in model developed at macro- and meso-level doesn't change the relations between these kind of (aggregated) variables much. Avoiding the difficulties of other approaches (e.g. use of instrumental variables) to overcome the endogeneity problem, our OLS model embodies a large number of combined dummy variables, for sectors, years and countries, to reproduce a sort of fixed-effect model.

Data

The variables used for explaining country attractiveness are the following:

- « asset-exploiting » variables are measures of market potential;
- « asset augmenting » variables are measures of scientific and technological strength; research, development and innovation strength.

Variables:

- Measures of market potential: GDP and Total sector production (labelled as Log of GDP and Ln of Sector size);
- Measures of S/T strength: the share of GBAORD (Government Budget Appropriation or Outlays for Research and Development) on GDP (labelled as: Ln of GBAORD); the number of tertiary graduates in science and technology (labelled as Ln of Education);
- Measures of RDI strength: number of residents' patents on GDP (labelled as Ln of Patents); sector domestic BERD on total value added (labelled as Ln of Domestic R&D;
- Other measures: Share of sector labour costs on total production (labelled as Ln of Labour cost).

Model

We use an OLS model without fixed-effects. Dependent (BERD inward) and independent variables (drivers) are all expressed in log, since a simple log (partially logarithmic) model didn't give robust results. A log-log expression can be referred to as a Cobb Douglas model, linearized from a product to a sum of factors (drivers). X_{ijt} are drivers by country i, sector j and year t. The coefficient β_k are the elasticities by factor k.

In levels, our regression model is a Cobb-Douglas regression:

$$Y_i = \prod_{j=1}^{K} X_{ij}^{\beta_j} \cdot e^{\varepsilon_i}$$ [1]

We apply a log-log transformation, thus obtaining:

$$\log(Y_i) = \sum_{j=1}^{K} \beta_j \log(X_{ij}) + \varepsilon_i$$ [2]

Equation [2] is the one estimated in the annex. See Annex table 1 ('Responsiveness score methodology').

Results

The results are very similar among the whole country population, EU28 and EU15. The factors that 'attract' inward BERD are:

1. the size of manufacturing industry, which is a more precise indicator of market size than GDP, given also that we consider inward BERD at the sector level;

2. patents of residents on GDP, as an indicator of country innovativeness;

3. labour cost intensity, which is an indicator of labour quality;

4. domestic BERD.

Public investment in R&D, proxied by GBAORD, and GDP turn out negative. One interpretation is that this tendency reflects the fact that the period include years close to the economic crisis. In EU13 group of countries there aren't significant factors, probably due to the low data availability. The adjusted R square is high, indicating a good specification of the model. The regression results are reported in annex table 2 ("Host county determinants of R&D internationalisation: 2009-2013")

5.2. Responsiveness Score

The Responsiveness score analysis provides additional information to the econometric model in the previous section and it may help us to understand if drivers are showing a tendency towards convergence or divergence in terms of countries and sectors. By making use of a Random Coefficient Regression, the Rscore approach provides a measure of the reaction coefficients (or responsiveness scores) of inward BERD to a series of factors that the literature considers potential determinants of MNE's investments in research and development. Moreover, this model also yields the distribution of the responsiveness. This step furnishes information about the characterization of the heterogeneity of the reaction of inward BERD to each individual factor. Due to the lack of data, we are only able to compute the responsiveness score for fourteen European Countries, including Norway, in a period that goes from 2008 to 2012.

Methodology

We provide a short presentation of the Random Coefficient Regression (RCR) used to compute the responsiveness scores of the individual countries. The basic econometrics of this model can be found in Wooldridge (2002, pp. 638-642). The application of RCR follows this simple protocol:

- Define y, the outcome variable, "Inward R&D investments from 2008 to 2012".

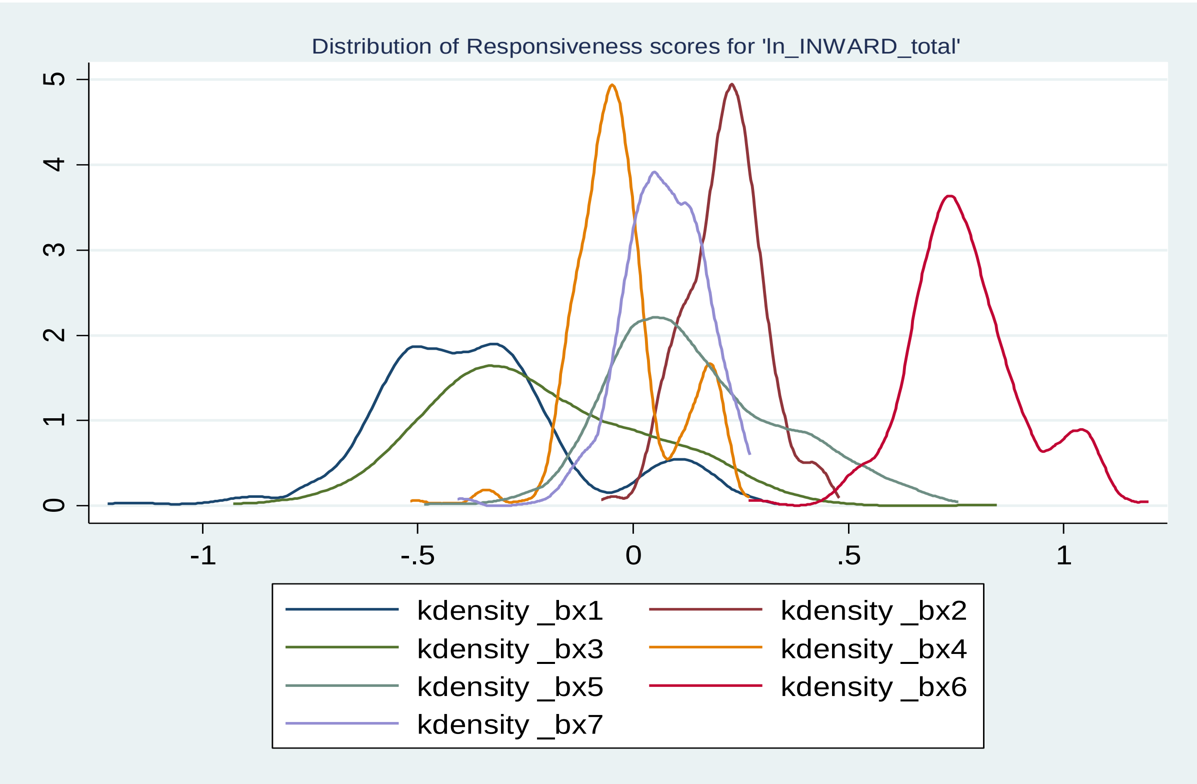
- Define a set of Q factors thought of as affecting y, and indicate the generic factor with xj.
- Define a RCR linking y to the various xj, and extract a Country-specific responsiveness effect of y to the all set of factors xj, with j=1, ..., Q.
- For the generic Country i and factor j, indicate this effect as bij and collect all of them in a matrix B.
- Finally, aggregate by country (row) and by factor (column) the bij getting synthetic Country and factor responsiveness measures.

An explanation of the methodology is presented in the annex table 1.

Results

Results for the "responsiveness score model" for total inward investments in R&D are summarized in the Figure 32. It plots the distributions of the responsiveness scores in terms of the effect of each factor for the total of inward BERD in the period (2008 to 2013). What is immediately visible is the high heterogeneity of responsiveness scores by factor. The driver with the highest positive responsiveness is "sector size (bx6)", while other factors have a more heterogeneous distribution (i.e. less concentrated). The left long tails of the factor "GDP" and the isolated pattern of" sector size" represents respectively the lowest and the highest values of the factor responsiveness.

Figure 32 Responsiveness score for Inward BERD, distribution



bx1= GDP; bx2= Labour cost; bx3=GBAORD; bx4=Education; bx5= Patent; bx6= Sector size; bx7= Domestic R&D

The analysis points to the importance of the sector-size, of labour cost, of resident patenting, and of the domestic R&D factors on inward BERD in general. As drivers, "Labour cost" records positive values throughout while 'residents' Patents and Domestic BERD register positive values on average. "Sector size" and "Labour cost" are the factors that register the highest Rscores in median terms. Factors, including

GDP, GBAORD, and education level (tertiary graduates in ST) vary little and thus seem likely not to influence inward BERD in a significant way.

Table 24 and Table 25 summarizes the results of the responsiveness score by factor for country and industry. The table shows the mean responsiveness score per factor in the considered time period and the maximum and minimum values recorded.

Table 24 Descriptive statics for RSCORE - By industry

	Obs.	Media	Std.Dev.	Median	Minimum	Maximum
GDP	29	-0.369	0.080	-0.371	-0.558	-0.226
LABOUR COST	29	0.209	0.072	0.208	0.065	0.405
GBAORD	29	-0.229	0.228	-0.201	-0.675	0.553
EDUCATION	29	-0.027	0.033	-0.031	-0.113	0.043
PATENTS	29	0.122	0.116	0.142	-0.140	0.361
SECTOR SIZE	29	0.773	0.046	0.778	0.675	0.848
RD DOMESTIC	29	0.075	0.051	0.077	-0.058	0.181

Sources: elaboration on our dataset.

Table 25 Descriptive statics for RSCORE - By country

	Obs.	Media	Std.Dev.	Median	Minimum	Maximum
GDP	14	-0.342	0.304	-0.376	-0.827	0.220
LABOUR COST	14	0.215	0.060	0.202	0.151	0.375
GBAORD	14	-0.248	0.285	-0.346	-0.731	0.211
EDUCATION	14	-0.068	0.180	-0.075	-0.479	0.184
PATENTS	14	0.173	0.218	0.097	-0.138	0.581
SECTOR SIZE	14	0.790	0.181	0.757	0.520	1.146
RD DOMESTIC	14	0.038	0.154	0.053	-0.400	0.221

Sources: elaboration on our dataset.

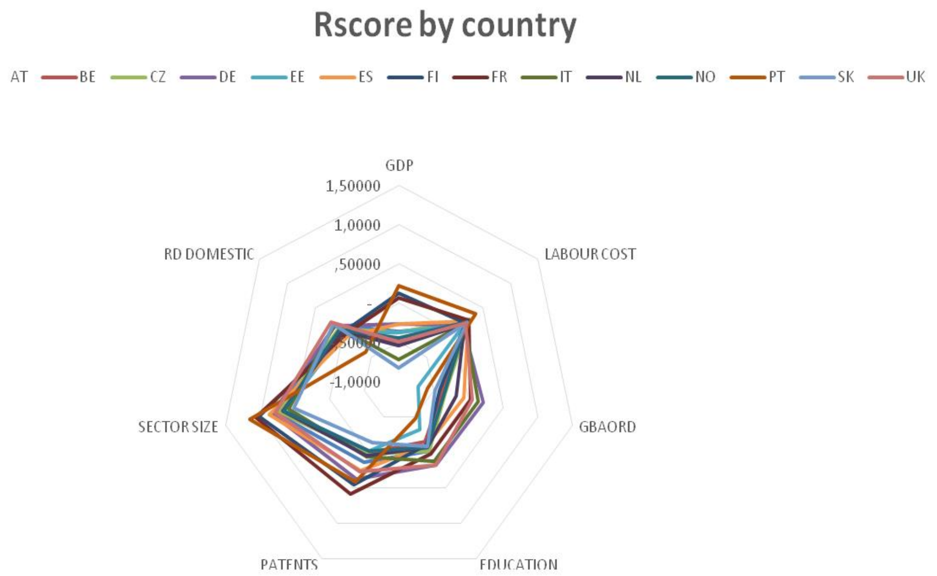
In terms of Rscore these results have to be read also in terms of level, indicating the reactivity strength of inward BERD to the different factors. The highest reactivity effects are recorded for industry size and labour cost, but also GBAORD, which has a very flat density curve, include high positive values. In order to investigate the differences of the RS among countries and sectors we propose a detailed analysis of Responsiveness scores

It is important to emphasise that the measurements of Rscore indicate the increase of response of inward BERD to the increase of a considered factor, conditioned on all other factors. Therefore, a low value of Rscore can imply both that a factor has a low relevance in the country or that its value has reached a maximum peak so that its growth produces a low and also a negative effect (see also the discussion above). The regression results are found in the annex Table 2 (Host country determinants of R&D internationalisation). In addition, Rscores are also presented and described in the sector-case studies found in the annexes and reported in the previous chapter.

Total responsiveness scores per country

In this section we present the results of the factor responsiveness score by country, measured on average for the whole period. Based on country-level data (see country report annex), we present a “responsiveness profile” for each of observed country, summarised in the radial graph below (see also Annex tables 3-5). In short, it illustrates that the country profiles do not significantly depart from one another but that there are country-level differences. In the majority of the observed countries there are similar patterns, but it is also possible to observe some exception. This presentation complements the country-case reports in the annex.

Figure 33 Radial graph of Rscore by Country and factors



To make clearer the results, Table 26 illustrates the magnitude of the factor responsiveness scores by country.

Table 26 Total factor responsiveness by country

Tab 2.4. Total factor responsiveness score by Country.

country	GDP	Labour Cost		GBAORD		EDUCATION		PATENT		SECTOR SIZE	
PT	0,22	PT	0,38	DE	0,21	UK	0,18	FR	0,58	PT	1,15
FI	0,13	CZ	0,28	IT	0,14	DE	0,18	FI	0,45	FR	1,06
FR	0,07	FR	0,25	UK	0,05	IT	0,12	PT	0,42	FI	1,01
DE	-0,26	ES	0,24	FR	0,03	FR	0,02	DE	0,38	ES	0,87
ES	-0,27	BE	0,24	ES	-0,07	CZ	-0,02	UK	0,27	DE	0,83
AT	-0,37	SK	0,22	NL	-0,18	AT	-0,02	ES	0,25	UK	0,79
CZ	-0,37	NO	0,21	CZ	-0,34	NO	-0,07	AT	0,14	AT	0,78
EE	-0,38	UK	0,19	NO	-0,35	NL	-0,08	IT	0,06	BE	0,73
NO	-0,45	FI	0,19	AT	-0,35	SK	-0,09	NL	0,05	CZ	0,73
UK	-0,49	IT	0,18	BE	-0,38	ES	-0,10	CZ	0,02	NL	0,68
BE	-0,52	NL	0,17	FI	-0,43	FI	-0,12	BE	0,00	EE	0,66
NL	-0,55	EE	0,16	SK	-0,49	BE	-0,16	NO	-0,02	NO	0,66
IT	-0,71	AT	0,15	PT	-0,59	EE	-0,33	EE	-0,03	IT	0,59
SK	-0,83	DE	0,15	EE	-0,73	PT	-0,48	SK	-0,14	SK	0,52

The results can be interpreted as follows:

Italy. The factor with the highest responsiveness score is “Sector size”, but all other factors are positive, with the exception of “GDP”. Italy is among the few countries for which GBAORD and education are positive. Italy holds the second position in terms of GBAORD and the third position for Domestic BERD and Education. This suggests that the country is attractive for the observed factors and specifically for knowledge augmenting drivers.

Germany. The only factor that records negative value is “GDP”. “GBAORD”, “Patent”, “Education” and “Domestic R&D” are all positive, thus indicating a good response to asset seeking factors. It is also interesting to notice that Germany is the country with the highest value of GBAORD (first position) and has a second rank for Education. Sector size has the higher value measured between factors in the country.

France. France records the highest responsiveness scores among countries for “Patent” and it is ranked fourth for “GBAORD” and “Education”, albeit with values near to zero, while Domestic BERD records negative values. With respect to Germany and Italy, “GDP” has positive responsiveness score, indicating that market drivers have a major strength.

Austria. GDP, GBAORD and Education record negative values in Austria. The country registers the highest value between factors in Sector size, Labour costs and Domestic BERD. Also “Patent” has a positive value but near zero. Results show a prevalence of market drivers.

Netherlands: “Education”, “Patent” and “GDP” are the factors with negative responsiveness scores. Patent and Domestic BERD are positive, but with values close to zero. “Labour cost” and “Sector size” records positive scores, with the latter that is, as usual, the most responsive driver among factors. In sum, market drivers prevail in explaining inward BERD responsiveness (see also Chapter 2).

United Kingdom: UK records the highest responsiveness scores for “Education” and “Domestic BERD” among the countries observed. It is the third most responsive for GBAORD, while it records negative values for “GDP”. Among all factors the highest responsiveness score is found in “Sector size”. However, R&D internationalisation in the UK is consistent with a knowledge-augmenting profile.

Portugal: Portugal records the highest responsiveness score for “Labour cost”, “GDP” and “Sector size”. “GBAORD”, “Domestic R&D” and “Education” are negative, with the last two recording the lowest values among the observed countries. In sum, the market exploiting factors show a clear predominance.

Norway: The most responsive factors are the “Sector size” and “Labour cost”. GBAORD “Education”, “Patent” and “GDP” are negative, while “domestic BERD” is positive but close to zero. It doesn’t seem likely that inward BERD in Norway is reacting to “asset seeking” factors.

Czech Republic: Czech Republic records negative responsiveness scores for the factors “Education”, “GBAORD” and a positive but low RScore for “Patent” and “Domestic BERD”. This result suggest that inward BERD is not responsive to the “knowledge augmenting” factors in this country. “Sector size” and “Labour cost” record positive RScores.

Slovakia: Among all the observed countries, Slovakia has the lowest responsiveness score for GDP, “Patent” and “Sector size”, even if in the last case values are positive. Labour cost and Domestic BERD are the other positive factors. The country ranks second in terms of domestic BERD and has a negative Rscore near to zero for Education. The combination of Rscores doesn’t provide a clear picture.

Belgium: The only two factors with positive values are “Labour cost” and “sector size”. The Rscores for “Education”, “GBAORD”, “Patent” and “Domestic BERD” are all either negative or equal to zero. In Belgium it seems that the "knowledge augmenting" factors do not generate a positive response to inward BERD.

Estonia: Also in this case "Sector size" and "Labour cost" are the only factors with a positive RSs. "Education", "Patent", "Domestic R&D" and "GBAORD have all a negative value, with the latter factors recording the lowest value among all the observed countries.

Spain: "Patent", "Labour cost" and "Sector size" are the only factors with a positive Rscore but none register high values.

Finland: Inward BERD to Finland appears to be characterized by market oriented factors. In this case, GDP and Patent are positive and both have the second highest rank among countries. Sector size is positive and is ranked third.

Total factor responsiveness by sector

In line with the presentation in the preceding chapters, we move from the country-level to describe the results of the factor responsiveness score by industrial sectors, measured on average for the total period. In table Table 27, we report the sector RScores for a range of sectors. The logic is consistent with the presentation at the country level. The growth (decline) of a particular factor may determine an increase (decrease) in inward BERD investments in a particular sector.

