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Internationalisation of business investments in R&D and analysis of their economic impact

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1. INTRODUCTION

In a seminal paper on research and development (R&D) in large multinational enterprises, Pari Patel and Keith Pavitt concluded in 1991 that the production of technology remains "far from globalized", but concentrated in the home countries of the enterprises (Patel and Pavitt 1991, p. 17). In their words, research and development is "an important case of non-globalisation".

20 years later, a vast amount of evidence draws a different picture of R&D internationalisation: Enterprises not only produce and sell, but increasingly also develop goods and services outside their home countries. Today, it seems to be the rule, not the exception, that large European firms have R&D activities at different locations inside and outside the Single Market. In addition, firms from the United States and other non-European countries have considerably extended their R&D activities in the European Union, and new players from emerging economies are entering the scene: India, the People's Republic of China (referred to as China in the report), and other locations have come into focus as host countries for the R&D activities of European multinational enterprises (MNEs) in recent years.

These developments form the background of the project "Internationalisation of business investments in R&D and analysis of their economic impact". More specifically, the project pursues the following aims:

- Collect data on R&D expenditures by foreign-owned firms;
- Identify the most pressing needs for new data on R&D expenditure of foreign-owned firms;
- Describe and analyse business R&D internationalisation at the national level, the sectoral level and in a cross-country perspective;
- Analyse the drivers and impacts of the internationalisation of R&D on home and host countries.

This report summarizes the outcomes of the project. It starts with a survey of the literature on business R&D internationalisation in chapter two. Chapter three describes how we collected data, points to various challenges and pitfalls in the interpretation of this data and discusses the most pressing data needs.

Chapter four investigates the current status and future directions of R&D internationalisation, identifies the countries and sectors where the share of foreign-owned firms on R&D expenditure is particularly high, looks at R&D expenditure of domestic firms abroad, and at the relations between the United States and the European Union in the internationalisation of R&D. The chapter finishes with a view on new players from emerging economies. Chapter five looks at R&D activities of non-European companies in the European Research Area. Chapter six analyses the structure of R&D internationalisation from a network perspective. The potential drivers of R&D internationalisation are studied in chapter seven whereas Chapter eight looks at the impacts of R&D of foreign-owned firms on domestic R&D performance and other economic indicators. Chapter seven and eight apply econometric methods as well as provide evidence from case studies. Finally, chapter nine summarizes key messages from the study and draws conclusions.

2. LITERATURE SURVEY

This section summarizes the key findings of the literature on the internationalisation of R&D focussing on three issues: first, it reviews the drivers of the process - why firms go abroad with R&D activities. Second, we discuss recent findings on the effects of the internationalisation of R&D on the host countries. Finally, it analyses the impacts of R&D internationalisation on the home countries of the firms.

This survey has two important limitations: first we will not include the literature on the internationalisation of R&D at universities or public research centres. Second, the literature on foreign direct investment (FDI) and multinational enterprises is only covered if it is related to R&D. Internationalisation refers to the internationalisation of business R&D through the remainder of this chapter, unless otherwise stated.

The oldest literature on the internationalisation of R&D dates back to the end of the 1960s and the beginning of the 1970s (e. g. Dunning 1958; Brash 1966; Safarian 1966). Only few articles and surveys emerged in the 1970s (e. g. Creamer 1976; Ronstadt 1977; Lall 1979) and in the 1980s (Behrman and Fischer 1980). Since the early 1990s a growing body of empirical literature provides empirical evidence that the internationalisation of R&D is gaining momentum (e. g. OECD 2005a; UNCTAD 2005; Hatzichronoglou 2008; OECD 2008a; OECD 2008b; OECD 2008c; OECD 2010). This literature has been accompanied by contributions studying the motives and strategies of firms, among them Cantwell (1989), Pearce (1989, 1992), or Bartlett and Ghoshal (1990).

2.1. Drivers of R&D internationalisation

The internationalisation of R&D is the product of a number of actors at different levels. The most important actors are firms which, for a variety of reasons, decide to do R&D at locations abroad. The benefits and costs associated with the internationalisation of R&D vary between firms, industries, regions or countries. It is therefore important to distinguish between these three levels. We will start with a discussion of the drivers at the regional and country level and then go to the sectoral and firm level.