Table 27 Total factor responsiveness by sector

Table 2.5 Total factor responsiveness by sector

GDP	Labour Cost	GBAORD	Education	Patent	Sectoral size
Research and development	Services sector	Research and development	Coke, refined petroleum products and nuclear fuel	Coke, refined petroleum products and nuclear fuel	Research and developme
Chemicals [...]	Manufacturing	Wood and paper products [...]	Wood and paper products [...]	Computer, electronic and optical products	Computer and related activities
Other business activities	Computer and related activities	Textiles, apparel, leather	Mining [...]	Research and development	Other business activities
Coke, refined petroleum products and nuclear fuel	Wholesale, retail trade and motor vehicle repair	Rubber and plastic products	Food, beverages and tobacco	Other Transport Equipment	Services sector
Manufacturing	Research and development	Coke, refined petroleum products and nuclear fuel	Electricity, gas, water.	Pharma	Wholesale, retail trade a motor vehicle repair
Machinery and equipment,	Motor Vehicles, trailers and semi-trailers	Chemicals [...]	Transportation and storage	Chemicals [...]	Financial intermediation
Other Transport Equipment	Financial intermediation	Computer and related activities	Textiles, apparel, leather	Motor Vehicles, trailers and semi-trailers	Machinery and equipme
Computer, electronic and optical products	Construction	Other Transport Equipment	Basic metals [...]	Manufacturing	Textiles, apparel, leather
Motor Vehicles, trailers and semi-trailers	Computer, electronic and optical products	Machinery and equipment,	Motor Vehicles, trailers and semi-trailers	Machinery and equipment,	Rubber and plastic produ
Rubber and plastic products	Machinery and equipment,	Computer, electronic and optical products	Pharma	Rubber and plastic products	Manufacturing
Computer and related activities	Chemicals [...]	Motor Vehicles, trailers and semi-trailers	Construction	Computer and related activities	Other Transport Equipm
Pharma	Rubber and plastic products	Pharma	Computer, electronic and optical products	Textiles, apparel, leather	Pharma
Textiles, apparel, leather	Other Transport Equipment	Food, beverages and tobacco	Other Transport Equipment	Basic metals [...]	Construction
Services sector	Other business activities	Mining [...]	Rubber and plastic products	Wood and paper products [...]	Wood and paper produc
Wood and paper products [...]	Food, beverages and tobacco	Construction	Financial intermediation	Food, beverages and tobacco	Transportation and stora
Food, beverages and tobacco	Basic metals [...]	Other business activities	Wholesale, retail trade and motor vehicle repair	Transportation and storage	Chemicals [...]
Construction	Pharma	Manufacturing	**Manufacturing**	Mining [...]	Computer, electronic an optical products
Financial intermediation	Electricity, gas, water.	Services sector	**Chemicals [...]**	Services sector	Food, beverages and tob
Wholesale, retail trade and motor vehicle repair	Textiles, apparel, leather	Wholesale, retail trade and motor vehicle repair	**Services sector**	Other business activities	Motor Vehicles, trailers a semi-trailers
Basic metals [...]	Mining [...]	Financial intermediation	**Machinery and equipment,**	Construction	Basic metals [...]
Mining [...]	Wood and paper products [...]	**Basic metals [...]**	**Computer and related activities**	Electricity, gas, water.	Electricity, gas, water.
Electricity, gas, water.	Transportation and storage	**Electricity, gas, water.**	**Research and development**	Wholesale, retail trade and motor vehicle repair	Mining [...]

The most responsive sectors to GDP include "Research and development", "Chemicals" and "Other Business activities". It is interesting to notice that the most responsive sectors to the "Labour Cost" factor are the broad "Services" and "Manufacturing" categories. Labour costs are also important for inward BERD in the "Computer and related activities" sector. The "Research and development" sector is the most responsive sector to "GBAORD". The sectors that are among the most responsive to domestic patenting are "Coke and refined petroleum product", "Computer, electronic and optical products", "Research and development" and "Pharma". The table also indicates that "Coke and refined petroleum product" is the most responsive sector for the factor "Education". Intuitively, the more the share of tertiary educated in science and technology increases, the more the total R&D investments of foreign companies increase in that sector.

5.3. Two explorative case studies

Against this backdrop, we now showcase two extensions of the approaches developed in this project to explore a couple of questions policymakers are interested in understanding better. In the first explorative case study, we demonstrate how the empirical material of the project can be used to study the effects of the financial crisis on R&D internationalisation. The second special topic case goes on to focus on the role of fiscal policies to shape the localisation decisions of R&D activities of firms that are headquartered elsewhere.

This is primarily an experimental exercise to complement the study of determinants (above) and of effects (below) of inward BERD on host-countries. The goal is to demonstrate how the approaches developed in this project can be used to study policy-relevant issues. The exploration of these two special topics is beset by the patchiness of the data. These models are run on reduced sets of countries. In this sense, the aim of these explorative cases is more to indicate the way the data can be analysed to address such policy-relevant questions than it is to provide definitive answers to these questions. Still, the results of these two case studies produce indications of how inward BERD may be affected by these very different phenomena: at the one level, the effects of a shock, and at the other, the effects of deliberate policy interventions.

5.3.1. The financial crisis and BERD flows: a case study

This section utilises the analytic approach to focus on the effect of the financial crisis of 2008-2009 on inward BERD. This section presents a sub-study which is separate from the two main sets of analysis on determinants and effects. Its aim is to adapt the approach in order to explore the impact of the financial crisis. As with the section on fiscal policy impacts (section 5.4. below), it is primarily an experimental exercise. It can be used to demonstrate how the approaches developed in this project can be used to study policy-relevant issues.

It is recognised that the global financial crisis has severely affected the international economy and the flows of trade and investments. Inward and outward R&D activities of multinational enterprises have also declined in most advanced economies. In the most recent years, the share of overseas R&D activities of the emerging economies has increased (especially China and India) whereas the relative importance of European and North American Countries has appeared to decline in part (see chapter 3 above).

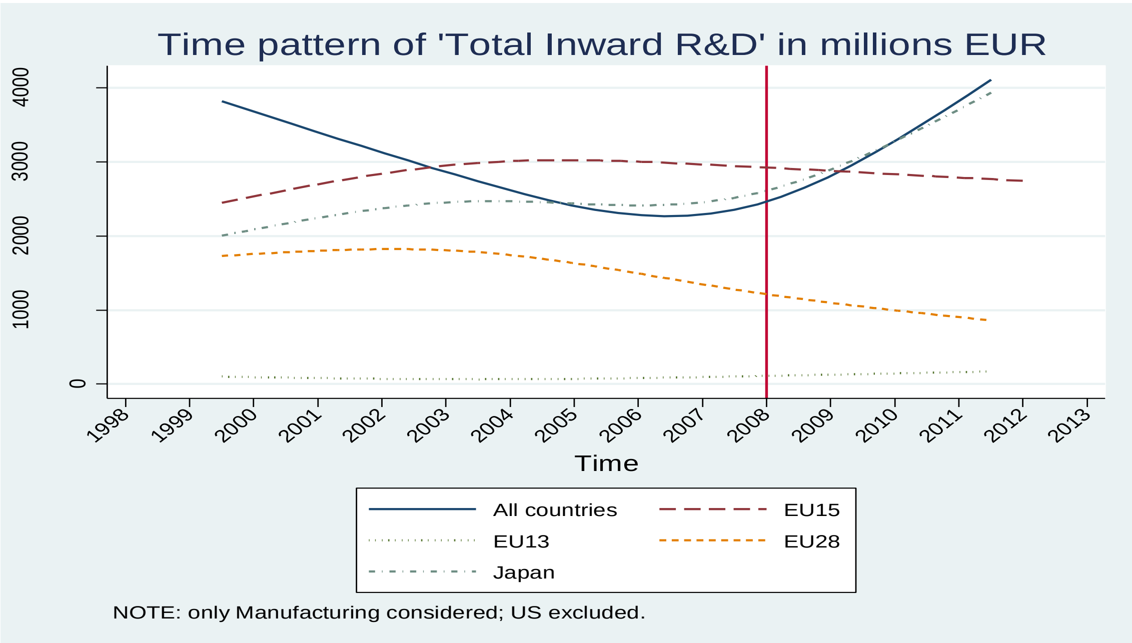
Europe has recorded the most pronounced decline in inward BERD investments (see graphs below). The upward trend of inward BERD observed during the 2003-2007 period, which was supported by the global economic climate and other factors, was indeed hit by the crisis in 2008-2009. Among the effects, there has been an apparent redistribution of R&D activities of MNE's, not only between countries, but also between industries. In particular, the service sector has appeared in the data to have gained more importance in comparison with manufacture industries. The progressive shift from traditional to most innovative industries, especially knowledge-intensive ones, may be partially explained by the relative weight that some of the determinants of the internationalisation of business R&D have acquired during the most recent years.

We analyse the role of a series of factors that have been recognized as crucial determinants of inward BERD on both sides of the crisis: GDP of host economies; the level of Foreign direct investments; GBAORD; the share of labour force with a tertiary education; Labour cost; the number of patents as proxy of innovation capabilities of a particular country. The aim is to understand if these factors continued to have their established effects or whether, in consequence of the crisis, their effects have been shifted. Through univariate regressions we are able to capture the presence and the magnitude of a structural break of each of the main drivers between the two periods (pre and post crisis).

Time Pattern of inward BERD

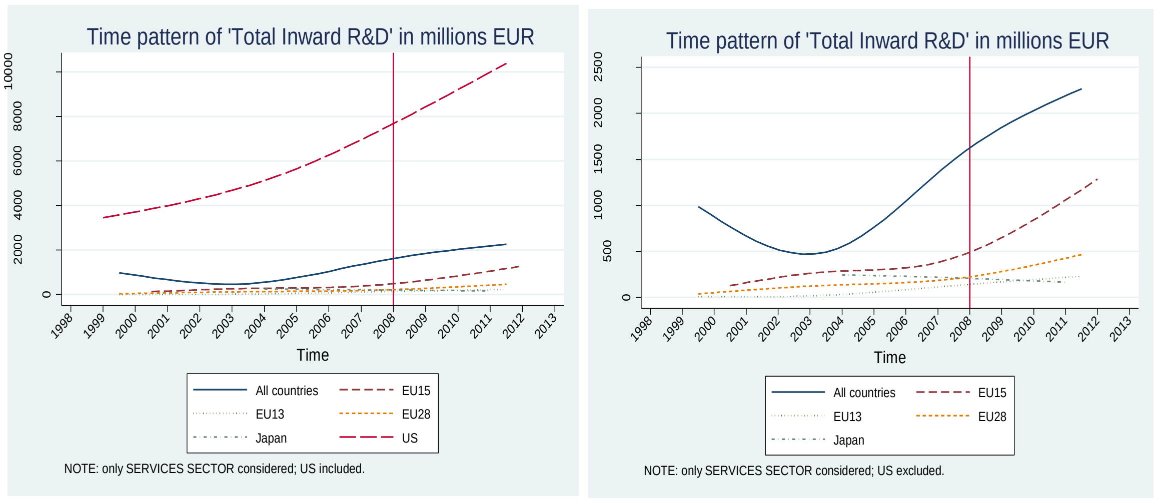
In this section we present how inward BERD developed in recent years for five countries or groups of countries, namely United States, European Union, EU 15, EU13 and Japan. We start from the observation that the trend of the average inward investments in manufacturing sector in the US has increased after the 2008 economic and financial crisis. The trend-line for the US however distorts the general overview for the period (see annex figure 6). The average trend in the manufacturing sector in European countries becomes clearer if we remove inward BERD for the US. The figure Figure 34 reveals that average inward BERD slightly decreased after the crisis. This is true both for EU28 and for EU15. The average for "All Countries" records an increasing trend, perhaps driven by the US and Japan.

Figure 34 Total average Inward BERD in manufacturing: by country without the US



As already stressed, among the effects of the crisis, there also has been a redistribution of investments from traditional sectors to most innovative ones. Indeed, there has been an increasing trend of inward BERD in the service sector in general (see the figures below). The increase is much more pronounced in US than in the other countries observed. In the European Union the positive trend is much more evident for EU 15 than for the rest of Europe. Japan records a negative trend in the service sector, while the trend is positive in the manufacturing industry.

Figure 35 Time pattern of Total Average Inward BERD in the service sectors per groups of countries: with and without the US



The approach and results

To analyse the effects of the financial crisis and BERD flows in more formal terms, we adapt standard (structural break—or switching—regression) model to test whether there is an effect that is associated with the 2008 crisis or not. We test whether the response of the inward R&D to each driver had a significant change between the pre and post crisis period. It is important to emphasise two aspects of this analysis. The first is that we only look at the "association", not at direct "causation", between inward BERD and the individual factors. The second aspect to note is that the statistical setting of this analysis is different from that developed by our previous econometric model (see section 2). Here, we identify the "total" effect of a factor on inward BERD, which sums up the "direct" and "indirect" effects whereas the multivariate regression approach (above in section 2), on the contrary, only identified the "direct" effect of each driver. The specifics of this model and the details of the results are provided in the annex (see annex table7 model to analyse the effect of the crisis). Here we report the general results.

A first question is whether the intensity of inward R&D – i.e. the share of inward BERD in total BERD—changed significantly before and after crisis. The Figure 36 indicates that there is an average increase of inward R&D intensity after the crisis of around 10%. However, t-test shows that this magnitude is not significant. It remains descriptively interesting.

Figure 36 The distribution of inward R&D intensity before and after the crisis

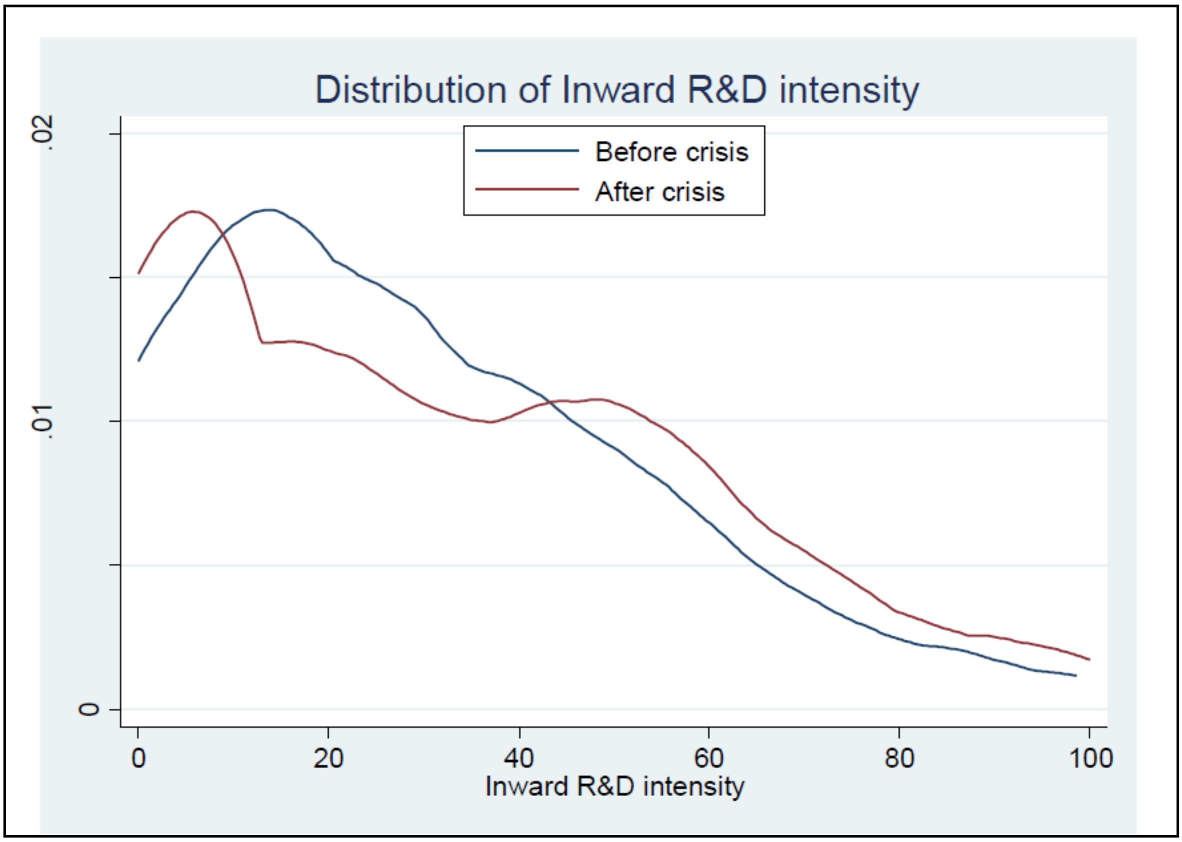


Table 28 Summary of results on the effects of financial crisis

Driver	Factor's strength before the crisis	Change of the factor's strength after the crisis
GDP	Positive and significant	Increase of factor importance
Foreign direct investments	Not significant	Increase of the factor importance, but still not significant
GBAORD	Positive and significant	Decrease of the factor importance
Total labour force, tertiary educated	Positive and significant	Decrease of the factor importance
Labour cost	Positive and significant	Increase of factor importance but not significant
Patent to GDP	Not significant	Slightly decrease of the factor importance, but still not significant

In this light, the table can be read as follows: if for driver x we find that the interaction coefficient is negative and significant, it means that the response of inward BERD to this driver decreases its strength after the crisis (and vice versa for a positive value). Noting the difference between the focus and approach here from that reported in the previous analysis, the

Table 28 indicates that three factors have increased their strength in the aftermath of the crisis, namely GDP, Labour cost and FDI (foreign direct investments). While the first two are positive and significant, foreign direct investments have increased their strength but, as in the pre-crisis period, are still not significantly correlated with inward BERD.

Conversely, GBAORD and the "total labour force tertiary educated", the factors that accounts for the stock of human capital in a particular country, have partially decreased their importance as drivers. The number of patent application in percentage of GDP, used as an indicator of the innovation capabilities of the host economy, seems not to be significantly correlated with total inward, both before and after the crisis. In fact, the value of the interaction coefficients $\beta_1 - \beta_0$ indicate a slight loss of importance of the driver in aftermath of the economic crisis. However, some possible channels can be envisioned. More specifically, we can maintain that, when a EU15 country experienced a decrease in GDP, peculiar feedback effects can take place. This country can become both economically and politically weaker, thus increasing the "negotiation power" of multinationals vis-à-vis local authorities. This may attract further BERD investment, driven by the aim of exploiting such a phase of weakness.

The results add to the information from the earlier econometric exercise which again differs in focus and thus also in results. For instance, in contrast from what was found above, GDP and GBAORD are both positive and significant (even if the latter decreases its positive value after the crisis). One interpretation is that, while a "direct" effect of these factors may be negative on average inward BERD, the indirect effect of each of them on other moderating factors can be higher, thus ultimately compensating the direct negative sign. Moreover, countries affected by negative downturns generally try to adopt counter-cyclical policies, such as R&D fiscal incentives, which potentially represent effective instruments for fostering BERD inflows (see the R&D fiscal incentive case study in the next section). Therefore, the "total" effect of GDP may turn out to be positive on BERD inward, despite having a negative direct impact. However, it was not possible to estimate a fully specified structural model representing all the mediating channels between specific factors and inward BERD.

5.3.2. Fiscal incentives and their impact on inward BERD: a case study

This section uses the analytic approach to focus the measureable effect of fiscal incentives on inward BERD. National governments have increasingly viewed foreign-controlled multinational enterprises as pivotal actors in the national economic system and as a potential motor for change and innovation. As result, there has been increasing competition among countries to attract the R&D activities of multinational enterprises in recent years. The economic literature suggests that there are several drivers for BERD location decision of MNE's.

Policy intervention are recognized to be able to affect some but not all of these potential drivers. Governments can intervene to attract foreign investments in R&D by focusing on: the availability of skilled employees; the quality of public research; an efficient intellectual property rights regime; quality of institutions. Among all these elements, the most straight-forward policy instrument is to provide public incentives to business R&D. These incentives may be both fiscal and financial. In recent years a growing number of new and different subsidy schemes for business R&D have been implemented.

In this section we will try to understand and measure the importance of the tax incentive as a driver of R&D investments decision of MNE's. Due to the lack of data, we will concentrate our analysis for only eight OECD countries, Australia, France, United Kingdom, Japan, Korea, Netherlands, Canada and United States.

Earlier findings

A large body of literature has investigated how R&D tax incentives and corporate taxation can be an important element at the base of the location decision of a MNE's. De Mooij and Ederveen (2003), conducing a meta-analysis of several studies on the impact of corporate taxes, find that a decrease by one percentage point in the host country tax rate leads to an increase of foreign direct investment by around 3.3 percent. Wilson (2009), working on the States of U.S., finds that R&D tax incentives attract R&D from other federal States, while the overall amount of R&D from U.S. is not affected. He concludes that incentives are "a zero-sum game among States".

Dischinger and Riedel (2011) shows that the flows of investments in intangible assets go mainly to those affiliates that, relative to other subsidiaries, were located in Countries with lower tax rates. According to the author, "a 1 percentage point decrease in the average tax rate differential with the other subsidiaries translates in 1.7% increase in the stock of intangible assets in the lower-tax subsidiary". Thus, the authors provide evidence that European multinational companies do involve in profit-shifting activities.

Along the same lines, other studies find out that R&D activities are especially sensitive to corporate taxes changes (Desai et al., 2006; Stöwhase, 2002; Grubert and Slemrod, 1998). The location of patent applications by European corporations is also responsive to corporate income tax rates (OECD, 2013b). Karkinsky and Riedel (2012) estimated that an increase of one percentage point in the corporate tax rate results in a fall in the number of patent applications from 3.8 to 3.5 percent.

Griffith et al. (2014) analyse variations in tax rates across countries. They find that the share of patent locations in Luxembourg is most responsive to tax rates, compared to Germany. A one percentage point increase in the corporate tax rate in Luxembourg leads to a 3.9 percent decrease in the share of patent applications, while in Germany this is only 0.5 percent.

Tax incentives in R&D

This section briefly describes different types of tax incentives. According to OECD Scoreboard, in 2015 28 of the 34 OECD countries as well as a number of non-OECD economies gave preferential tax treatment to R&D expenditures, using a variety of instruments. In particular, incentives for business R&D expenditures include allowances and credits, as well as other forms of tax treatment, such as allowing for the accelerated depreciation of R&D capital expenditures or innovation or patent boxes, under which income attributable to intellectual property (IP), developed through R&D, is taxed at a favourable rate. The specific design, type and number of R&D tax incentives differ substantially across countries. Tax incentives may vary for the scope of the policy, the target, the stability and the time horizon of the policy over time.

The scope of an R&D tax scheme defines how the incentive is applied and what type of expenditure and income is exempted. There are four different types of R&D tax incentives: (i) a tax credit, (ii) an enhanced allowance, (iii) accelerated depreciation or (iv) reduced corporate taxes (patent boxes, for example). Essentially, all the incentives have the ultimate aim of reducing costs for firms that implement R&D activities (input-related R&D tax incentives) or for firms that have income from commercializing intellectual property rights (output-related R&D tax incentives). Input-related R&D tax incentives decrease the price of R&D inputs faced by firms, which makes it more attractive to engage in R&D. Output-related R&D tax incentives increase the returns from innovative products that are protected by IPR. The incentive can be “volume-based”, applying to all R&D activity; or it can be “incremental” and only applying to new R&D activity.

In addition, the tax exemption can refer to different sorts of R&D expenditures. Usually, an R&D tax incentive applies to specific inputs that are used in R&D processes (incentive base) and requires some degree of novelty for the intended outcome (requirement of novelty). Also the target of a tax scheme can vary across countries and years. Governments may decide to incentivize R&D activities in a certain zone, or increase the level of R&D spending of a specific group of enterprises, diversified according to their size, their age or their field of activities. The effectiveness of R&D incentives, both direct and indirect, also depends on the stability and the time horizon of the policy. For instance, when R&D tax policy changes often, the impact of R&D tax incentives may be reduced. In the annex (annex table 23-24) we present a review of relevant literature as well as a taxonomy of the instruments, their definition and the country where the policy is implemented.

Table 29 Tax Instruments, definition and countries where interventions are implemented

	Definition	**Countries**
Tax credits	Tax credit decreases the corporate income tax rate a firm has to pay. Rate can be applied to corporate tax, payroll tax paid for R&D workers or personal income.	AT; BE; BG; CA; ZA; DK; FR; IE; IL; IT; JP; MT; NL;NO;PL; PT; SK; ES; SE; UK; US
Enhanced allowances	An enhanced allowance effectively decreases the base amount that is taxed by allowing to 'inflate' the R&D expenditure base.	HR;CY;CZ;DK; FI;EL; HU; IL; JP; LT; LV; NL;PL;RO; SI; UK
Accelerated depreciation	Accelerated depreciation scheme permits to depreciate the purchased fixed assets at higher rates in the first years of the asset's life.	BE; BG; CA; DK;FI;IL; IT; JPLT;RO; SI; UK; US
Reduced corporate tax rate (IP income)	Reduced corporate tax rate on intellectual property income ("Patent Box") are an outcome related incentive. It reduces the corporate income that firms pay on commercialization of innovative products that are protected by intellectual property (IP) rights.	BE; CY;FR; EL; HU;LU; MT; NL; PL; ES; UK

Approach and data

The panel data on R&D taxation is available only for eight OECD countries, Australia, France, United Kingdom, Japan, Korea, Netherlands, Canada and United States[12]. However, we will conduct our econometric analysis only on six of them, since we do not have inward data for Australia and Korea. We employ inward BERD data as the independent variable from 2000 to 2013 (INWARD BERD). In our econometric exercise, data on **direct and indirect taxation** comes from OECD.[13] In our econometric tests we run two models, the first with "indirect taxation", the second with the variable "direct taxation". In order to measure the influence that government R&D support may have on inward R&D investments, we use the **GBAORD** index, accounting for Government budget appropriations or outlays for research and development. GBAORD includes all appropriations (government spending) allocated to R&D in central (or federal) government budgets. The source of data is OECD, Science Technology and Innovation (STI) indicators.

Table 30 Tax support as a percentage of total (direct plus tax) government support for business R&D., 2000-2013

Year	Australia	Canada	France	Japan	Korea	Netherlands	United Kingdom	United States
2000	70	88	22	28	N/D	N/D	6	29
2001	59	82	23	31	N/D	60	15	27
2002	59	87	18	28	N/D	N/D	32	26
2003	65	87	15	39	N/D	67	31	24
2004	65	90	27	74	N/D	N/D	31	22
2005	63	87	32	79	N/D	67	37	23
2006	65	87	38	81	N/D	N/D	39	23
2007	70	90	44	81	53	77	43	24
2008	78	89	61	70	55	N/D	49	19
2009	84	87	68	65	52	79	45	16
2010	85	84	69	73	52	69	44	20
2011	85	84	71	73	54	78	43	23
2012	N/D	83	70	75	54	85	50	26
2013	N/D	85	70	82	58	87	48	N/D

Source: OECD, own elaboration

Patents Application are used as a proxy of the innovation capabilities of countries. Data are taken from World Bank, World Development Indicators. In order to capture the capability innovation of the country we have added to the number of patent applications of residents the patent applications of non-residents.

Data on **foreign direct investment** inflow are taken from OECD, FDI Statistics according to Benchmark definition 4th edition (BMD4). We use the variable of foreign direct investments net inflow.

12 See the annex for more information on the estimation methodology and regression results.

13 http://www.oecd.org/sti/rd-tax-stats.htm

Data on **corporate income taxation** are taken from OECD tax database. In the annex (annex table 23), a table presents the trends in government tax incentive and direct support for business R&D, 2000-2013. Tax support is expressed as a percentage of total (direct plus tax) government support for business R&D. It illustrates that the indirect component of government-support to R&D increased strongly in some country such as France and Japan. USA are instead characterized by a persistent higher role of financial direct government support of R&D[14].

Model Specification

In order to test the effect of R&D tax incentives we employ a fixed effects model. Usually, the fixed effects model is useful when we are only interested in analysing the impact of variables that vary over time. *Fixed effects model explores the relationship between independent variables and dependent variable within an entity. Each country has its own characteristics that, may or may not, influence the predicted dependent variable. When we use a fixed effects model we assume that something within the country may impact both the dependent and independent variables. This is because there is the assumption of correlation between error term and independent variables.* "Fixed effects model" drop the effect of those time-invariant attributes, so we can assess the net effect of the independent variables on the dependent one. Another important assumption is that time invariant attributes are unique to the country and should not be correlated with other countries' characteristics. Each country is different, therefore the error term and the constant (which captures the regional characteristics) should not be correlated with the others

Results

First, we run our econometric test in order to identify the effect of taxation on R&D. In the second specification of the model we include among the independent variables the logarithm of direct government funding to R&D. This second specification allows us to capture the different impact on inward BERD of direct funding and tax incentives for R&D. In both tests we also try to measure the impact of corporate income tax. The results show (see annex table 9 for full results) a significant and positive correlation between taxation and inward BERD. Only the variable accounting for "resident total patents" (ln_PATENT) has an effect on inward BERD that is higher than "R&D tax exemption". The variable "log of corporate income tax" is negative, pointing in the direction that an increase of the corporate taxation would imply a decrease in inward BERD, but it is not significant.

14 In the Annex trends on granting tax incentives per countries are presented.

Table 31 Result of 1st regression model

ln_total_inwad	Coef,	Robust Std, Error	t	P>|t|	[95% Conf. Interval]	
ln_tot tax incentives	0,075	0,035	2,14	0,099*	-0,022	0,173
ln_GBAORD	0,053	0,235	0,23	0,832	-0,600	0,707
ln_PATENT	0,608	0,270	2,25	0,088*	- 0,141	1,357
FDI	0,002	0,004	0,74	0,502	-0,008	0,014
ln_corp_inc_tax	-0,977	0,668	-1,46	0,218	-2,834	0,879
_cons	4,483	3,77	1,19	0,300	-5,992	14,95
sigma_u	0,936					
sigma_e	0,130					
Rho	0,980	(fraction of variance due to u_i)				

In the second specification we do not find any positive and significant correlation between direct funding government support (variable Log tot_dir_level) and inward BERD. This seems in line with the logic of the direct support, that it is often designed and implemented to meet the need of young or small firms, that are often in disadvantage position vis-à-vis large firms or multinational enterprises. Also in this case, "corporate income tax" is negative but not significant and the variable accounting for "resident total patent" is confirmed as a relevant driver with the highest positive and significant coefficient. The details of the results, are found in the annex.

Table 32 Results of the second regression model

ln_total_inward	Coef,	Robust Std. Error	t	P>|t|	[95% Conf. Interval]	
ln_tot_dircect incentives	0,015	0,059	0,26	0,807	-0,1496	0,180
ln_GBAORD	0,188	0,187	1,01	0,371	-0,330	0,708
ln_PATENT	0,665	0,247	2,69	0,055*	-0,022	1,354
FDI	0,000	0,005	0,15	0,886	-0,014	0,016
ln_corp_inc_tax	-2,226	1,357	-1,64	0,176	-5,995	1,541
_cons	7,202	3,850437	1,87	0,135	-3,487	17,893
sigma_u	0,925					
sigma_e	0,133					
Rho	0,979	(fraction of variance due to u_i)				

Our analysis demonstrates that fiscal incentives to R&D has a significant and positive effect on the amount of inward BERD. This policy instrument has been widely used in European countries, and its relevance has increased in recent years in relation to financial direct support offered by governments. This evolution may be explained by the differential financial cost of the indirect policy instrument compared to the direct one together with the lower implied administrative management burden. The USA is an exception, where the level of direct financial support of R&D is still higher than the fiscal one. Moreover, the indirect R&D incentive is a more suitable policy for attracting MNEs R&D in Europe, given the size of the foreign companies and the European legislation on State Aid and Competition, which is designed to avoid financial subsidies for large companies.

5.4 Impact analysis. A dose response treatment model application

In the last section of this chapter, we focus on the impact that inward BERD has on host-countries. The literature on MNE's R&D impact on host countries has yielded heterogeneous results: a positive effect on aggregate national R&D expenditures in the short and long term (OECD, 2010), but also a possible negative effect through a substitution of domestic BERD (Aghion et al., 2009). MNE's R&D investments are expected to lead to an increase of the knowledge stock and this can be beneficial in terms of new entrepreneurial opportunities. Empirical evidence suggests that small countries, generally more internationalized, benefit most in relative terms than large countries, where domestic firms suffer more for the competition on resources (Dachs et al, 2014; Lonmo and Anderson, 2003; Costa and Filippov, 2008). It should be possible to find a more positive effect also for transition economies, characterized by a high degree of internationalisation. Some other scholars suggest that inward BERD increases the likelihood of firm exit due to increased competition, while the impact on the likelihood of entry of domestic firms is statistically insignificant (Anwar & Sun, 2015). Effects linked to spillovers from foreign-owned firms can be different at sectoral level, due to absorptive capacity, strength of protection of proprietary knowledge, propensity and type of interaction between foreign owned and domestic organizations (Veugelers and Cassiman, 2004). In general horizontal spillovers between competitors are more difficult to find in all sectors. Sectoral impact is furthermore differentiated by host country; for instance, Motohashi and Yuan (2010) show that in China vertical spillover (towards part industrial suppliers) is stronger in the automotive sector than in electronic industry.

Summing up the literature underlines that there are several potential opportunities and challenges for host countries. The positive impact of BERD inflows can be due to the following opportunities: an increase in aggregate R&D and innovation expenditure, the knowledge diffusion to the host economy; demand for skilled persons; agglomeration effect; and sometimes structural change. On the side of negative impact there are several risks: competition with the foreign firms for national resources; loss of control on national innovation capacity; less strategic research and more adapting innovation and separation between R&D and production (Dachs et al., 2014). Our work gives a contribution in this direction, highlighting the impact of inward BERD by factor in EU 15, EU 13 and in our overall sample.

The impact evaluation analysis using dose-response model

A crucial element for a rigorous evaluation study is the presence of a proper counterfactual sample, especially in the case that the unit of the analysis (geographical entities or companies) receive a different amount of treatment. In our case, we were not able to build up a counterfactual sample due to the fact that each country observed has received inward BERD investments along all the considered time period (1999-2013). Thus, from an evaluation perspective we face the problem of evaluating the impact of inward BERD without the existence of proper "treated and untreated" groups. In order to overcome this problem, we considered as untreated, or control group, all units of analysis, i.e. Country/sector/year, with zero inward BERD (i.e. a ratio inward BERD / Total value added = 0).

Then, for each level of treatment (inward BERD /total BERD) which varies between 0 and 1 we compute the expected difference in the outcome between being treated ('Inward BERD') and untreated (no Inward BERD). The outcome variable for the host countries that we study in this analysis are three: labour productivity; resident patents as a proxy of innovation capacity; and Domestic BERD. By studying the shape of the dose response function, i.e. the average treatment effects over all possible values of the treatment levels, we are able to catch the impact of BERD inward, or better, to study whether effects on the outcome variables change when the level of inward BERD changes. With this strategy we focus not only on the difference of the binary treatment status, but also on the level of inward exposure (or “dose”).

Data and empirical application

We applied the continuous treatment model on three outcomes, that are our dependent variables: labour productivity (total production on employees), resident patents as share of GDP as proxy of innovation effect and domestic BERD on manufacturing value added. The unit of analysis is country/sector/year and all variables are expressed in log, in the period 2008-2013. Independent variables are the levels of inward BERD (treatment) and the controls are: ln GDP; ln labour cost intensity, ln GBAORD, ln total graduates in Science and Technology in percentage of national total, ln manufacturing size production.

We run our regression on the total sample, on EU 15 and on EU 13. For managing the possible endogeneity problem, we regress data with one-year time lag for the overall sample, but given the effect of units of observation strong reduction, we don’t apply this procedure to EU15 and EU13.

Results

Here we present the figures of the patterns of dose response analysis in terms of the impact that inward BERD has on labour productivity, on patenting, and on domestic BERD. Detailed results of the regressions are presented in the annex (cf annex table 20-22).

The response of **labour productivity** to inward BERD shows different patterns in the different samples considered. That said, the coefficient of the regressions indicates a generally positive and significant correlation between the "treatment" (in terms of Inward BERD as share of value-added) and labour productivity (see the annex for regression results). It is not unequivocal however. Figure 38 demonstrates the response for EU15. It indicates that the dose response function stays very close to zero but becomes positive and significant for values of the treatment between the 40th and 60th percentile, before decreasing into negative territory after the 70th percentile.

Figure 37 Dose Response Function. Labour productivity, complete sample

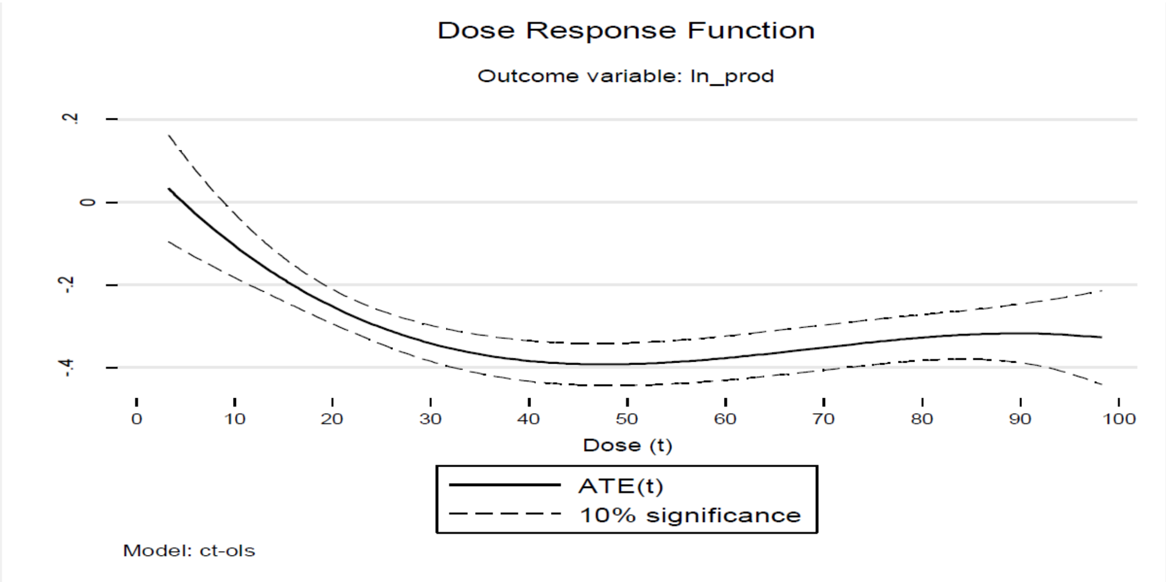


Figure 38 Dose Response Function. Labour productivity, EU15

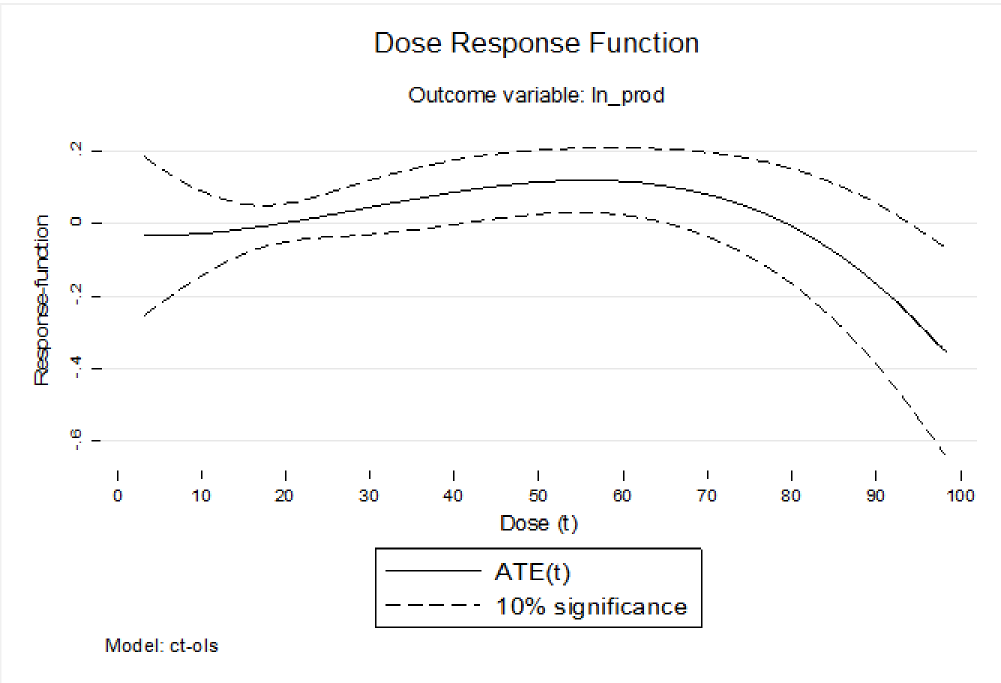
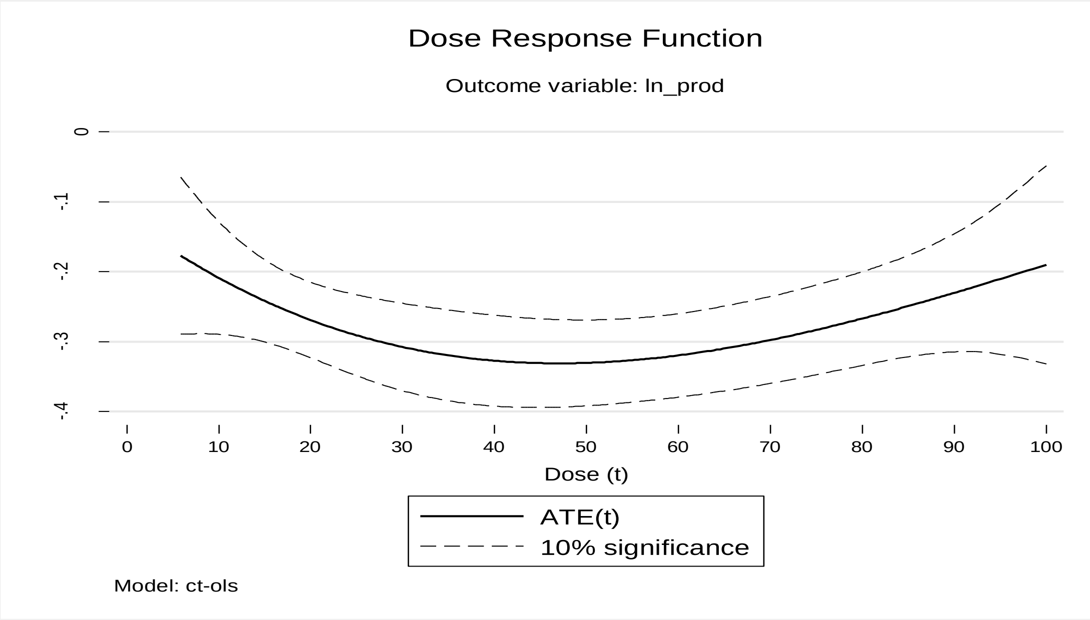


Figure 39 Dose Response Function. Labor productivity, EU13



The effect of inward BERD on country productivity is slightly positive and significant only for EU15. The picture for the total sample with a time-lag is different. In short, we observe a decreasing pattern with negative values for the dose response indicating an inverse relation between productivity and inward BERD. The results there are not significant

The impact of inward BERD on **patents** is positive with a slight increase in the overall sample and on EU15. While in the first case we observe a trend that remains stable for the different amounts of the inward BERD.