The host country or the region shapes the internationalisation decisions of firms by providing different framework conditions for R&D. Drivers at the regional or country level are also important from a policy perspective, because they give room for policy intervention to increase the locational advantages of regions or countries.

A first important regional or country level driver is income and market size. Empirical evidence indicates that the internationalisation of R&D predominantly takes place between high-income countries. Income is an important driver for various reasons; first, high income and high income growth attracts FDI (Ekholm and Midelfart 2004; Blonigen 2005; Jensen 2006). R&D investments often follow FDI, and overseas R&D activities are, in most cases, an extension of existing overseas production and marketing activities (Birkinshaw and Hood 1998; Birkinshaw et al. 1998; Archibugi and Iammarino 1999). Moreover, firms may find it easier to cover the cost of R&D in a country with a large market where they expect larger absolute revenues than in a country with a small domestic market, even if wages are considerably lower.

Another important attractor of foreign R&D is a skilled workforce and the quality of education systems (Thursby and Thursby 2006; Kinkel and Maloca 2008; European Commission 2010). Skills shortage and a growing demand for engineers and scientists in the home country is often a motive for firms to go abroad with R&D. Ernst (2006), for example, relates the success of India and other Asian countries in attracting foreign R&D to their expanding pool of graduates in science and technology. Hedge and Hicks (2008) demonstrate that the innovation activities of overseas US subsidiaries are strongly related to the scientific and engineering capabilities of the host countries. In the research of Lewin et al. (2009), an emerging shortage of high skilled science and engineering talent partially explains the relocation of product development from the United States to other parts of the world, most notably Asian countries. Kinkel and Maloca (2008) find that capacity bottlenecks are the most frequent reason why German firms move R&D to locations abroad.

Closely related to the quality of the education system are also knowledge spillovers between foreign-owned firms and host country organisations (see section 2.2 for a detailed discussion). The search by foreign-owned firms for such spillovers is known as the asset-seeking motive (Dunning and Narula 1995), home-base augmenting strategy (Kuemmerle 1999), or global R&D strategy (von Zedtwitz and Gassmann 2002) in the literature. 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; Dachs and Pyka 2010).

Knowledge spillovers may be even more relevant at the regional than at the country level, because spillovers diminish with distance between sender and receiver (Jaffe et al. 1993; Breschi and Lissoni 2001). As a consequence, firms which want to utilize such localized knowledge spillovers have to be present where they occur, and innovative activity tends to cluster locally in industries with a high level of spillovers (Audretsch and Feldman 1996). This effect is related to institutional or technological conditions, such as tacitness of the knowledge base, but also to the existence of specialized local or regional labour markets (see the survey of Breschi and Lissoni 2001).

Differences in labour cost between the home country and locations abroad are one of the most important motives for the internationalisation of production. Empirical evidence that differences in the cost of R&D personnel are a major driver for the internationalisation of R&D, however, is weak; survey results as well as econometric studies see only a modest influence of cost advantages on R&D location decisions compared to other factors (Booz Allen Hamilton and INSEAD 2006; Thursby and Thursby 2006; Kinkel and Maloca 2008; Belderbos et al. 2009; European Commission 2010). However, cost differences may gain importance when firms consider to locate R&D and innovation activities in emerging economies, or when firms have to choose between two similar attractive locations (Booz Allen Hamilton and INSEAD 2006; Thursby and Thursby 2006; Cincera et al. 2009).

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; Dachs and Pyka 2010). This distance effect is often explained by additional co-ordination cost, the cost of transferring knowledge over distance, and a loss of economies of scale and scope when R&D becomes more decentralized (von Zedtwitz and Gassmann 2002; Gersbach and Schmutzler 2006; Sanna-Randaccio and Veugelers 2007). In addition, the distance effect may also be explained by cultural, social and institutional factors. The international management literature stresses that foreign firms have to master additional institutional and cultural barriers in their host countries. This disadvantage is known as the 'liability of foreignness' (Zaheer 1995; Eden and Miller 2004) or the 'liability of outsidership' (Johanson and Vahlne 2009) in the literature. It may include a lack of market knowledge and understanding of customer demands, but also a lower degree of embeddedness in informal networks in the host country. Disadvantages from the liability of foreignness tend to decrease over time, but may even exist in long-established affiliates with a local management and staff, because the subsidiary is still embedded in intra-firm networks and have to stick to the rules, norms and standards of the multinational group.

Finally, public policy can considerably shape the attractiveness of regions or countries for overseas R&D activities. Recent surveys of policy measures in the field of R&D internationalisation include Dachs et al. (2005), UNCTAD (2005), CREST (2007), OECD (2008a), TAFTIE (2009), Verbeek et al. (2009) and Schwaag Serger and Wise (2010).

There is a consensus in this literature that governments that want to attract R&D of foreign multinational firms should focus on the economic fundamentals rather than grant special incentives to foreign-owned firms. Governments should provide a healthy business environment, political stability, good public infrastructure, reasonable tax rates, and a stable legal system including the protection of intellectual property rights. This opinion is based on empirical studies on the location decisions of MNE R&D activities (Cantwell and Mudambi 2000; Kumar 2001; Cantwell and Piscitello 2002; Thursby and Thursby 2006; Kinkel and Maloca 2008; European Commission 2010), but also on the political practice in Europe, which is characterized by non-discrimination of foreign-owned firms (Dachs et al. 2005; Guimón 2009).

In addition, science, technology and innovation (STI) policy measures can significantly shape locational advantages and influence internationalisation decisions of firms in R&D. This includes all measures to stimulate the creation, diffusion and utilisation of new knowledge and technologies (Steinmueller 2010). Examples of such measures are public subsidies for R&D performing firms or measures to foster co-operation between firms and universities. Science policy also includes university education - the availability of skilled researchers is one of the most important location criteria for R&D.

There is a consensus in the literature that special incentives to foreign-owned firms are not an appropriate instrument to attract R&D of foreign-owned firms. This consensus is based on empirical studies on the location decisions of R&D activities of MNEs (Cantwell and Mudambi 2000; Kumar 2001; Cantwell and Piscitello 2002; Thursby and Thursby 2006; Kinkel and Maloca 2008; European Commission 2010), but also on the political practice in Europe, which is characterized by non-discrimination of foreign-owned firms (Guimón 2009). However, it is also clear from the literature that public support for R&D, including tax incentives, can create important additionalities and can help leverage R&D efforts of firms, including foreign-owned firms. Hence, public support may not be appropriate to attract R&D or foreign-owned firms but helps to further augment R&D expenditure of foreign-owned firms already located in a host country.

A second important level for the analysis of drivers is the industrial sector of the firm. The industry matters in two ways: on the one hand, 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 (Markusen 1995, p. 172). Hence, R&D internationalisation can mainly be observed in R&D or knowledge-intensive sectors.

On the other hand, R&D processes differ considerably across sectors. Firms in the same industry operate with a (mostly) similar knowledge base and have to solve similar problems in the innovation process. These intersectoral differences shape innovation behaviour of firms to a considerable degree, resulting in vast differences between sectors in many R&D and innovation indicators (Marsili 2001; Malerba 2005; Castellacci 2007, Peneder 2010). We may assume that the same factors also alter decisions to locate R&D

abroad, leading to different degrees of internationalisation at the sectoral level.

A first important determinant at the industry level is the degree of tacitness of the knowledge base of a sector. Tacitness results from the fact that cognitive capabilities and abstract concepts are not easy to articulate explicitly and to transfer between people (Cowan et al. 2000). A knowledge base which is highly tacit and bound to individuals may be an obstacle to internationalisation, because it makes knowledge exchange over distance costly. Tacitness, however, may also be a driver for internationalisation, because firms have to move to the place where this knowledge is available when it cannot be transferred over distance.