Figure 40 Dose Response Function. Patent, Overall sample

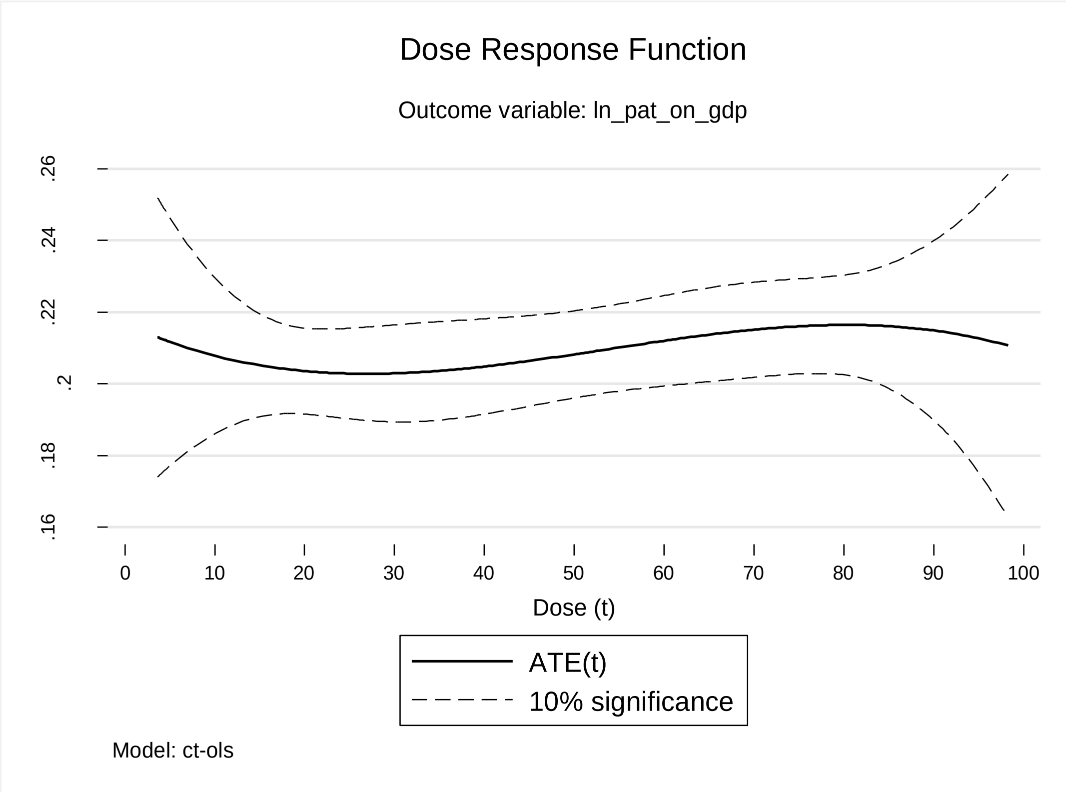


Figure 41 Dose Response Function. Patent, EU15

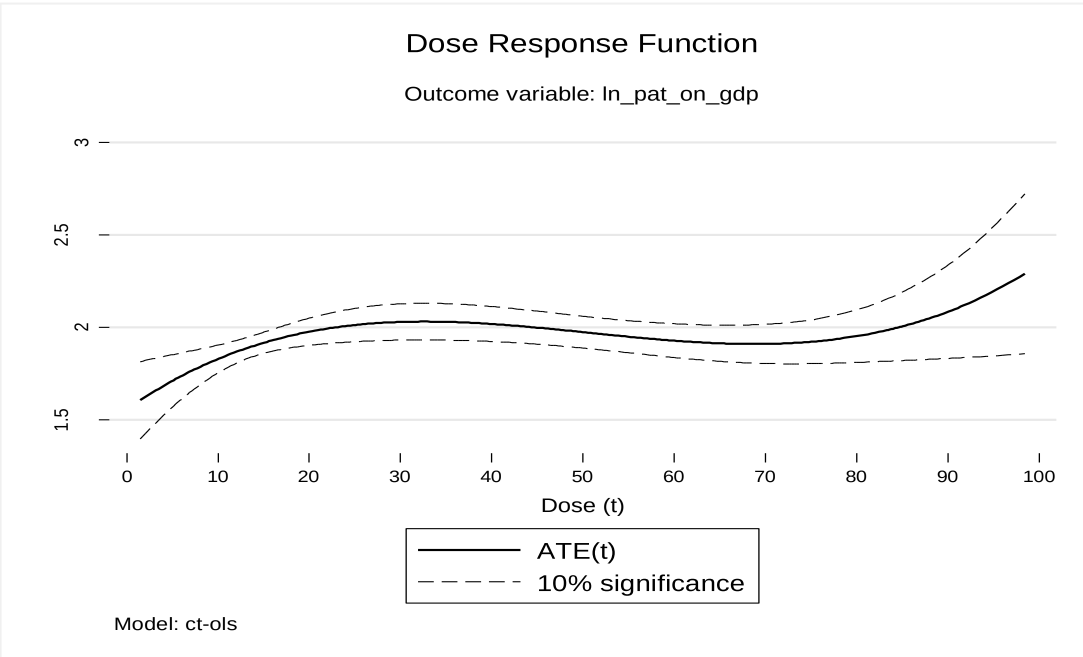
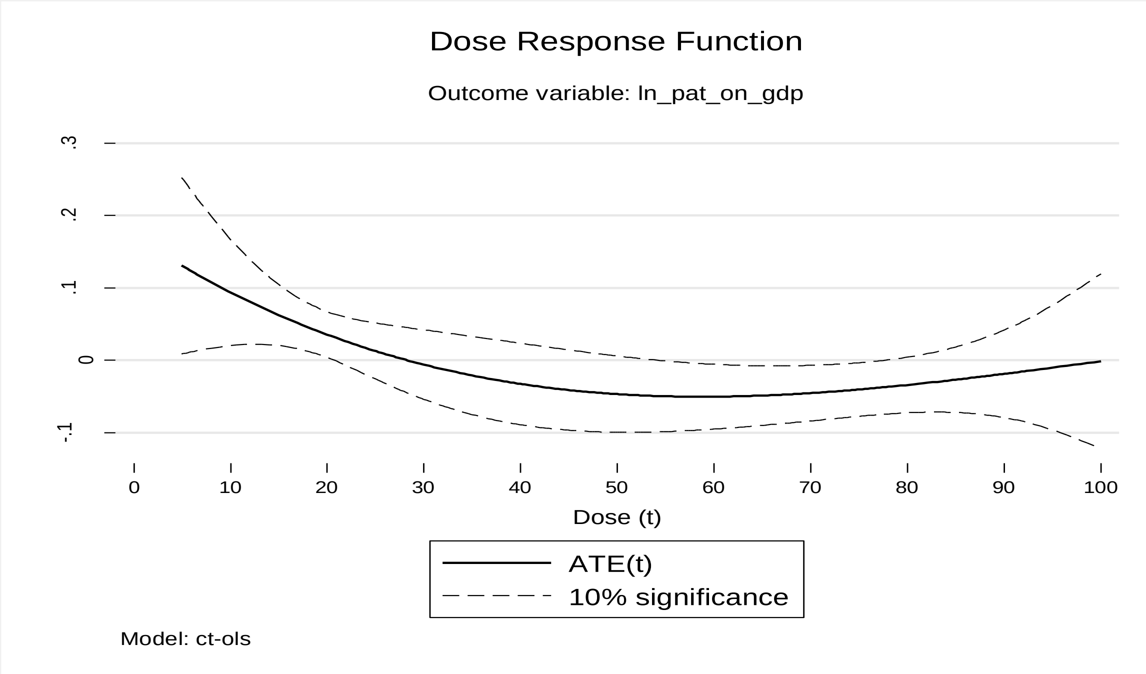


Figure 42 Dose Response Function. Patent, EU13



In the sub-sample for EU15 we have a trend that increase until the 30% of "treatment" and then it remains stable with large confidence intervals after the 80th percentile. In EU13 we observe a positive, but decreasing effect of the response function until 20% of MNE's inward R&D, above this threshold the dose response values are negative but statistically not significant.

The impact of inward BERD over value-added on **Domestic Business R&D** in the overall sample, with a time lag, is positive and increasing until 20% of the treatment, then it remains positive but decreasing until 40% and after this threshold the value are not significant. When we run a contemporaneous relation between inward BERD and domestic BERD, we get the following graph.

Figure 43 Dose Response Function. RD domestic, Overall sample

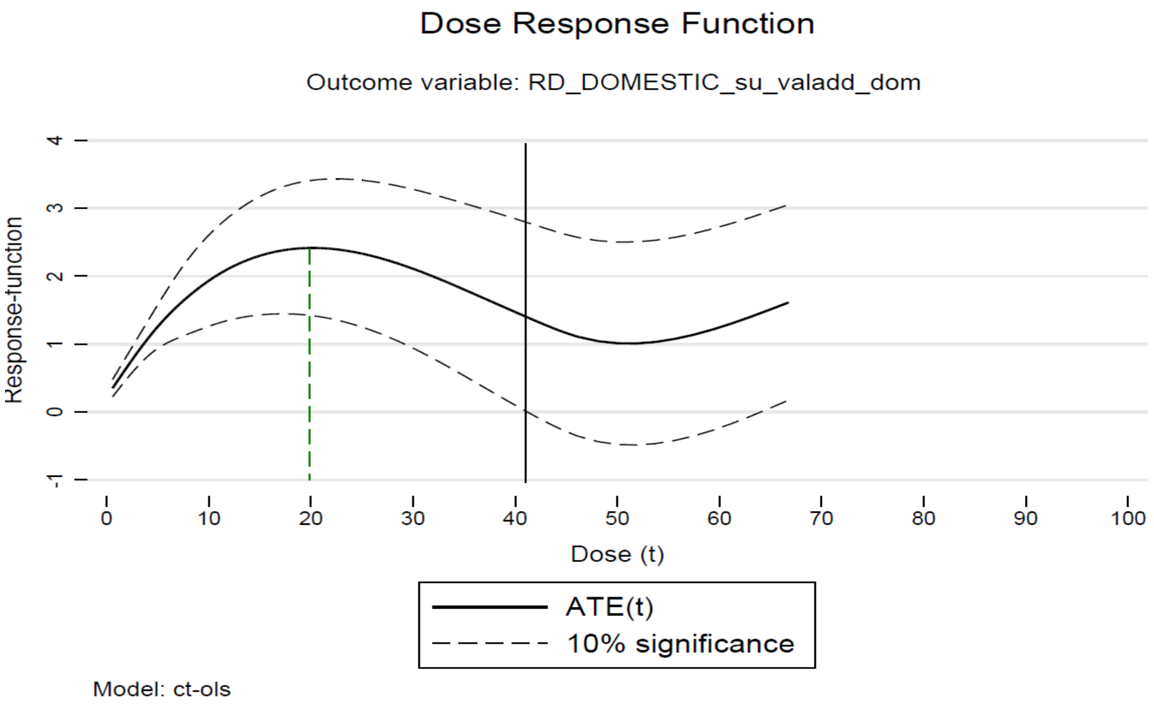
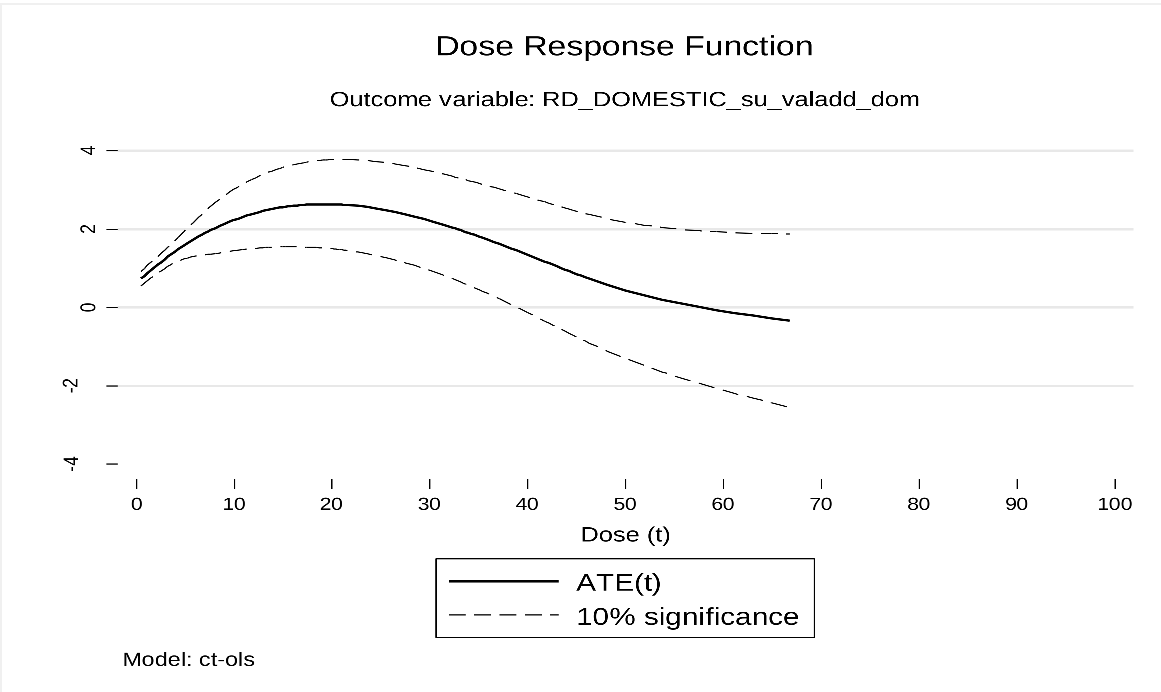


Figure 44 Dose Response Function. RD domestic, EU15



In the EU15 group of countries, the inward BERD impact on domestic BERD is positive and increasing until 20%, then it is positive but decreasing until 40% and at 60% it is negative but not significant. In the group of EU13 countries the impact is positive and it grows until 10%, then remains positive but decreases to 15%; after this threshold the missing values break the graph off in the middle.

In sum, the MNEs inward impact differently if we consider core or peripheral European countries and the type of outcome. Summarizing, the results suggest a positive pattern. This result is established in the first step (the univariate exercise) and confirmed in the second (the multivariate approach reported in the figures) until a certain threshold. Thus, our results seem to point towards a moderately positive effect, overall. Working within the constraints of the data, the results are not to be interpreted as being strictly causal; instead they should be taken as a good description of the impact on these outcome variables. Together we can say that (i) a crowding-out is excluded, and (ii) a positive relation is particularly envisaged in between 0 and 20%. In terms of labour-productivity the impact is positive for EU 15 and negative in the other cases. As for the impact on patenting, there are three different patterns and the highest value are found in the overall sample, which remain stable for different dose of treatment

Chapter 6.

Most urgent data needs for future analysis

Bernhard Dachs and Georg Zahradnik

Chapter 6 Most urgent data needs for future analysis

Bernhard Dachs & Georg Zahradnik

One important aim of this project is to promote a better understanding of data on inward and outward BERD and the limitations of these data. Our experience working with these core-data both in this study and its predecessor (Dachs et al, 2012) has acquainted us with strengths and weakness of using the data in terms of their scope, their timeliness, the availability of time series, their periodicity, and their coherence. This chapter briefly summarizes findings that have emerged from this work, and draws conclusions about data availability and quality.

It is first important to start by realising that the regulation that governs the collection of the core inward and outward BERD data underwent a significant change in Europe during the two projects. This transition, which takes place before and after 2008 helps to inform the discussion of how to improve the data-collection to improve policy-relevant data analysis of inward and outward BERD. In brief the transition consists of the following:

- Until reference year 2007, the collection of inward and outward BERD data was regulated by two binding documents[15] on the definitions of characteristics for structural business statistics. See the 2007 edition of the FATS Recommendations Manual.
- From reference year 2008 on, the new FATS regulation on structural business statistics[16] took effect to obtain inward BERD data from all Member States of the European Union. This had a couple important consequences. In contrast to the other FATS data to be collected, the R&D data - total intra-mural R&D expenditures and total number of R&D personnel – were from that point on to be delivered every odd year and only for NACE Rev. 2 sections B, C, D, E and F.
    - The first consequence was that there was no obligation to collect inward BERD data for service firms.
    - The second consequence was that there was no obligation to collect outward BERD data, either.

In addition, country coverage is affected by the so-called 1 % rule[17] which also applies for data on foreign-controlled R&D expenditures. A number of the newest EU member states in particular fall under this provision and therefore are not obligated to report this information (see below).

In short, the changes in legislation that were introduced in 2008 did not improve data-availability on this front. While we observed a noticeable increase in attention of

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[15] by the Commission Regulation (EC) No 1670/2003 of 1 September 2003 implementing Council Regulation (EC, Euratom) No 58/97 with regard to the definitions of characteristics for structural business statistics and amending Regulation (EC) No 2700/98

[16] In addition to collection of inward and outward BERD data, the FATS-R also requires collecting nine more characteristics (Number of enterprises, Turnover, Production value, Value added at factor cost, Total purchases of goods and services, Purchases of goods and services purchased for resale in the same condition as received, Personnel costs, Gross investment in tangible goods, Number of persons employed) on an annual basis for the whole business sector.

[17] 'If the total amount of turnover or the number of persons employed in division of NACE Rev. 2 sections B to F represent, in a Member State, less than 1% of the Community total, the information necessary for the compilation of statistics relating to characteristics 22 11 0 and 22 12 0 need not to be collected for the purposes of this Regulation. If necessary for Community policy requirements, the Commission may, in accordance with the procedures laid down in Article 10(2) of this Regulation, request ad-hoc collection of this data.'

national statistical offices for R&D internationalisation and an extension of survey programmes from the year 2003 to 2007, this trend did not continue in the following years. The countries with available data remained mostly unchanged since 2007 for both EU and non-EU countries.

Availability of inward BERD Data

In this section, we account for the data that was used for this project and the source. This is key in understanding the data-coverage issues we point out in the project.

The first core-data is Inward BERD. This data looks at R&D internationalisation from the host country point of view, and reports the R&D expenditures of foreign-owned firms in a particular host country (inward BERD). Data collected by **Eurostat (ESTAT)** in used for this project (see the definitions as outlined in section 2 of the D2 methodology report and the legal framework). We used the most up-to-date data (last data update in March 2016) which for this study means: data R&D characteristics for **NACE Rev. 2 sections B, C, D, E and F** for reference years (odd) between 2009 and 2013. The first reference year for the R&D characteristics was 2007, for the years before 2007 data was provided by national statistical authorities on a voluntary basis.