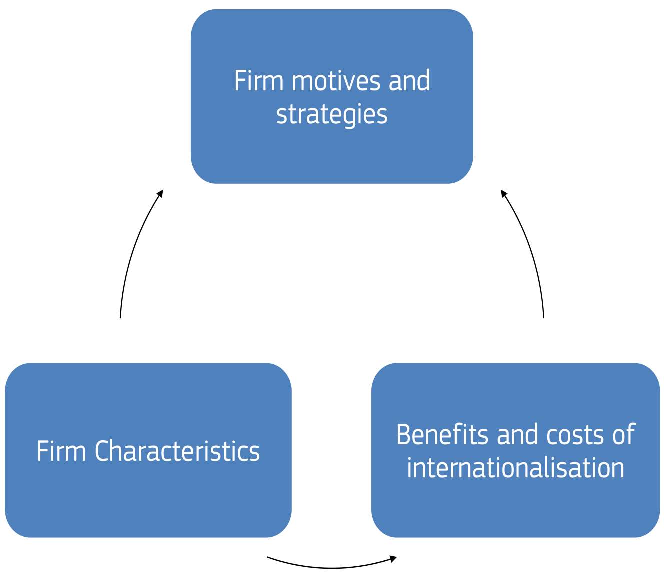
Second, sectoral knowledge bases also differ in their degree of cumulativeness, or, in other words, in the degree future innovation success depends on the knowledge which has been built up in the past (Marsili 2001). Cumulativeness is high in chemicals, pharmaceuticals, telecommunications and electronics, and low in mechanical engineering, food, clothing, or civil engineering (Malerba and Orsenigo 1996; Marsili 2001). A high degree of cumulativeness may require a high degree of specialisation in R&D, which gives advantages to centralized R&D. Cumulativeness may 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. Moreover, cumulativeness of the knowledge base may also imply that R&D activities require a certain minimum scale in order to be successful.

Third, sectors also differ in terms of appropriability, the degree to which an innovation can be protected from imitation (Cohen et al. 2000; Cohen 2010). Firms in sectors with a low degree of appropriability, like many service sectors, may be reluctant to internationalize R&D because they have only weak means to prevent involuntary knowledge spillovers.

Forth, another potential source for inter-sectoral differences is the firm's network of external relations with suppliers, clients, universities, public authorities etc (Marsili 2001; Malerba 2002). Some industries, such as biotechnology or pharmaceuticals, have strong linkages to basic science. Firms in these industries may find it useful to locate R&D close to excellent research universities. Firms in other sectors, such as the automotive of the electronics industry, are closely connected to suppliers and customers through international production networks. Suppliers in these sectors may be forced to internationalise their R&D to have development capabilities in proximity to key clients. The existence of lead users or other potential co-operation partners may also pose a strong incentive to locate R&D in a particular country.

Finally, the firm level is decisive for the explanation of overall patterns of R&D internationalisation. Internationalisation paths of two firms can be completely different - even if they are located in the same country and region and operate in the same industry - because firms differ in their capabilities, characteristics, organisation and strategies. The interplay of firm characteristics, firm motives and strategies and the benefits and costs that arise from internationalisation, together with framework conditions from the country, egional and sectoral level, determines the degree of R&D internationalisation of firms (see Figure 1 below).

Figure 1: Determinants of R&D internationalisation at the firm level



Source: own illustration

Decisions on exports and FDI and R&D strategies of firms are mutually connected. Joseph Schumpeter (1911) already regarded the opening of new markets as a type of innovation, together with product, process, organisational innovation and the conquest for a new source of supply. All come from the same source: entrepreneurship.

More recent contributions give evidence that R&D and innovation intensity is positively related to FDI and exports. Theoretical as well as empirical research argues that firm heterogeneity leads to self-selection in the internationalisation strategies of firms (Head and Ries 2003; Helpman et al. 2004; Helpman 2006). Only the most productive firms expand their operations via FDI, while less productive firms choose to export or serve only domestic markets. FDI (and hence MNEs) exists because firms possess superior, firm-specific assets and exploit these assets at foreign markets via their subsidiaries (Dunning 1973; Markusen 1995; Caves 1996 (1974); Markusen 2002). Dunning (1973; 1981) suggests that firms exploit these assets via FDI and not via exports or licensing because of ownership, location and internalisation advantages associated with this mode of exploitation.