The geographic breakdown of home/host countries is in the ESTAT database in line with the country coverage requirements of this project. The sectoral coverage is in line with the required basic sector breakdown Annex 6A of the ToR only for the NACE 2.0 sections B, C, D, E, and F but does not include the services sector and also does not provide data on the NACE 2.0 4-digit-level needed for the additional breakdown as of Annex 6B in the ToR (see also section 3 of D2 methodology report). Five smaller countries (Cyprus, Latvia, Lithuania, Luxembourg and Malta) have a derogation for foreign-controlled R&D and do not collect such data.

In addition to Eurostat data, the OECD provides data on inward and outward BERD as part of the OECD Statistics on Measuring Globalisation[18] for a number of OECD member countries. This database is especially valuable for countries included in this project, which are not EU member countries and therefore not covered in the ESTAT database. Additionally, OECD data also covers the service sector, which is not included in the ESTAT database from 2009 onwards. The geographic breakdown of home/host countries is in this database in line with the country coverage requirements of this project (see Appendix A1). Sectors are classified in ISIC 4 and not NACE 2.0; however, ISIC 4 can be easily transferred in NACE 2.0. The sectoral coverage is in line with the required basic sector breakdown (Annex 6A of the ToR) but does not provide data on the NACE 2.0 4-digit-levels needed for the additional breakdown as of Annex 6B in the ToR. The OECD discontinued to actively collect data for EU-28 member countries as these countries have to provide the respective data to ESTAT. However, the OECD still updates some national data for EU-28 member countries (e.g. Germany) and is also regularly updating data for non-EU countries[19].

The tables below summarize data availability of inward BERD data for the EU-countries and non-EU-countries.

[18] *http://www.oecd-ilibrary.org/finance-and-investment/data/oecd-statistics-on-measuring-globalisation_global-data-en*

[19] *Conversation with Isabelle Desnoyers-James, OECD*

Table 33: Availability of inward BERD data for the EU-countries

Country	Breakdowns	
	Sector	*Country of Origin*
Bulgaria	2000-2007, 2009, 2011 and 2013	2000-2007, 2009, 2011 and 2013
Belgium	2000-2013	2000-2013
Czech Republic	1998-2014	2003-2007, 2011 and 2013
Germany	2001, 2003, 2005, 2007, 2009, 2011, 2013	1993, 1995, 2001, 2003, 2005, 2007, 2009, 2011, 2013
Denmark	2007 and 2013	2007 and 2013
Estonia	2003-2007, 2009, 2011, 2013	2003-2007, 2009, 2011, 2013
Greece	1999 and 2013	1999, 2009, 2011, 2013
Spain	2003-2007, 2009, 2011, 2013	2003-2007, 2009, 2011, 2013
France	1998, 2001-2007, 2009	2001-2007, 2009, 2013
Croatia	2011 and 2013	2003-2007, 2009, 2011, 2013
Ireland	1999, 2001, 2003, 2005, 2007 Total for 2008, 2010, 2012, 2014	2005
Italy	2001-2007, 2011 and 2013	2011 and 2013
Cyprus	No (derogation)	No (derogation)
Latvia	2003-2007 (2003 values zero)	2003-2007 (2003 values zero)
Lithuania	No (derogation)	No (derogation)
Luxembourg	No (derogation)	No (derogation)
Hungary	2003-2007, 2009 to 2013	2003-2006, 2009 to 2013
Malta	No (derogation)	No (derogation)
Netherlands	1998-2001, 2007, 2009-2013	1998-2001, 2007, 2009-2013
Austria	2003, 2004 and 2007, 2009, 2011, 2013	2003, 2004 and 2007, 2009, 2011, 2013
Poland	1998-2007, 2009, 2011, 2013	2009, 2011, 2013
Portugal	2005, 2007, 2011, 2013	1999, 2001-2003, 2005, 2007, 2011, 2013
Romania	2004-2007, 2009, 2011, 2013	2004-2007, 2009, 2011, 2013
Slovenia	2003-2004, 2006-2007, 2009, 2011 and 2013	2003-2004, 2006-2007, 2009, 2011 and 2013
Slovakia	2003-2007, 2009, 2011, 2013	2003-2007, 2009, 2011, 2013
Finland	1998-2001, 2005-2007, 2009, 2011	1998-2001, 2004-2007, 2009, 2011, 2013
Sweden	1998-2003, 2005, 2007, 2009, 2011, 2013	1998-2003, 2005, 2007, 2009, 2011, 2013
United Kingdom	1998-2002, 2005-2009, 2011, 2013	1999, 2002-2013

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

Table 34: Availability of inward BERD data for the non-EU-countries

Country	Breakdowns	
	Sector	*Country of Origin*
Turkey	1998-2000, 2002	1998-2000, 2002
Norway	2005-2007, 2009, 2011, 2013	2007, 2009, 2011, 2013
China	No (only total)	No (only total)
India	Not in line with methodology (2006-2010)	No
Japan	1998-2012	1998-2007
United States of America	1998-2013	1998-2013
Canada	1998-2013	1998-2004 (2005-2013 only US vs. non-US)
Brazil	Not in line with methodology (2008 and 2011)	No
Israel	2007-2011	2010-2011

Note: Only countries included with inward BERD data available, full table see Annex

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

The terms of reference of this project required us to collect data for the following additional breakdowns of inward BERD:

1. Inward BERD by current/capital expenditure
2. Inward BERD by type of activity (basic research, applied research, experimental, other)
3. Inward BERD by sector of performance (business, government, higher education, other)

In the course of the pilot phase, we found out that neither Statistics Austria nor the Bureau of Economic Analysis provides this data. This result was also confirmed during the full-data collection as national statistical offices are not able to provide such data – at least not without additional costs. Provision of such data would only be possible for a small number of countries with very limited data coverage for substantial extra costs.

Availability of outward BERD Data

In terms of core-data, Inward BERD was intended to be complemented by Outward BERD or R&D internationalisation from the home country point of view where it corresponds to the R&D expenditures of domestically-owned firms abroad (outward BERD). This intention could not be followed up due to coverage issues. As noted, the collection of outward BERD data is not required according to the FATS regulation and is therefore voluntary for both EU and non-EU countries. The table indicates how sparse this data currently is.

Table 35: Availability of outward BERD data for the EU-countries

Country	Breakdowns	
	Sector	*Destination country*
Germany	1999, 2001, 2003, 2005, 2007, 2009, 2011	No
Italy	No	Yes (only 2003)
Sweden	No	1999, 2001, 2003, 2005, 2007

Note: Only countries included with Inward BERD data available, full table see Annex

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

Table 36: Availability of outward BERD data for the non-EU-countries

Country	Breakdowns	
	Sector	*Destination country*
Switzerland	2000, 2004, 2008 and 2012	No
Japan	1999-2013	1999-2007
United States of America	1998-2013	1998-2013
Israel	2007-2011	2007, 2009, 2011

Note: Only countries included with inward BERD data available, full table see Annex

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

Major data gaps and other data issues

While data quality and completeness improved to some extend over the last 10 to 15 years especially for the EU member countries, various data gaps and data quality issues still significantly hamper the analysis of R&D internationalisation. This section summarizes the most pressing gaps and quality issues.

- A main issue is **late data delivery** by national statistical offices to ESTAT and, as a result, late publication of data by ESTAT.

While the cut-off date for this project was postponed several time till March 2016 in order to enable the inclusion of all data for 2013, inward BERD data was available for only 18 of the 28 EU member countries (Bulgaria, Czech Republic, Denmark, Germany, Estonia, Greece, Spain, France, Croatia, Italy, Hungary, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia) and Norway from ESTAT by end of March 2016. A number of countries, most notable the United Kingdom, Finland, Belgium, Ireland and Sweden were still missing at the cut-off date. Three countries, Belgium (9 June), Finland (11 July) and the United Kingdom (5 September), were uploaded well after the cut-off date. The Table 37 below illustrates the publication record of the data at Eurostat.

In some cases, it is possible to supplement data from the national statistical offices. We could include Belgian data into the database as the data was provided from the national source in December 2015. Some national data was also provided for the UK, however, this data was not complete, not identical with the data in the ESTAT FATS statistics and not directly comparable with UK total BERD data or inward BERD data for other countries. Finland was not included at all due to late publication. Five smaller countries (Cyprus, Latvia, Lithuania, Luxembourg and Malta) have a derogation for R&D and another two countries (Ireland and Sweden) did not deliver IFATS R&D for

2013 to ESTAT. We were able to include some national data for both Ireland and Sweden; however, this data is again not directly comparable with the data provided by ESTAT and not in line with the methodology of this project.

Table 37: Inward BERD data for the EU-countries – major data issues (2013)

Country	*Service sector data*	*Late delivery ESTAT*	*Other issues*
Bulgaria	No	No	No
Belgium	Yes (national data)	9 June 2016 (national data used instead)	ESTAT data unreliable, national data used
Czech Republic	Yes (national data)	No	No
Germany	Partly (OECD data)	No	No
Denmark	No	No	No
Estonia	No	No	inward FATS data cover enterprises with 20 or more employees only
Greece	No	No	No
Spain	No	No	No
France	No	No	Only country breakdown
Croatia	No	No	No
Ireland	No	Yes (not delivered as of 17/10/2016)	National data (2014) on inward BERD does not match total BERD data provided by ESTAT.
Italy	Yes (OECD data)	No	No
Cyprus	No (derogation)	No (derogation)	No (derogation)
Latvia	No (derogation)	No (derogation)	No (derogation)
Lithuania	No (derogation)	No (derogation)	No (derogation)
Luxembourg	No (derogation)	No (derogation)	No (derogation)
Hungary	Yes (national data)	No	No
Malta	No (derogation)	No (derogation)	
Netherlands	Yes (national data)	No	No
Austria	Yes (national data)	No	No
Poland	No	No	No
Portugal	No	No	ESTAT data unreliable – not used for most analysis
Romania	No	No	No
Slovenia	Yes (national data)	No	No
Slovakia	No	No	No
Finland	No	11 July 2016 (not included in database)	No amounts for 2013 due to late delivery
Sweden	Only total services (national data)	Yes (not delivered as of 17/10/2016)	Only national data used with limited breakdowns
United Kingdom	Yes (national data)	5 September 2016 (national data used instead)	National data used is classified by product field and not main activity. Inconsistencies with total BERD classified by main activity.

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

- Another main issue is the **lack of data for service sectors** in most countries.

After the revision of the FATS regulation, data on total intra-mural R&D expenditures are collected for every odd year and for NACE Rev. 2 sections B, C, D, E and F at ESTAT. This means national statistical offices are not required to collect data for services sectors by the regulation.

As a result, the is less data available for service sectors for the year 2013 than it was for 2007. Services sectors are not included in the totals provided by the ESTAT database or the sectoral data, even if such data is collected at the national level. Some statistical offices have stopped to prepare inward BERD data for service sectors. The table below shows the availability of the data at country level.

- Furthermore, there is a general **lack of outward BERD data.**

One reason for this poor coverage is the fact that collecting outward BERD data is more difficult than collecting inward BERD data. Inward BERD data is often generated from the data created by R&D surveys by adding the ownership information. A firm-level survey of outward BERD addresses R&D performing firms located abroad. Statistical offices may have very little information about this population, because they typically address the domestic firm population.

Data availability for **non-European countries** is considerably worse than for EU countries. We found no official data published for South Korea, Russia, India, and Brazil. There is only rudimentary data for China. Canada does not collect data on R&D expenditures of foreign-owned firms according to the country of origin anymore. Data for Israel is limited to the period from 2007 to 2011. This is a serious obstacle to a global analysis of R&D internationalisation, since emerging economies are gaining importance in the process, both as home and host countries.

While data provided by ESTAT and the OECD was the preferred data source, we also data at the national level for the following reasons:

- To have more recent data
- To include data on service sectors
- Non-European countries are not covered by ESTAT or OECD
- NACE 2.0 4-digit-level: Needed for the additional breakdown as of Annex 6B in the ToR and is not collected by ESTAT. Such detailed data was not available for almost all countries and could therefore not be integrated into the dataset.

We observed that **national data is often not in line** with the methodology of this project and analyses based on national data have to be done very carefully. In some cases, data provided at the national level had major deviations from data at ESTAT: Reasons for deviations between national data and data published by ESTAT include

- The classification of (inward) BERD by product group and not main activity (e.g. national data for UK)
- Different data-sources used

In at least two cases (Portugal and Belgium), data provided by ESTAT has serious **quality issues**. According to ESTAT IFATS R&D, total inward BERD for Belgium in the year 2013 is only 1.5 million EUR (NACE B-F) while national data indicates inward BERD of 4.2 billion EUR (total business sector) and a total BERD of 6.7 billion EUR. ESTAT IFATS R&D data for Portugal indicates also a very low value for Portugal of only 0.5 million EUR of inward BERD and 6 million of total BERD (both NACE B-F) while BERD in the manufacturing sector alone (NACE C) is already more than 600 million EUR according to ESTAT Statistics on research and development. In the case of Belgium, the national data provided is to our knowledge the preferred source while in the case of Portugal had to be excluded from most analysis altogether.

Systematic comparisons of data from different sources can uncover other inconsistencies. We also compared **Inward BERD data** for several countries with the corresponding outward BERD data provided by the US. This comparison revealed huge differences, for example between the value of inward BERD of US firms in Austria reported by Austrian and US sources. Colecchia (2006) reports similar issues with older data. Among other errors, the most likely reason for these discrepancies is the assignment of firms to an ultimate home country, which may differ between inward and outward BERD sources. Moreover, another potential sources may be differences between the immediate investor country and the ultimate investor country (see OECD 2015, p. 307). A possible reason is the hand-over of R&D funds from the European headquarters of US firms to affiliates in other European countries.

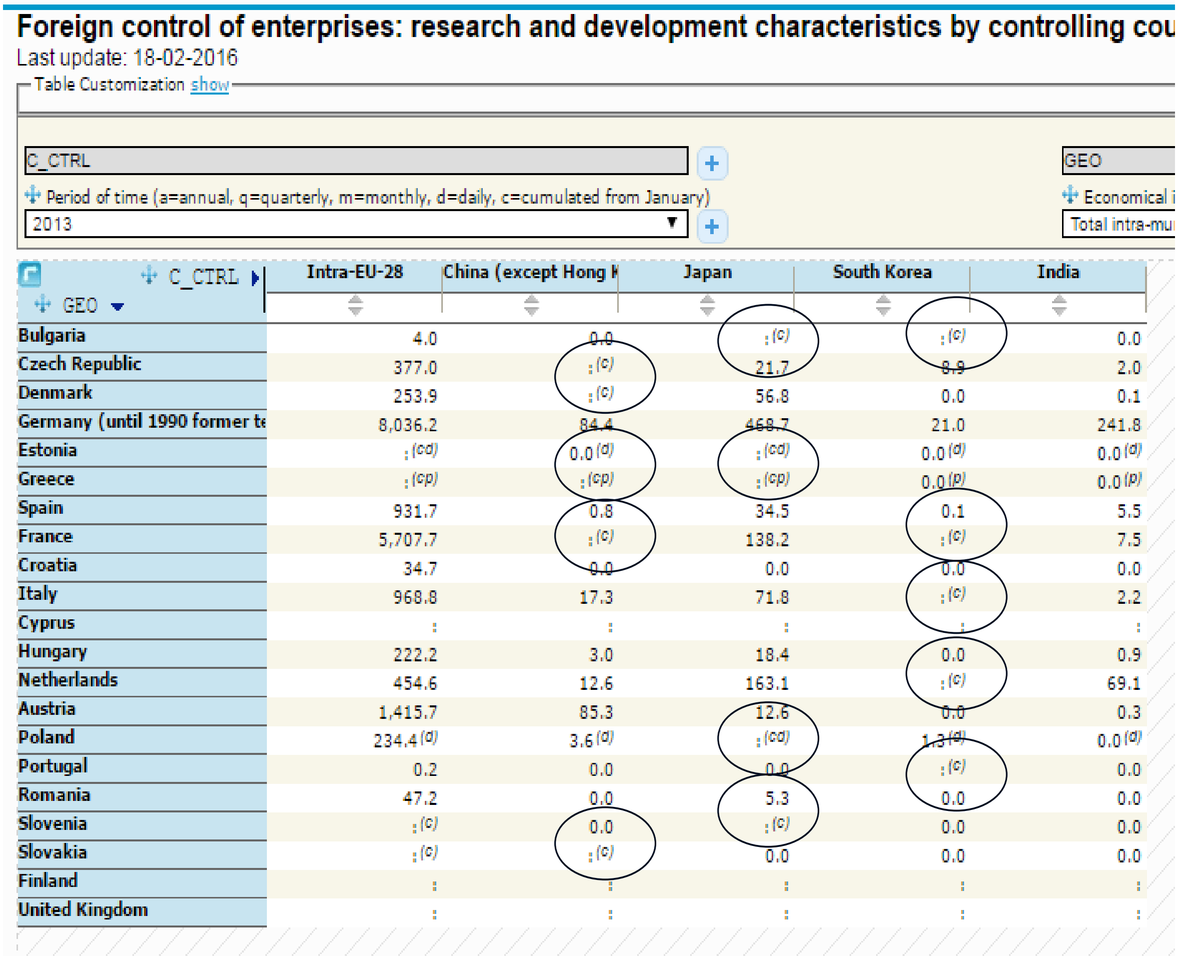
The change from NACE 1.1 to 2.0 (between 2007 to 2008) caused **some breaks in series**. Within the manufacturing sector, most NACE 1.1 sectors have a directly corresponding NACE 2.0 sector. The only major exceptions are the NACE 1.1 sectors 24 (which combined chemicals and pharma and was split up into two sectors in NACE 2.0) and 30-33 (which were reclassified into just two sectors in NACE 2.0). In case of the services sector, the changes were more significant, especially for some of the KIBS sectors.

R&D internationalisation is the result of the activities of a small number of multinational firms. This concentration makes the collection and publication of inward BERD data difficult, because ESTAT and national statistical offices will not publish results for less than three enterprises in a particular breakdown. Thus, in smaller countries, **confidentiality issues** arise at the NACE 2-digit-level when there are less than three foreign-owned enterprises in a particular industry. The same rule applies for foreign-owned firms classified by the home country.

The figure below is a screenshot of the ESTAT FATS database on inward BERD. It shows total inward BERD by Chinese-owned, Japanese-owned, Korean-owned and Indian-owned firms in EU countries. Obviously, there are a number of countries where data cannot be published because of confidentiality. In this context however, the resulting data gaps not only limit the analysis of the respective country but also make it impossible to calculate country aggregates including inward BERD for all EU member countries in a certain sector or total inward BERD for all EU member countries from a certain home country.

This limitation could be easily addressed. By adding up these data from all member states into one single figure for the EU, it would be possible to provide information on the size of Chinese, of Korean, and of Indian R&D activities in the EU while still ensuring the important issue of confidentiality. So far, such information can only be estimated based on the patchy information we have. EU-wide aggregates would also increase our knowledge in sectors where only a few foreign-owned enterprises are active.

Figure 45: Screenshot from the ESTAT FATS database


Foreign control of enterprises: research and development characteristics by controlling cou

Last update: 18-02-2016

Table Customization show

C_CTRL

Period of time (a=annual, q=quarterly, m=monthly, d=daily, c=cumulated from January)

2013

GEO

Economical i

Total intra-mu

C_CTRL / GEO	Intra-EU-28	China (except Hong K	Japan	South Korea	India
Bulgaria	4.0	0.0	: (c)	: (c)	0.0
Czech Republic	377.0	: (c)	21.7	8.9	2.0
Denmark	253.9	: (c)	56.8	0.0	0.1
Germany (until 1990 former te	8,036.2	84.4	468.7	21.0	241.8
Estonia	: (cd)	0.0 (d)	: (cd)	0.0 (d)	0.0 (d)
Greece	: (cp)	: (cp)	: (cp)	0.0 (p)	0.0 (p)
Spain	931.7	0.8	34.5	0.1	5.5
France	5,707.7	: (c)	138.2	: (c)	7.5
Croatia	34.7	0.0	0.0	0.0	0.0
Italy	968.8	17.3	71.8	: (c)	2.2
Cyprus	:	:	:	:	:
Hungary	222.2	3.0	18.4	0.0	0.9
Netherlands	454.6	12.6	163.1	: (c)	69.1
Austria	1,415.7	85.3	12.6	0.0	0.3
Poland	234.4 (d)	3.6 (d)	: (cd)	1.3 (d)	0.0 (d)
Portugal	0.2	0.0	0.0	: (c)	0.0
Romania	47.2	0.0	5.3	0.0	0.0
Slovenia	: (c)	0.0	: (c)	0.0	0.0
Slovakia	: (c)	: (c)	0.0	0.0	0.0
Finland	:	:	:	:	:
United Kingdom	:	:	:	:	:

Source: ESTAT, retrieved September 2016

Four recommendations to overcome data issues

The observation and data gaps and shortcomings in core data for the internationalisation of R&D leads us to four recommendations which could – in our opinion – greatly increase the utility European policy as well as researchers can get from inward and outward BERD data.