In addition, there is also evidence for a positive relationship between innovation and exports at the firm level (Greenhalgh and Taylor 1990; Lachenmaier and Wößmann 2006; Harris and Li 2009). Export experience or experience with production in foreign markets is an important pre-requisite for the internationalisation of R&D. The internationalisation of R&D follows the internationalisation of other economic activity, in particular production and sales; overseas R&D is in most cases an extension of existing overseas production and marketing activities (Birkinshaw and Hood 1998; Birkinshaw et al. 1998; Archibugi and Iammarino 1999).

We can therefore assume that there is a mutual relationship between R&D and international activities. This relationship also affects the internationalisation of R&D. Firm characteristics that drive internationalisation are also positively related to the propensity to do R&D and R&D intensity. Empirical analysis (Dogson and Rothwell 1994; Cohen 1995; Kleinknecht and Mohnen 2002; OECD 2009a; Cerrato 2009) has examined the determinants of R&D and innovation in detail, so we will only give a very short overview of this literature.

R&D and R&D intensity is, at first, associated with firm size. There are different advantages and disadvantages of small and large firms in the innovation process, leading to a U-shaped relationship between size and R&D (Kleinknecht 1989; Cohen 1995). Regression analysis also finds a significant and positive association between firm size and the internationalisation of R&D or innovation activities (Arvanitis and Hollenstein 2006; Kinkel and Maloca 2008; Schmiele 2009). Innovativeness and R&D is also positively related to the internal knowledge and capabilities of the firm (Cohen and Levinthal 1989; Cohen and Levinthal 1990; Teece et al. 1997; Verona 1999). These capabilities enable the firm to create new knowledge, but also absorb knowledge from external sources.

Besides firm characteristics, there is also a considerable influence of firm strategy and managerial intentionality on the internationalisation R&D. It is not enough that firms operate in sectors with a high degree of internationalisation; the head office of the MNE has to allow a higher degree of decentralisation by changing firm organisation and giving a higher degree of autonomy to the subsidiaries (Birkinshaw and Hood 1998; Birkinshaw et al. 1998; Zanfei 2000).

This decision may be influenced by the costs of a decentralized organisation of R&D (Gersbach and Schmutzler 2006; Sanna-Randaccio and Veugelers 2007). These costs first comprise the foregone benefits of R&D centralisation, including economies of scale and scope from specialisation, or a tighter control over core technologies of the firm. Second, additional costs also arise from higher co-ordination efforts and the cost of transferring knowledge within the MNE. Proximity also facilitates co-ordination of R&D and innovation activities with other parts of the firm, such as production and marketing (Ketokivi and Ali-Yrkkö 2009). Third, a concentration of R&D activity in the home country is also favoured by various linkages between the firm and the host country innovation system. Patel and Pavitt (1999) or Narula (2002) point out that firms are strongly embedded in and dependent on their embeddedness in the home country innovation system. The ties that bind firms to their home country include relations with external actors such as formal R&D co-operations with domestic universities, but also informal networks that grew from doing business together in the past. Informal networks between firms may also evolve from joint training of staff at universities and labour mobility. Removing these linkages by moving R&D abroad would incur considerable costs on the firms, because they would need to re-install similar linkages with host country organisations.

The costs of R&D internationalisation have to be seen alongside the benefits of R&D internationalisation. A fist benefit is that R&D can support overseas production. Products and technologies often have to be adapted to consumer preferences, regulation, or environmental conditions of foreign markets in order to facilitate their exploitation in these markets. These adaptations can be done more easily in proximity to potential clients in the host countries. MNEs therefore locate design, engineering and R&D units in main foreign markets to support marketing and production facilities abroad. There are various names for this motive in the literature, including asset-exploiting behaviour (Dunning and Narula 1995), competence-exploiting subsidiary mandates (Cantwell and Mudambi 2005), home-base exploiting strategies (Kuemmerle 1999), or market-driven internationalisation of R&D (von Zedtwitz and Gassmann 2002).

A second benefit and important driver of R&D internationalisation at the firm level is access to knowledge and the creation of new knowledge abroad. This is known as the asset-seeking motive (Dunning and Narula 1995), competence-creating subsidiary mandate (Cantwell and Mudambi 2005), home-base augmenting strategy (Kuemmerle 1999), or global R&D strategy (von Zedtwitz and Gassmann 2002) in the literature.

Asset-seeking strategies are driven, on the one hand, by the existence of superior local knowledge and favourable framework conditions for R&D in various host countries. Some types of knowledge are tacit, bound to their local context, and transferable over distance only at high costs (Cowan et al. 2000; Breschi and Lissoni 2001). This knowledge may be found at universities and other research organisations, in clusters, or be available from clients, suppliers or competitors. Various authors describe foreign-owned subsidiaries as 'surveillance outposts' or 'antennas' (Florida 1997; Almeida 1999) that extensively monitor and assimilate knowledge from local sources.

On the other hand, asset-seeking strategies may also be driven by factors related to the nature of various technologies and changing firm strategies. Narula and Zanfei (2005) for example, suggest that the increasing complexity of products is a driver of the internationalisation of R&D. Rising technological complexity increases the knowledge requirements of firms and forces them to search for new knowledge abroad. A similar argument is brought forward by Chesbrough (2003a; 2003b). He points out that many innovative firms have shifted to an 'open innovation' model where they exploit ideas and knowledge not only provided by internal R&D, but also from a broad range of external sources and actors. In this respect, asset-seeking can be seen as a variant of 'open innovation' strategies with a focus on their geographical dimension.

There is evidence that asset-seeking strategies have become more frequent in the recent years, although asset-exploiting strategies still prevail (Narula and Zanfei 2005; Sachwald 2008). Moreover, some authors (for example Criscuolo et al. 2005) stress the fact that the two motives cannot be separated in a number of cases. Firms – intentionally or unintentionally - often follow both strategies simultaneously. Microsoft's efforts to adapt their products to the Chinese language resulted in new knowledge that could also be used in other contexts (Gassmann and Han 2004).

2.2. Impacts of foreign-owned R&D and innovation activities on host countries

The technological and economic characteristics of countries provide different locational advantages and disadvantages for foreign-owned firms to set up R&D activities. In turn, the R&D activities of foreign-owned firms 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 (see Table 1).

Table 1: Potential opportunities and challenges for national innovation systems from the internationalisation of R&D and innovation

	Opportunities	Challenges & Risks
Host country	• Increases in aggregate R&D and innovation expenditure • Knowledge diffusion to the host economy • Demand for skilled personnel • Structural change and agglomeration effects	• Loss of control over domestic innovation capacity and commercialisation • Less strategic research, less radical innovations, more adapting • Separation of R&D and production • Competition with domestically owned firms for resources ('Crowding out')
Home Country	• Improved overall R&D efficiency • Reverse technology transfer • Market expansion effects • Exploitation of foreign knowledge at home	• Loss of jobs due to relocation • 'Hollowing out' of domestic R&D and innovation activities • Technology leakage and involuntary knowledge diffusion

Source: Adapted from Sheehan (2004), UNCTAD (2005), Veugelers (2005).

Most of these effects are rooted in the following three important facts about multinational firms:

First, economic theory states that multinational firms possess some types of valuable intangible assets – technologies, knowledge, trademarks, business practices, etc. – that allow them to enter foreign markets and exploit these assets internationally. These assets may be – voluntarily or involuntarily - transferred to the host economy through various channels, generating considerable benefits for domestic organisations.

Second, the size of R&D expenditure of multinational firms is considerable, even if we compare it with aggregate R&D expenditure of countries (OECD 2010, p. 121). Foreign-controlled R&D expenditure exceeds public funding of R&D in the business sector in a number of countries (OECD 2009b, p. 120f). Hence, a new R&D venture of a foreign-owned firm may affect aggregate R&D activity in the host country.

Finally, the literature has pointed out that multinational firms differ in their R&D strategies from firms that operate only in one country (Narula and Zanfei 2005; Dunning and Lundan 2009). MNEs have various choices in the location and organisation of R&D which mono-national firms do not have. They can, for example, move R&D activities between countries. This has implications for policy.