A first recommendation is to support an **alignment of survey methods** between EU and non-EU countries. There is a considerable gap in data availability as well as in the definitions used for inward and outward BERD between the EU and non-European countries. It would be very useful to have more data for the two groups which are immediately comparable, in particular for China, for India and for other emerging economies. We see this as a task for the OECD, which has included recommendations for the collection of data on R&D activities of multinational firms in its latest edition of the Frascati Manual (OECD 2015).

A second measure with immediate benefits is to find ways **to speed up the publication of the data**. The most recent data for inward BERD is for 2013, and there was also a gap between delivery of the data to ESTAT and publication of four or more months.

The service sector is of unquestioned importance in the modern economy. Policy development as well as more academic analysis would also benefit from an **inclusion of service industries in the FATS regulation**. The evidence provided in this report suggests that the share of services on total inward BERD is rising fast in all countries where data is available. Services currently account for a quarter to a third of total inward BERD. More service data would help to understand this phenomenon in more detail. Moreover, the additional burden for statistical offices is very light, since most of them collect data on R&D activities of service firms in their R&D surveys, and just need to add ownership information in the same way they do for manufacturing firms. Aggregates for NACE B-F should nevertheless be provided.

Finally, there is a need for **more aggregate data on EU inward BERD**. Currently, ESTAT only publishes inward BERD figures for each individual member state based on the national data by statistical offices. However, it does not provide a total for the EU-28. The first reason why we need more aggregates is the demand from policy for a thorough comparison of Europe with the US and other countries. This is only possible with one figure that represents all 28 EU countries. A second, less obvious reason for more aggregates are limitations in the data that come from the fact that only a small number of firms from one particular home country operate in one country, as described above. Aggregates for all firms from one home country operating throughout the EU would considerably increase our understanding of the dynamics of R&D internationalisation and the attractiveness of the EU as a host country for doing R&D.

Chapter 7.

Policy conclusions

Bernhard Dachs, Parimal Patel, Eric Iversen, Mark Knell and Bianca Poti

Chapter 7 Policy Conclusions

Bernhard Dachs, Parimal Patel, Eric Iversen, Mark Knell & Bianca Poti

In the EU policy-frame, there is a need to improve the evidence-base for R&I policymaking. European priorities (cf. Europe 2020) emphasise the potential of research and innovation to promote renewed growth. In order to realise this potential, we ask what contributions of the internationalisation of research and innovation might be. The previous chapters of this study have brought to light and analysed a number of trends from different perspectives on this front. We have underlined the fact that the internationalisation of R&D may carry considerable benefit for countries but that it may also pose challenges for policy.

This chapter ends the study with a discussion of appropriate policy conclusions in light of the composite material of the project. In addition to this report, this material includes the literature review, the methodology and the dataset itself. A general premise is that innovation systems are internationalising in step with the internationalisation of value-chains, of financial systems, and of production systems. In this light, research and innovation systems are showing the tendency to become more international as firms go abroad in search of new markets, new learning opportunities and/or new production possibilities. As we have seen, this tendency is by no means uniform across geography (some countries are more internationalised than others), across sectors (some industries are more active on this front than others), nor across time (the rate of internationalisation may increase or decrease, as discussed in relation to the financial crisis of 2008).

Contributing to informed policymaking

The work presented here has been designed to improve the evidence-base for R&I policy making as it seeks sources for renewed growth. It follows on the original EU project 'Internationalisation of business investments in R&D and analysis of their economic impact, DG Research and Innovation' (EUR 25195 EN, Dachs et al. 2012). There is a general and recognized need for better indicators and more sensitive analysis on this front, and the study here contributes to a wider call to improve the analytic basis in the area. Thus, this study is one element in a wider set of initiatives that are contributing to improve conditions for informed policymaking. The aim of the project has been to gather and analyse the most comprehensive official statistics to analyse internationalisation of R&D. The last chapter made a number of specific suggestions on how formal statistics can be improved to better meet the needs of the policy frame.

Internationalisation means openness, and openness is one of the leading principles of EU policies. In June 2015, the EU Commissioner for Research, Science & Innovation Carlos Moedas, launched a conference entitled "A New Start for Europe: Opening up to an ERA of Innovation", and announced a new chapter in European research and innovation policy, under the rubric of "Open Innovation, Open Science, Open to the World" (European Commission 2016).

This project has explored on the question to what extent European innovation systems are open; it has provided comprehensive information about whether this openness has increased in recent years and, if so, in which (country and sector) contexts and to which degree. More specifically we have examined the involvement of foreign-owned firms in research and development activities within different European countries. At the outset we acknowledge that R&D is only one aspect of innovation, which involves a broader set of activities. Thus firms can innovate by buying the requisite knowledge, by engaging in collaboration activities with other knowledge providers or by creating their own knowledge via setting up R&D facilities. In the project we concentrated on the last of these mechanisms and, more precisely, on situations where these facilities are located outside the home country.

Internationalisation of R&D is not a new phenomenon. The first major academic studies on the subject began appearing more than 30 years ago (for a summary of this early work see Granstrand et. al. (1992)). The main conclusion of the early work was that the world's largest R&D spending firms tend to locate a vast proportion of their innovative activities at home, in close proximity to the location of their headquarters (Patel & Pavitt 1991). Two major features related to the launching of major innovations were highlighted in the early literature as the main reasons for this geographic concentration: the key role played by 'person-embodied' knowledge inputs and the high degree of uncertainty surrounding outputs. Both of these are best handled through intense and frequent personal communications which enable rapid decision-making. While some interactions may be undertaken electronically, this is no substitute for geographic concentration of key units and personnel within the firm. This early literature tended to view the role of foreign R&D in a company's decision to offshore some production as simply a way to adapt existing products (and processes) to suit the local markets and to offer technical support. In the literature this type of activity has been described as "home base exploiting" or "asset exploiting" R&D (see Narula and Zanfei (2005)).

Since then many studies have argued that firms have become more globalized in terms of creation of new knowledge (i.e. knowledge related to the generation of new products and processes) and that this process has been driven by two factors: First is the emergence of significant centres of technology creation outside the Triad (i.e. US, EU and Japan). Second is the greater complexity of new products and processes requiring a wider array of knowledge-inputs. Both of these factors require firms to be present in an increasing number of geographic locations where such knowledge may be found. This form of R&D has been described as "home-base" or "asset" augmenting, implying that a particular company lacks vital innovation inputs in its home location, which could be access to latest scientific knowledge located in universities, highly qualified S&T personnel or advanced suppliers. The argument is that such a company is able find such resources more readily in foreign locations.

Main results of the study and its implications for policy

In a nutshell, the analysis of this project showed that:

- R&D Internationalisation is not globalisation: a concentration of inward BERD in the US, the EU, and in some Asian countries characterizes R&D internationalisation. Moreover, a considerable part of inward BERD goes between European countries, which underlines that geographical proximity is still important.
- There are diverging trends in R&D internationalisation since the crisis: altogether, the crisis seemed to slow down R&D internationalisation, at the sectoral-level, R&D internationalisation in services is currently growing much faster than in manufacturing.
- Europe is still attractive for Extra-EU firms: Europe is still the largest host for R&D of US firms abroad, and the rise of China or India has not led to a reduction of US activity in Europe. At the global level, the EU-US relationship is still the dominant relation in R&D internationalisation.
- Sector studies in seven industries reveal a large degree of sectoral heterogeneity in R&D internationalisation. Sectors differ in terms of their degree of internationalisation, in terms of their main home- and host-countries, in terms of the dynamics of the process and in terms of sector-specific drivers of R&D internationalisation.
- The internationalisation of R&D has benefited small and medium-sized countries. In particular, Belgium, Austria, Ireland, the Czech Republic, Hungary as well as other small and medium-sized countries could increase their share of

total EU inward BERD. It seems that this trend partly reversed after the crisis in 2008.

- Manufacturing industry-size, patents of residents to GDP, labour-cost intensity and domestic BERD are important determinants for the size of inward BERD. The relationship between labour costs and inward BERD is positive, revealing that high-cost countries also attract more inward BERD. This is a clear indication that the quality of the workforce, rather than its costs, determines R&D internationalisation. There is also some evidence that tax incentives has had the effect of increasing inward BERD.
- R&D activities by foreign-owned firms in the EU15 have a positive effect on labour productivity, while the relationship for the whole sample is inconclusive. Empirical results also see a stimulating effect of inward BERD on domestic business R&D activity as well as on domestic patenting. See chapter 5 for a full discussion.
- Despite some improvements in the last years, we still lack data on R&D internationalisation, in particular data for emerging economies and aggregates for the EU as a whole that allow a comparison with the US. See chapter 6 for a full discussion.

There are some caveats to add to issues raised in relationship to data availability and coverage. It is necessary to underline that the relationship between labour productivity and Inward BERD needs to be treated carefully, for at least two reasons: first, that labour productivity is more sensitive to change in factors not considered here (e.g. work organization, fixed investments and process innovation) than to R&D activities; and second, that we have not found evidence of a positive and significant relation in our study. In future work, it would have been useful to test also the effect specifically on productivity at the level of researchers.

It is important to emphasise that the development of inward BERD in Europe described in the report has developed without the aid of concerted targeted policy interventions. This is consistent with the consensus in the literature that sound economic and innovation policy is more important than special incentives to attract foreign firms. Policy can contribute by focusing on the framework condition that foster innovation and R&D of both, domestic and foreign firms. Relevant policy areas include funding R&D, integrating foreign firms in the local innovation system, working on education policies, facilitating an appropriate level of mobility among academic and corporate researchers, as well as ensuring the availability of relevant data and promoting analytic work.

It should note that the internationalisation of business R&D can have different impacts in different scenarios. Inward BERD holds potential advantages:

- Contributions by foreign-owned firms to aggregate R&D expenditure
- Knowledge spillovers improve productivity and innovativeness
- Structural change and labour market effects

But there are potential costs to be vigilant about as well. These include:

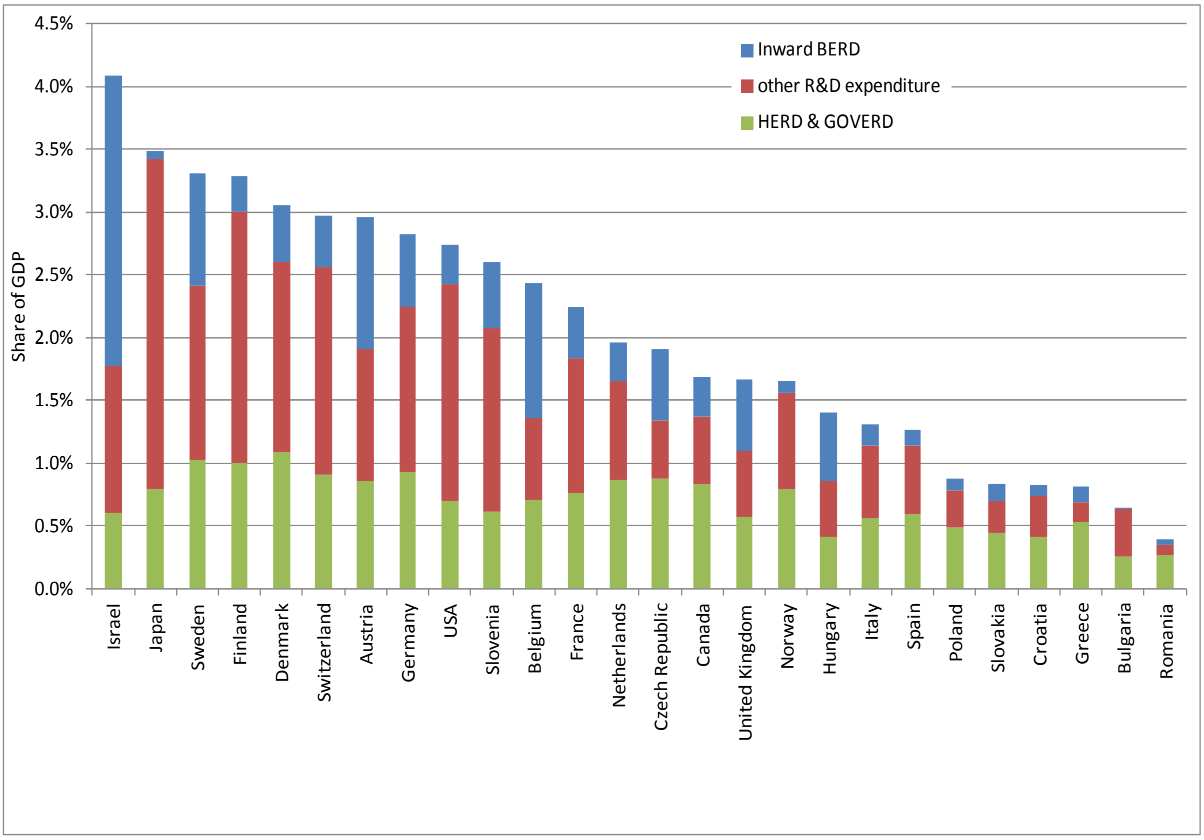
- Crowding-out of domestic R&D activities by foreign firms
- Foreign control, separation of innovation and production
- Degradation of basic research and more applied, adaptive R&D.

In this light and in the light of the project results, we venture some further conclusions with respect to policy:

We see a number of advantages for host countries from R&D internationalisation. A first, direct benefit involves increased R&D expenditures at the national level from the R&D activities of foreign-owned firms. These contributions of foreign-owned firms to aggregated R&D expenditure are substantial in some countries, as can be seen in the following graph. Inward BERD comes close to or is even higher than public R&D expenditures (HERD & GOVERD) in a number of countries, including Austria, Belgium, Hungary, the UK Slovenia or Sweden. In many other countries, aggregate R&D expenditure would be considerably lower without foreign-owned firms.

R&D expenditure consists to a considerable degree of personnel costs for scientists, engineers and other R&D personnel. Thus, a high degree of R&D internationalisation also implies that foreign-owned firms create considerable employment for scientific and engineering staff in their host countries.

Figure 46: Contribution of inward BERD, public R&D expenditures and other private R&D expenditures to overall R&D expenditures, 2013



Source: OECD, Eurostat, national statistical offices, own calculations

Another benefit from the presence of R&D activities of foreign-owned firms are knowledge-spillovers. There is a large literature on knowledge-spillovers, also in relation to foreign-owned firms (see the literature survey of this project). From the analysis of CIS data in this project, we have learned that foreign-owned firms are very active in co-operations both with partners in the host country and internationally. There is also evidence of a high willingness of foreign-owned firms to enter into co-operation with partners outside Europe.

This finding indicates that foreign-owned firms play an important role in international knowledge transfer, and make important contributions to Europe's openness to the world, by connecting European innovation systems with knowledge bases in their home countries. Domestic co-operation of foreign-owned firms ensures that this knowledge can further diffuse in their host innovation systems.

Besides knowledge diffusion, foreign-owned firms also have impacts on the host economies in terms of productivity and innovativeness. R&D activities of foreign-owned firms have a positive effect on labour productivity, at least in the EU15. Empirical results also demonstrate a stimulating effect of inward BERD on domestic business R&D activity as well as on domestic patenting. The latter effect is an indication of spillovers from foreign-owned firms to domestic companies. These effects may be knowledge-spillovers, but can also be effects from the competition of foreign-owned firms that force domestic firms to invest more in R&D.

What are possible negative consequences for host countries from R&D internationalisation? We may imagine a situation where additional demand for R&D personnel by foreign-owned firms in a particular country meets an inflexible supply of scientists and engineers because there are no available (unemployed) resources. In such a situation, a squeezing out of domestic firms may occur. Foreign-owned firms are attractive employers and often pay higher wages, so they may have the means to attract R&D personnel away from domestic firms. In this scenario, more R&D activities by foreign-owned firms would lead to a crowding-out of domestic R&D activity. Empirical evidence, however, does not support such a scenario. Instead, we found that R&D activities of foreign-owned firms are positively related to R&D of domestic firms. The implication is that the relationship is complementary rather than contrary.

The host innovation system may in certain cases be vulnerable to the decisions of foreign firms on R&D activities. In this setting, there is the theoretical danger that R&D internationalisation may lead to greater foreign control over the innovation capabilities of a particular country under certain conditions (e.g. when the MNE is dominant enough in terms of its role in the host R&D system and the decisions have implications of an existential nature).

Moreover, these multinational companies have various means to slice up their activities (research, development, testing, production, marketing, etc.) and shift some of these economic activities from one country to another. This ability to shift distribute economic activities across various countries is in contrast to the concept of national policies which assumes that the promotion of research and innovation leads to higher welfare and employment. If multinational firms locate the development of new products in country A and the production in country B, more R&D does not necessarily equate to more jobs at the national level.

This danger may seem compelling on the face of it. However, it is difficult to test how real the eventuality might be in practice.

The dominant presence of foreign-controlled R&D may have a third negative consequence if it leads to the degradation of basic research and more applied, adaptive R&D in firms. This may be a consequence of strategies of multinational firms to concentrate fundamental R&D in the home country and to use R&D abroad to adapt their products to local markets ('asset-exploiting rationale', see the literature survey). However, the literature has also identified another strategic rationale of foreign-owned firms, where affiliates abroad actively try to absorb new knowledge not available in the home country ('asset-augmenting rationale'). Empirical research (Laurens et al. 2015) has shown that the asset-exploiting rationale still dominates R&D internationalisation, which strengthens the point made above. However, the cited paper also shows that the gap between asset-exploiting and the asset-augmenting rationales is narrowing, indicating that there is some loss of relevance for the argument that a high share of foreign firms on BERD comes with a reduction of basic research. Based on the data available in the project, we cannot test this assumption, as only very few of the statistical offices allow a decomposition of inward BERD into basic and applied R&D activities. To sum up, the study does not find empirical evidence that foreign-owned firms hurt a national innovation system, e.g. by crowding out domestically-owned firms. This indicates that there is no immediate need for policy action to compensate negative effects from R&D internationalisation.

What can be done at the policy level?

Finally, we turn to the question of what policy actually might do to improve the benefits of R&D internationalisation to the wider research and innovation system and how they are distributed (e.g. short term vs longer term). Before we go into any detail, it is important to understand the framework that shapes the degree of freedom for national and transnational policy. There are some things policy cannot do. For example, EU competition legislation sets limits to state aid, including financial investment incentives to foreign-owned firms. That said, there may be exceptions granted for R&D investment, for example in poorer regions of Europe or for other well-defined reasons. Moreover, EU regulation prohibits unequal treatment of foreign-owned enterprises, such as the exclusion of R&D funding, because such unequal treatment may distort the free movement of goods, capital, persons and services in the Single Market. Similar non-discriminatory regulations are also found in bilateral and multilateral investment agreements between EU members and non-EU member countries.

A second important framework-condition for policies towards R&D internationalisation is the actor space. The case studies as well as other research have shown that R&D internationalisation is restricted to a small number of multinational companies. Only very few large firms from a limited number of high-income countries in a limited number of high- and medium technology sectors go abroad with their R&D activities.

In relation to R&D internationalisation, this means that governments in almost every case deal with large multinational companies who can mobilize considerable internal resources. Moreover, MNEs can slice their economic activities, leading to a potential separation of innovation and production. Countries could end up supporting R&D and not yielding the benefits from this R&D, because production and new employment takes place at a location in another country

What remains for national governments to do?

The empirical analysis on the drivers of R&D internationalisation shows that the strength of the manufacturing basis, a high level of innovativeness, and high R&D intensities of domestic firms attract inward BERD. A conclusion from this result is that policies to foster domestic R&D capabilities in the business sector also attract foreign R&D. This is also supported by another finding from the analysis; tax credits for R&D are positively related to inward BERD. Results for Austria suggest that foreign-owned firms prefer indirect to direct funding (Dachs 2016). Thus, indirect R&D funding is one ingredient in building a business-friendly environment that motivates foreign-owned firms to invest in R&D.

Policy development and policy integration

In terms of what the empirical study shows, the high level of R&D activities by foreign-owned firms provides a strong case for the attractiveness of Europe in the internationalisation of R&D. The clear indication is that Europe is an attractive location for R&D activities and that MNEs are in general capable of utilising these locational advantages. A conclusion to be drawn is that special incentives are not needed to actively support inward R&D by foreign-owned firms in Europe specifically.

More important than special incentives to attract foreign-owned firms are the more general lessons that can be drawn for research or innovation policy. In general, there is considerable scope for general innovation policy that promotes innovation capabilities of all firms in the economy, regardless of ownership status. Countries should attempt to attract R&D activities that are suitable for their position in global value chains. European countries can improve their attractiveness in some high-tech sectors or niches. Policies should stimulate the dynamism of local markets of these industries, and consider research or innovation policy in a broad sense.

Internationalisation of R&D offers the scope to increase the development, the spread and the accumulation of new knowledge across a range of borders. In an interconnected world, policy should continue to focus on improving our understanding of Global Innovation Networks and Global Value Chains (see above). This involves learning more about the dynamics of global production and innovation networks. It also means addressing the need for better data and for empirical studies on this front. In doing so, there is scope to look into better ways for policy to facilitate greater integration of MNE subsidiaries into domestic innovation networks, in particular to strengthen their links with other firms in the host country. Upstream and downstream links of domestic firms with foreign-owned firms, as well as pre-competitive co-operations with foreign-owned competitors, can help domestically owned firms to learn from these internationally experienced companies.

The role that domestic populations of researchers plays in this setting is integral as well. The analysis indicates that the quality of the S&T system was in general terms a positive dimension of what attracts inward BERD but that its role was more evenly distributed between the countries under study than other factors. Notwithstanding, expertise is clearly integral to shaping specific decisions about the extent and direction of inward BERD, and the study shows that its role varies in different industries. Above and beyond a good educational system and an active domestic research community, one dimension that policymakers could look into in more detail is the role of measures to facilitate and foster mobility of research personnel. A considerable part of knowledge transfers within multinational firms is via the mobility of researchers. If so, removing barriers to the international mobility of highly skilled labour may also promote R&D internationalisation. Measures that could be considered more broadly include the accreditation of qualifications, tax exceptions for foreign researchers or the alignment of social security systems for mobile researchers.

National or cross-national funding schemes

Here it is useful to distinguish policies at the European level, the national level, and even at the sub-national (or regional) level. Recent surveys of policy measures towards R&D internationalisation show that there is a considerable international consensus in the policy instruments employed (see TAFTIE2009). There are, however, two areas where no consensus exists. The first involves opening up of national R&D funding for foreign, non-domiciled firms. Here, the argument is that relevant knowledge is often only available outside the country; this is seen to particularly be the case for small countries. Moreover, there is the argument that global societal challenges can best be tackled in global co-operation. The European Union is following these arguments and has opened Horizon 2020 to firms, universities and research organisations from outside Europe. These arguments however run counter to the general preference of countries to fund domestic and domiciled foreign-owned firms. In most countries, direct funding for R&D seems to be limited to R&D activities carried out within the national borders.

A second question where no consensus exists is whether governments should provide financial support to firms that want to conduct R&D abroad. The recent literature provides evidence that home countries benefit from overseas R&D of domestic firms via reverse knowledge-spillovers.

Promoting R&D internationalisation at the EU level fits in with the objective of the European Commission to make European research more 'open to the World' (European Commission 2016). A main instrument here is Horizon 2020, which has induced a large number of R&D co-operations between foreign-owned firms and domestic universities and other partner organisations, to foster knowledge exchange. The European Commission provides abundant data on project participation in Horizon

2020, which allows one to trace international co-operation of European firms in this programme in detail.

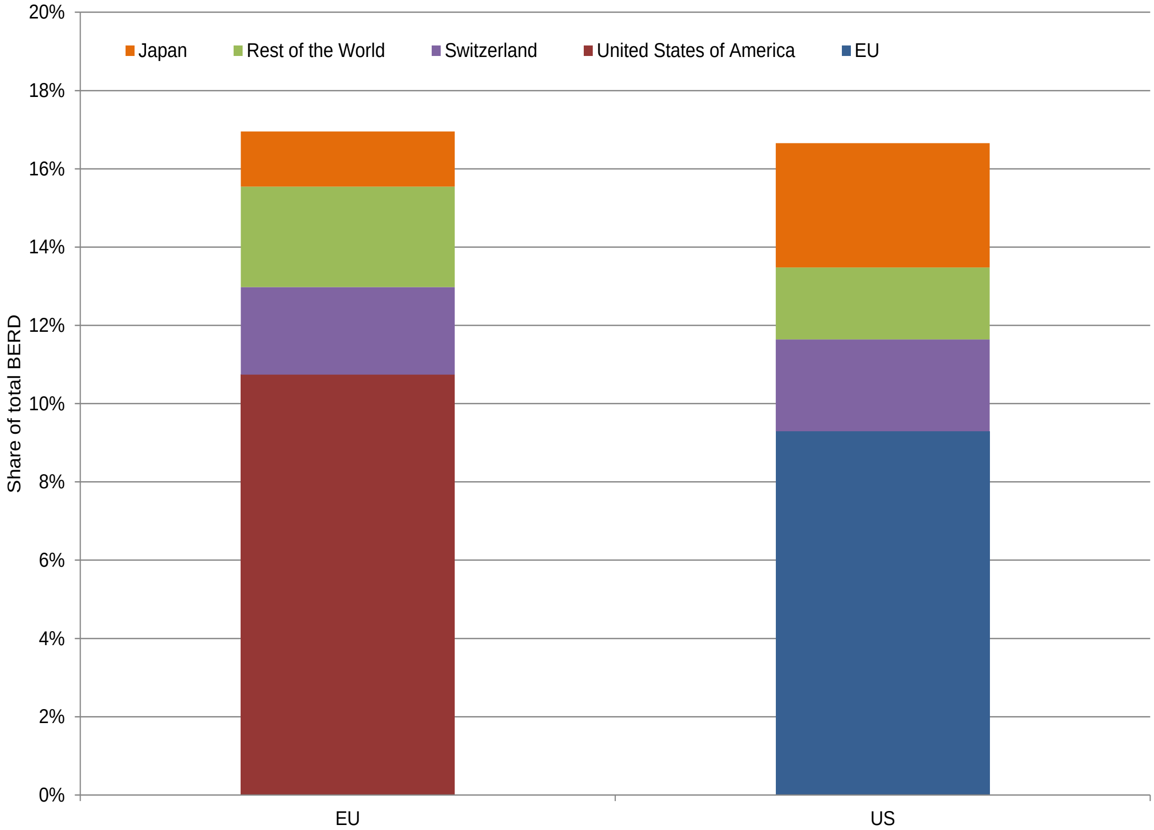
Outside Horizon 2020, our knowledge is limited about the openness of European firms in relation to their R&D activities. As a rough estimate for openness, we can estimate the share of non-EU firms on total business R&D expenditure in the EU and compare it with that in the US (see Figure below). The degree of openness in the EU is about the same as in the US or even higher[20]. There is no gap between the US and the EU, and the indication is that the EU is taking full advantage of internationalisation and the embeddedness in international firm networks. Patent data employed in European Commission 2016 (cf above), underestimate the openness of the EU.

We know even less about the R&D activities of EU firms in regions and countries outside Europe. EU firms account for about 22.2 billion EUR of R&D expenditures in the US, while US firms account for about 17.6 billion EUR in the European Union. Moreover, EU firms spend around 1.9 billion EUR on R&D in Japan, and approximately 1.5 billion EUR on R&D in China. We know little about EU firms in India.

The fact that the value for China is an estimation and lacking data for India shows that we still know too little about R&D internationalisation in the business sector. This lack of knowledge is in sharp contrast to academic research which can be tracked by co-publications and projects bilateral R&D programmes. Thus, it is clear that better data is required about R&D of European firms outside Europe, in particular in the emerging economies. This will help to get a more realistic picture of the contribution of business R&D for the goal of openness in the European Union, which is at least on par with the contribution of academia.

[20] *A lack of inward data for the service sector implies an underestimation of EU openness here.*

Figure 47: R&D expenditures of foreign-owned firms in the EU and the US as a share of total business R&D expenditures, 2013



Source: ESTAT, US Bureau of Economic Analysis, own calculations

Besides improvements in the availability of data and analysis of R&D internationalisation, we see only limited scope for policy measures at the EU level.

The volume of funding for R&D and innovation is still much larger at the member state level than at the EU level, so the leverage for measures towards R&D internationalisation may also be higher at member state level. The focus of EU policies should therefore lie on measures to increase co-ordination between member states in policies to attract R&D of non-EU firms. This may also include measures to avoid harmful competition between member states for inward BERD via tax credit etc. Moreover, we have seen in the case studies that R&D internationalisation is dominated by a small number of large firms, which may point to massive entry barriers for smaller companies. Helping small and medium-sized EU firms to set up R&D outside Europe to gain access to local knowledge and support the exploitation of their assets may be a goal is served best by measures at the EU level.

Data and data-needs

A final set of policy conclusions builds on the points made throughout the report but focused on in chapter 6. To sum up, the analysis has emphasised a number of important data gaps. In this light, it is clear that improvements in the data would greatly increase the utility that European policy can reap from the analysis of inward and outward BERD data. A first recommendation is to support an alignment of survey methods between EU and non-EU countries. A second measure with immediate benefit is to investigate ways to speed up the publication of the data. Policy as well as research would also benefit from an inclusion of service industries in the FATS regulation. The evidence provided in this report suggests that the share of services on total inward BERD is rising fast in all countries where data is available. Finally, there is a need for more aggregate inward BERD data at the EU level to facilitate comparisons of the EU with the US and account for the fact that R&D internationalisation is highly concentrated in a small number of companies.

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Annexes

Three sets of annexes are included in a separate document.

1. The 'in chapter' annexes include material (such as methodology and excerpted tables) that relate directly to the material in the main text. These are found together with this report.

In addition, extended annexes include:

1. the country reports include the updated country reports.
2. the sector reports and the four special topic case studies.

Chapter annexes

Chapter 5.

Annex Table 1 Responsiveness score methodology

Analytically, the responsiveness effect we are interested in, is defined as the "partial effect" of a RCR (Wooldridge, 1997; 2002; 2005). Define a random coefficient setting of this kind:

$$\begin{cases} y_i = a_{ij} + b_{ij} x_{ij} + e_i \\ a_{ij} = \gamma_0 + \mathbf{x}_{i,-j}\boldsymbol{\gamma} + u_{ij} \\ b_{ij} = \delta_0 + \mathbf{x}_{i,-j}\boldsymbol{\delta} + v_{ij} \end{cases}$$

where e_i, u_{ij} and v_{ij} are error terms with $E(e_i \mid x_{ij}) = E(u_{ij} \mid x_{ij}) = E(v_{ij} \mid x_{ij}) = 0$. It is easy to see that the regression parameters, a_{ij} and b_{ij}, are both non constant as depending on all the other inputs x except x_j (this is, in fact, the meaning of the vector $\mathbf{x}_{i,-j}$). Observe that δ_0 and γ_0 are, on the contrary, constant parameters. According to this model, we can define the regression line as:

$$E(y_i \mid x_{ij}\ , a_{ij}, b_{ij}) = a_{ij} + b_{ij} x_{ij}$$

From this, we define the *responsiveness effect* of x_{ij} on y_i as the *derivative* of y_i respect to x_{ij}, that is:

$$\frac{\partial}{\partial x_{ij}}\left[E(y_i \mid x_{ij}, a_{ij}, b_{ij})\right] = b_{ij}$$

where b_{ij} is called the *partial effect* of x_{ij} on y_i. We can repeat the same procedure for each x_{ij} (j=1, ..., Q) so that it is possible eventually to define, for each region i =1 ..., N and factor j=1, ..., Q, the N x Q matrix **B** of "partial effects" as follows:

$$\mathbf{B} = \begin{pmatrix} b_{11} & \cdots & b_{1Q} \\ \vdots & b_{ij} & \vdots \\ b_{N1} & \cdots & b_{NQ} \end{pmatrix}$$

If all variables are standardized, partial effects are *beta coefficients* so that they are independent of the unit of measurement and can be compared and summed.
Once matrix **B** is known, we can define for each region i the Total Country Responsiveness (TCR) and the Mean Country Responsiveness (MCR) as:

$$\text{TCR}_i = \sum_{j=1}^{Q} b_{ij} \quad \text{and} \quad \text{MCR}_i = \frac{1}{Q}\sum_{j=1}^{Q} b_{ij}$$

and for each factor j, the Total (or Mean) Responsiveness of y to factor j's unit change (TFR and MFR) as:

$$\text{TFR}_j = \sum_{i=1}^{N} b_{ij} \quad \text{and} \quad \text{MFR}_j = \frac{1}{N}\sum_{i=1}^{N} b_{ij}$$

In a cross-section data setting, the estimation of each b_{ij} can be done by Ordinary Least Squares of this regression:

$$y_i = \gamma_0 + \mathbf{x}_{i,-j}\boldsymbol{\gamma} + (\delta_0 + \bar{\mathbf{x}}_{-j}\boldsymbol{\delta})x_{ij} + x_{ij}(\mathbf{x}_{i,-j} - \bar{\mathbf{x}}_{-j})\boldsymbol{\delta} + \eta_i$$

$$\eta_i = u_i + x_{ij} v_i + e_i$$

where $\bar{\mathbf{x}}_{-j}$ is the vector of the sample means of $\mathbf{x}_{i,-j}$. Once previous regression parameters have been estimated, we can get for the generic Country i an estimation of the partial effect of factor x_j on y as:

$$\hat{b}_{ij} = \hat{\delta}_0 + \mathbf{x}_{i,-j}\hat{\boldsymbol{\delta}}$$

By repeating this procedure for each Country i and factor j, we can finally obtain $\hat{\mathbf{B}}$, the estimation of matrix **B**.
When a longitudinal dataset is available, the estimation of **B** can be obtained either by using random-effect or fixed-effects estimation of this panel regression:

$$y_{it} = \gamma_0 + \mathbf{x}_{it,-jt}\boldsymbol{\gamma} + (\delta_0 + \overline{\mathbf{x}}_{-jt}\boldsymbol{\delta})x_{ijt} + x_{ijt}(\mathbf{x}_{it,-jt} - \overline{\mathbf{x}}_{-jt})\boldsymbol{\delta} + \alpha_i + \eta_{it}$$

where the added parameter α_i represents a Country-specific effect accounting for unobserved heterogeneity. In particular, fixed-effect estimation, by assuming free correlation between α_i and η_{it}, can mitigate a potential endogeneity bias due to misspecification of previous equation and measurement errors in the variables considered in the model (Wooldridge, 2010, pp. 281-315). As such, a panel dataset allows for more reliable estimates of the true responsiveness scores than usual OLS.

Annex Table 2 Host county determinants of R&D internationalization: 2009-2013

	(1) Overall OLS	(2) EU15	(3) EU13	(4) EU28
Log of GDP	-0.068	-0.256***	0.490	-0.074
	(0.10)	(0.16)	(0.88)	(0.10)
ln_labor_cost_intensity	0.188***	0.232***	0.165	0.193***
	(0.19)	(0.35)	(1.05)	(0.20)
ln_GBAORD_perc_gdp	-0.171***	-0.131***	0.325	-0.172***
	(0.44)	(0.53)	(3.22)	(0.44)
ln_tgs	-0.025	-0.003	0.011	-0.040
	(0.23)	(0.27)	(0.84)	(0.25)
ln_pat_on_gdp	0.207***	0.176***	-0.402	0.214***
	(0.16)	(0.18)	(6.46)	(0.16)
ln_size_sett	0.599***	0.812***	0.269	0.612***
	(0.06)	(0.16)	(0.55)	(0.06)
ln_RD_DOMESTIC_on_valadd_dom	0.081*	0.012	-0.036	0.112**
	(0.06)	(0.07)	(0.10)	(0.06)
N	462	315	136	451
adj. R2	0.827	0.798	0.943	0.827
ll	-542.82	-387.77	-40.38	-528.94
F-test	104.61	60.04	1125.01	103.70
F_pvalue	0.0000	0.0000	0.0000	0.0000

Standardized beta coefficients; Standard errors in parentheses

Dependent variable: ln_INWARD_total.

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

Annex Table 3 Total factor responsiveness by sector

Table 2.5 Total factor responsiveness by sector

GDP	Labour Cost	GBAORD	Education	Patent	Sectoral size
Research and development	Services sector	Research and development	Coke, refined petroleum products and nuclear fuel	Coke, refined petroleum products and nuclear fuel	Research and developme
Chemicals [...]	Manufacturing	Wood and paper products [...]	Wood and paper products [...]	Computer, electronic and optical products	Computer and related activities
Other business activities	Computer and related activities	Textiles, apparel, leather	Mining [...]	Research and development	Other business activities
Coke, refined petroleum products and nuclear fuel	Wholesale, retail trade and motor vehicle repair	Rubber and plastic products	Food, beverages and tobacco	Other Transport Equipment	Services sector
Manufacturing	Research and development	Coke, refined petroleum products and nuclear fuel	Electricity, gas, water.	Pharma	Wholesale, retail trade a motor vehicle repair
Machinery and equipment,	Motor Vehicles, trailers and semi-trailers	Chemicals [...]	Transportation and storage	Chemicals [...]	Financial intermediation
Other Transport Equipment	Financial intermediation	Computer and related activities	Textiles, apparel, leather	Motor Vehicles, trailers and semi-trailers	Machinery and equipme
Computer, electronic and optical products	Construction	Other Transport Equipment	Basic metals [...]	Manufacturing	Textiles, apparel, leather
Motor Vehicles, trailers and semi-trailers	Computer, electronic and optical products	Machinery and equipment,	Motor Vehicles, trailers and semi-trailers	Machinery and equipment,	Rubber and plastic produ
Rubber and plastic products	Machinery and equipment,	Computer, electronic and optical products	Pharma	Rubber and plastic products	Manufacturing
Computer and related activities	Chemicals [...]	Motor Vehicles, trailers and semi-trailers	Construction	Computer and related activities	Other Transport Equipm
Pharma	Rubber and plastic products	Pharma	Computer, electronic and optical products	Textiles, apparel, leather	Pharma
Textiles, apparel, leather	Other Transport Equipment	Food, beverages and tobacco	Other Transport Equipment	Basic metals [...]	Construction
Services sector	Other business activities	Mining [...]	Rubber and plastic products	Wood and paper products [...]	Wood and paper produc
Wood and paper products [...]	Food, beverages and tobacco	Construction	Financial intermediation	Food, beverages and tobacco	Transportation and stora
Food, beverages and tobacco	Basic metals [...]	Other business activities	Wholesale, retail trade and motor vehicle repair	Transportation and storage	Chemicals [...]
Construction	Pharma	Manufacturing	**Manufacturing**	Mining [...]	Computer, electronic an optical products
Financial intermediation	Electricity, gas, water.	Services sector	**Chemicals [...]**	Services sector	Food, beverages and tob
Wholesale, retail trade and motor vehicle repair	Textiles, apparel, leather	Wholesale, retail trade and motor vehicle repair	**Services sector**	Other business activities	Motor Vehicles, trailers a semi-trailers
Basic metals [...]	Mining [...]	Financial intermediation	**Machinery and equipment,**	Construction	Basic metals [...]
Mining [...]	Wood and paper products [...]	**Basic metals [...]**	**Computer and related activities**	Electricity, gas, water.	Electricity, gas, water.
Electricity, gas, water.	Transportation and storage	**Electricity, gas, water.**	**Research and development**	Wholesale, retail trade and motor vehicle repair	Mining [...]

Annex Table 4 Model to analyse the effect of the crisis

In order to implement the analysis we used a structural break (or switching) regression model, where the coefficient of the interaction between the single driver and the crisis dummy - $(\beta_1 - \beta_0)$

represents the difference in the two regression slopes before and after the crisis.

The model is:

$$y_1 = \alpha_1 + \beta_1 x + \varepsilon_1 \quad post-crisis\ regression\ line$$

$$y_0 = \alpha_0 + \beta_0 x + \varepsilon_0 \quad pre-crisis\ regression\ line$$

$$y = y_0 + \Delta(y_1 - y_0)$$

$$Y = \alpha_0 + \beta_0 x + \varepsilon_0 + \Delta\alpha_1 + \Delta\beta_1 x + \Delta\varepsilon_1 - \Delta\alpha_0 - \Delta\beta_0 x - \Delta\varepsilon_0$$

$$Y = \alpha_0 + \beta_0 x + \Delta(\alpha_1 - \alpha_0) + (\beta_1 - \beta_0)\Delta x + \eta$$

$$Y = \mu + \gamma x + \delta\Delta + \zeta\Delta x + \eta$$

$$\begin{Bmatrix} \mu = \alpha_0 & \delta = (\alpha_1 - \alpha_0) \\ \gamma = \beta_0 & \zeta = (\beta_1 - \beta_0) \end{Bmatrix}$$

where:

Δ : *is the pre-post crisis binary dummy variable;*

$\alpha_1 - \alpha_0$*: is the difference of the intercept of the two equation lines;*

$\beta_1 - \beta_0$*: is the difference of the two regression slopes before and after the crisis.*

Annex Table 5 Results of the structural model (crisis analysis)

ln_INWARD_total	Coef,	Robust Std,	t	P>|t|	[95% Conf, Interval]	
GDP	0,024	0,005	4,45	0,000***	,01355	,0349
$\alpha_1 - \alpha_0$	-0,560	0,239	-2,35	0,019**	-1,121	-0,091
$\beta_1 - \beta_0$	0,008	0,005	1,49	0,137	-,0020	,0201
FDI	-0,062	0,149	-0,42	0,675	-,3570	,2313
$\alpha_1 - \alpha_0$	-3,458	8,210	-0,42	0,674	-1,960	1,268
$\beta_1 - \beta_0$	0,052	0,151	0,35	0,728	-,2457	,3513
GBAORD	0,060	0,010	5,6	0,000***	,0393	,0818
$\alpha_1 - \alpha_0$	0,433	0,604	0,72	0,473	-,7528	1,620
$\beta_1 - \beta_0$	-0,019	0,011	-1,78	0,076*	-,0410	,0020
LABOR COST	0,024	0,012	2,04	0,041*	,0009	,0484
$\alpha_1 - \alpha_0$	-1,184	0,552	-2,14	0,032	2,268	-0,100
$\beta_1 - \beta_0$	0,009	0,013	0,69	0,488	-,0177	,0371
std100_pat_on_gdp	0,023	0,015	1,49	0,137	-,0075	,0548
$\alpha_1 - \alpha_0$	-0,415	0,257	-1,61	0,107	-,9214	,089536
$\beta_1 - \beta_0$	-0,001	0,016	-0,07	0,941	-,0341	0,0316

Annex Table 6 Regression results for the dose-response model: labour productivity

Regression results for LABOUR PRODUCTIVITY

Overall sample

Linear regression — Number of obs = 162; R-squared = 0.9939; Root MSE = .11918

ln_prod	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
treat_1	-.2256146	.5651072	-0.40	0.690	-1.344983	.8937541
ln_gdp_1	-.4185089	1.768901	-0.24	0.813	-3.922362	3.085344
ln_labor_cost_intensity_1	-1.075772	.2526698	-4.26	0.000	-1.576262	-.5752816
ln_GBAORD_perc_gdp_1	.1336946	.1865819	0.72	0.475	-.2358883	.5032774
ln_tgs_1	-1.478966	1.173109	-1.26	0.210	-3.802669	.8447364
ln_size_sett_1	.6053447	.1393615	4.34	0.000	.3292965	.8813929

EU15

Linear regression — Number of obs = 323; R-squared = 0.9390; Root MSE = .16328

ln_prod	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	.5401808	.2626869	2.06	0.041	.0230397	1.057322
ln_gdp	-.7128804	.5038636	-1.41	0.158	-1.704816	.2790555
ln_labor_cost_intensity	-.9443575	.1206407	-7.83	0.000	-1.181858	-.7068571
ln_GBAORD_perc_gdp	-3.442675	.7089542	-4.86	0.000	-4.838364	-2.046985
ln_tgs	-.0322085	.1072875	-0.30	0.764	-.243421	.1790041
ln_size_sett	.0565201	.048738	1.16	0.247	-.0394284	.1524685

EU13

Linear regression — Number of obs = 262; R-squared = 0.9841; Root MSE = .25023

ln_prod	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	-.2526366	.0777898	-3.25	0.001	-.4059731	-.0993002
ln_gdp	-.3358262	.1994361	-1.68	0.094	-.7289474	.0572951
ln_labor_cost_intensity	.1876919	.2032484	0.92	0.357	-.212944	.5883278
ln_GBAORD_perc_gdp	-.1297175	.2546195	-0.51	0.611	-.6316143	.3721792
ln_tgs	-.7673956	.295238	-2.60	0.010	-1.349358	-.185433

```
  ln_size_sett |   .7566496   .0558486    13.55   0.000     .6465629    .8667364
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Annex Table 7 Regression results for the dose-response model: patenting

Regression results for RESIDENT PATENTS

Overall sample

Linear regression — Number of obs = 143; R-squared = 0.9753; Root MSE = .02966

ln_pat_on_gdp	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
treat_1	.1785487	.0510114	3.50	0.001	.0773183	.2797792
ln_gdp_1	-1.113471	.2230178	-4.99	0.000	-1.556042	-.6708993
ln_labor_cost_intensity_1	.0091582	.0329216	0.28	0.781	-.0561737	.07449
ln_GBAORD_perc_gdp_1	1.665377	.0989741	16.83	0.000	1.468967	1.861788
ln_tgs_1	-.0407023	.0852927	-0.48	0.634	-.2099628	.1285583

EU15

Linear regression — Number of obs = 392; R-squared = 0.6187; Root MSE = .56034

ln_pat_on_gdp	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	1.801667	.7712959	2.34	0.020	.2845861	3.318748
ln_gdp	-3.188801	1.168583	-2.73	0.007	-5.487316	-.8902867
ln_labor_cost_intensity	.7114453	.3090117	2.30	0.022	.1036425	1.319248
ln_GBAORD_perc_gdp	-7.202956	1.83336	-3.93	0.000	-10.80904	-3.596876
ln_tgs	.6927424	.3655974	1.89	0.059	-.0263602	1.411845
ln_size_sett	.4068914	.1260412	3.23	0.001	.1589779	.6548049

EU13

Linear regression — Number of obs = 183; R-squared = 0.9445; Root MSE = .09609

ln_pat_on_gdp	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	.0050622	.0325643	0.16	0.877	-.0593443	.0694688
ln_gdp	.1167835	.1529883	0.76	0.447	-.1858007	.4193677

ln_labor_cost_intensity	-.247576	.1317033	-1.88	0.062	-.5080623	.0129103
ln_GBAORD_perc_gdp	.6307802	.3336864	1.89	0.061	-.0291933	1.290754
ln_tgs	.1024356	.1561986	0.66	0.513	-.206498	.4113693
ln_size_sett	.056472	.0558137	1.01	0.313	-.0539178	.1668617

Annex Table 8 Regression results for the dose-response model:domestic BERD

Regression results for DOMESTIC BERD

Overall sample

Linear regression — Number of obs = 696; R-squared = 0.4680; Root MSE = 1.5021

RD_DOMESTIC_su_valadd_dom	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	.5865248	.2704547	2.17	0.030	.0554483	1.117601
ln_gdp	-.2174098	.3227065	-0.67	0.501	-.8510902	.4162707
ln_labor_cost_intensity	.290881	.2439046	1.19	0.233	-.1880605	.7698226
ln_GBAORD_perc_gdp	.5428749	.5594192	0.97	0.332	-.5556247	1.641375
ln_tgs	-.320406	.2809646	-1.14	0.255	-.8721201	.2313081
ln_size_sett	.0440292	.0738257	0.60	0.551	-.1009381	.1889964

EU15

Linear regression — Number of obs = 36; R-squared = 0.6210; Root MSE = 1.552

RD_DOMESTIC_su_valadd_dom	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	.9933633	.3976866	2.50	0.013	.2109435	1.775783
ln_gdp	-1.346537	.5767735	-2.33	0.020	-2.481297	-.211776
ln_labor_cost_intensity	.0521642	.3579522	0.15	0.884	-.6520811	.7564095
ln_GBAORD_perc_gdp	-.5810922	1.10804	-0.52	0.600	-2.761082	1.598897
ln_tgs	-.6201945	.3494463	-1.77	0.077	-1.307705	.0673161
ln_size_sett	.5153452	.295109	1.75	0.082	-.0652605	1.095951

EU13

Linear regression — Number of obs = 312; R-squared = 0.4230; Root MSE = 1.183

RD_DOMESTIC_su_valadd_dom	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
w	1.798813	1.168638	1.54	0.125	-.5023049	4.09993
ln_gdp	-.4598733	1.196083	-0.38	0.701	-2.815033	1.895286

ln_labor_cost_intensity	.5310236	.5639691	0.94	0.347	-.5794651	1.641512
ln_GBAORD_perc_gdp	.6841183	.5847448	1.17	0.243	-.467279	1.835516
ln_tgs	-.490555	.9582435	-0.51	0.609	-2.377394	1.396284
ln_size_sett	.0962837	.2737651	0.35	0.725	-.4427761	.6353435

Annex Table 9 Tax instruments, definition and countries, where the policy is implemented

	Definition	Countries
Tax credits	Tax credit decreases the corporate income tax rate a firm has to pay. Rate can be applied to corporate tax, payroll tax paid for R&D workers or personal income .	AT; BE; BG; CA; ZA; DK; FR; IE; IL; IT; JP; MT; NL;NO;PL; PT; SK; ES; SE; UK; US
Enhanced allowances	An enhanced allowance effectively decreases the base amount that is taxed by allowing to 'inflate' the R&D expenditure base.	HR;CY;CZ;DK; FI;EL; HU; IL; JP; LT; LV; NL;PL;RO; SI; UK
Accelerated depreciation	Accelerated depreciation scheme permits to depreciate the purchased fixed assets at higher rates in the first years of the asset's life.	BE; BG; CA; DK;FI;IL; IT; JPLT;RO; SI; UK; US
Reduced corporate tax rate (IP income)	Reduced corporate tax rate on intellectual property income ("Patent Box") are an outcome related incentive. It reduces the corporate income that firms pay on commercialization of innovative products that are protected by intellectual property (IP) rights.	BE; CY;FR; EL; HU;LU; MT; NL; PL; ES; UK

Source: OECD http://www.oecd.org/sti/rd-tax-stats.htm

Annex Table 10 . R&D tax incentives, estimation methodology

Australia: Estimates, on an accrual basis, refer to the R&D tax concession and R&D Tax Incentive, as published in the Taxation Expenditures Statement. The R&D Tax Incentive provides a refundable tax offset for eligible entities with an aggregated turnover of less than AUD 20 million, unless controlled by tax exempt entities, and a non-refundable tax offset for all other eligible entities. The Research and Development (R&D) Tax Concession was replaced by the R&D Tax Incentive for income years beginning on or after 1 July 2011. The key elements of the R&D Tax Concession were: (1) a 125% Tax Concession (for investment in R&D which is 'Australian-owned') introduced in 1986; (2) an R&D Tax Offset for small companies, enabling them to cash out any tax losses (in relation to Australian-owned R&D only) introduced in 1986; (3) an R&D incremental (175% Premium) Tax Concession for additional investment in Australian-owned R&D (available as of 1 July 2001); and (4) a 175% International Premium incremental tax concession for additional investment in 'foreign-owned' R&D (available as of 1 July 2007). Break in BERD data series in 2001 and 2006.
Canada: Estimates, on a cash basis, refer to the scientific research and experimental development tax credit for current and capital R&D expenditures, as published in the Tax Expenditures and Evaluations reports. They do not reflect the cost of provincial governments' R&D tax incentives provided by many Canadian provinces in order to ensure the comparability of R&D tax incentive estimates across countries. Estimates for the cost of accelerated depreciation provisions are not available.
France: Estimates, on an accrual basis, refer to the crédit d'impôt recherche (CIR) and special provisions for social security contributions by young and innovative firms (JEIs) and young university enterprises (JEUs), but exclude the cost of accelerated depreciation incentives for capital R&D. The JEI and JEU status were established in 2004 and 2008 respectively. Since 1 January 2008, the CIR - previously hybrid - has been calculated solely on the volume of R&D expenditures, with no ceiling. An enhanced tax credit rate of 35% was initially applicable up to an R&D expenditure ceiling of EUR 16 million, which was increased to EUR 100 million in 2008. As a temporary measure, an immediate refund of all unused credit was offered to all firms (instead of 3 years waiting period) in 2009. Break in BERD data series in 2004. The estimate of direct funding for 2013 is based on imputing the share of direct government-funded BERD in the previous year to the current ratio of BERD to GDP.
Japan: Estimates, on a cash and final revenue loss basis, cover the system of volume-based and incremental R&D tax credits in Japan. The volume-based R&D tax credit is currently available in addition to either an incremental-based R&D tax credit or high R&D intensity-based tax credit. Prior to fiscal year 2003, only an incremental-based R&D tax credit had been available which was complemented by a volume-based R&D tax credit in 2003, only one of which could then be selected by firms. In 2006, the R&D tax incentive system in Japan was altered and an incremental tax credit became available as an additional measure aside the volume-based R&D tax credit. In 2008, the incremental component of R&D tax relief system was further modified to introduce on a temporary basis (until March 2017) a high R&D intensity-based tax credit as alternative option to the incremental R&D tax credit.
Korea: The R&D tax credit has a volume and incremental component only the larger one of which applies; a volume-based R&D tax credit is further available for high-growth firms with original technology. The Growth Industry and Basic Technology tax credit is set to expire in 2015. Korea additionally offers an R&D investment credit for developing new R&D facilities. No further details available on cost estimates.

Netherlands: Estimates, on a cash basis, refer to the WBSO payroll tax credit for R&D labour. The estimates for 2012 and 2013 further reflect the value of the R&D tax allowance (RDA) for non-labour related R&D expenditures which was introduced in January 2012. In 2005, the scope of the R&D definition applicable under WBSO was broadened. In 2009, the WBSO tax credit rate for SMEs and large firms was increased from 42% for the first EUR 110,000 (14% above this threshold) to 50% (64% for start-ups) for the first EUR 150,000 of the R&D wage bill (18% above this threshold). The R&D wage expenditure threshold was further increased to EUR 220,000 in 2010. Break in BERD data series in 2011.
United Kingdom: Estimates, on an accrual basis, refer to the Research & Development Relief for Corporation Tax. The estimate for fiscal year 2013 further refers to the Research and Development Expenditure Credit (RDEC) Scheme for large companies, introduced for expenditure incurred on or after 1 April 2013. Estimates for the cost of accelerated depreciation provisions are not available. R&D tax credits were first introduced for SMEs in 2000 and extended to large companies from 2002. In July 2008, the deduction rates applicable under the Research & Development Relief for Corporation Tax were increased from 150% to 175% for SMEs and from 125% to 130% for large companies. The SME rates were subsequently increased to 200% in 2011 and to 225% in 2012. As of 2008, an enlarged definition of SMEs (from 250 employees and GBR 50M of turnover to 500 employees and GBR 100M of turnover) has also been applicable for tax purposes. For accounting periods ending on or after 1 April 2012, the R&D expenditure threshold of GBP 10,000 per year ceased to apply and the total amount of tax support per R&D project has been capped at EUR 7.5 million.
United States: Estimates refer to the federal research and experimentation tax credit (only corporations), based on SOI corporate tax return data. For international comparability, the cost of allowing for the expensing of research and experimentation expenditures is not included. The federal research credit is a temporary provision. It expired at the end of 2013 and was retrospectively extended from January 1 through December 31 2014 (Tax Increase Prevention Act of 2014).The research credit has four components: the regular research credit (RRC), an alternative simplified research credit (ASC), a credit for certain energy research and a credit for basic research. From 1997 through 2008, companies had the option of claiming an alternative incremental research credit (AIRC) instead of the regular research credit. Under current law, companies have the option of claiming the ASC rather than the regular credit the former of which was first made available for taxable years beginning after December 31, 2006.

Source: OECD, R&D Tax Incentive Indicators, www.oecd.org/sti/rd-tax-stats.htm and Main Science and Technology indicators

Chapter 6

Annex Table 11: Availability of inward BERD data for the non-EU-countries

Country	**Breakdowns**

	Sector	*Country of Origin*
Turkey	1998-2000, 2002	1998-2000, 2002
Montenegro	No	No
FYROM	No	No
Serbia	No	No
Switzerland	2012	No
Iceland	No	No
Liechtenstein	No	No
Norway	2005-2007, 2009, 2011, 2013	2007, 2009, 2011, 2013
China		No
India	Not in line with methodology (2006-2010)	No
South Korea	No	No
Japan	1998-2012	1998-2007
United States of America	1998-2013	1998-2013
Canada	1998-2013	1998-2004 (2005-2013 only US vs. non-US)
Brazil	Not in line with methodology (2008 and 2011)	No
Israel	2007-2011	2010-2011
Russian Federation	No	No

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

Annex Table 12: Availability of outward BERD data for the EU-countries

Country	**Breakdowns**	
	Sector	*Destination country*
Belgium	No	No
Bulgaria	No	No
Czech Republic	No	No
Denmark	No	No
Germany	1999, 2001, 2003, 2005, 2007, 2009, 2011	No
Estonia	No	No
Greece	No	No
Spain	No	No
France	No	No
Croatia	No	No
Ireland	No	No
Italy	No	Yes (only 2003)
Cyprus	No	No
Latvia	No	No
Lithuania	No	No
Luxembourg	No	No
Hungary	No	No
Malta	No	No
Netherlands	No	No
Austria	No	No
Poland	No	No
Portugal	No	No

Romania	No	No
Slovenia	No	No
Slovakia	No	No
Finland	No	No
Sweden	No	1999, 2001, 2003, 2005, 2007
United Kingdom	No	No

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

Annex Table 13: Availability of outward BERD data for the non-EU-countries

Country	**Breakdowns**	
	Sector	*Destination country*
Turkey	No	No
Montenegro	No	No
FYROM	No	No
Turkey	No	No
Switzerland	2000, 2004, 2008 and 2012	No
Iceland	No	No
Liechtenstein	No	No
Norway	No	No
China	No	No
India	No	No
South Korea	No	No
Japan	1999-2013	1999-2007
United States of America	1998-2013	1998-2013
Canada	No	No
Brazil	No	No
Israel	2007-2011	2007, 2009, 2011
Russian Federation	No	No

Source: OECD, ESTAT and national statistical offices (see data quality report for details)

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This report presents and analyses the internationalization of business R&D investments in Europe in light of earlier work. Using established metrics, a composite approach is employed to better understand the distribution and development of this important phenomena over time. Core and secondary data-sources are used to analyse the developments in the context of 35 countries and of 7 sectors. Moreover, the report applies a set of innovative methods to analyse factors that motivate cross-country R&D investments and their effects on host countries. In light of European policy priorities, the report aims to improve the evidence base for R&I policy making. It discusses policy conclusions, including ways to improve the quality of international R&D expenditure data.

Foreign-owned firms are among the most active performers of research and development (R&D) in a number of European countries. Results indicate that the internationalisation of R&D predominantly takes place between high-income countries in the US and Europe. R&D is much less globalized than trade or FDI. While patterns differ between industries, there are clear indications of the rising importance of the service sector. Europe remains the largest host region for R&D of US firms abroad, while the importance of Asian countries is growing slowly. Econometric evidence suggests that R&D of foreign-owned firms is positively related to domestic R&D and to labour productivity in the manufacturing sector. In such cases, R&D by foreign-owned firms can be said to help to scale up national innovation systems and to increase R&D expenditure in several European countries.

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