We first discuss impacts from the perspective of the host country. The presence of foreign-owned firms can help to increase aggregate R&D and innovation expenditure. R&D expenditure by MNEs constitutes a considerable share of gross R&D expenditure in many countries and often exceeds public funds for R&D (Lonmo and Anderson 2003; Costa and Filippov 2008). Empirical evidence suggests that small countries benefit most in relative terms because they usually exhibit higher degrees of internationalisation in FDI than large countries.

MNE subsidiaries – in contrast to domestically owned firms - can also access financial means of their parent enterprise abroad; expansion of R&D activity is therefore not limited by a lack of internal resources or incomplete credit markets in the host country. Moreover, the threat of market entry by R&D intensive MNEs may also spur R&D activities of domestically owned firms (Aghion et al. 2009).

A second, more indirect benefit for the host country is the diffusion of information and knowledge (referred to as knowledge diffusion in the text) 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, for example, the surveys by Keller (2004 and 2010) or Mayer and Sinani (2009)). According to Blomström and Kokko (2003), spillovers are the strongest argument as to why countries should try to attract inward investment. Empirical evidence on the size and the effects of these spillovers, however, is mixed. Meta-studies (Görg and Greenaway 2004; Mayer and Sinani 2009; Havránek and Iršová 2010) as well as literature surveys show no clear relationship between foreign presence and the performance of domestically owned firms. Görg and Strobl (2001) for example indicate that the number of studies that identify positive spillovers roughly equals those identifying no effects or even negative consequences from the presence of foreign-owned enterprises. In the majority of cases considered by Görg and Greenaway (2004), no significant effect of MNE presence on domestic firm productivity is observed. Reinhilde Veugelers (2005, p 37) finds that it is "fair to conclude that the results on positive spillovers on host economies are not strong and robust".

Empirical evidence is clearer at the aggregate level. New contributions by Keller and Yeaple (2009) and by Coe, Helpman and Hoffmaister (2009) reveal substantial spillover effects from foreign R&D stocks and the presence of foreign-owned firms at the sectoral level. Moreover, Coe et al (2009) show the importance of institutional factors and thus institutional distance for the degree of R&D spillovers.

A main reason for this vagueness of the results, besides measurement and estimation issues, is the fact that spillovers from foreign-owned firms to the local economy are bound to specific industry and economy-wide conditions to occur. There have to be specific factors or conditions in place for the host countries to benefit from activities of foreign-owned firms. These factors include a certain level of absorptive capacity (Cohen and Levinthal 1989; 1990; Cantner and Pyka 1998) of domestic organisations; weak instruments of foreign-owned firms to protect proprietary knowledge, which is mostly sector-specific; and the propensity of the transfer channel or type of interaction between foreign-owned firms and domestic organisations.

Foreign-controlled R&D activity in a particular country may also help to enhance the level and quality of human resources. R&D activities of foreign-owned firms may create additional demand for researchers and give incentives to governments to improve higher education systems. MNEs are attractive employers, because they can offer international career perspectives and pay higher wages than domestically owned enterprises (Lipsey 2002; Bailey and Driffield 2007). Moreover, jobs created by foreign-owned firms appear to be more persistent than jobs generated in domestically owned plants (Görg and Strobl 2003). There may, however, also a challenge from the presence of foreign-owned firms when domestic and foreign-owned firms compete for skilled personnel.

Finally, foreign-owned firms can also contribute to structural change towards a higher share of technology-intensive firms and the emergence of clusters. Structural change is related in two ways to the presence of foreign-owned firms. On the one hand, foreign-owned firms operate predominantly in technology-intensive industries. Market entrance and subsequent growth of the foreign-owned firm will therefore move the industrial structure of a country towards higher technology intensity. There is also evidence that FDI contributes to the shift in labour demand towards skilled labour in the host country (Blonigen and Slaughter 2001; Driffield et al. 2009).

On the other hand, MNE subsidiaries trigger structural change because their demand for inputs favours the growth of domestic technology-intensive suppliers. This demand may lead to the emergence of clusters and other agglomerations at the regional or local level in the host country (Young et al. 1994; Bellandi 2001; Pavlínek 2004). Agglomeration effects may be further intensified by the degree foreign-owned firms are embedded into their local environment. Foreign-owned subsidiaries in clusters are often strongly embedded locally, but also internationally-oriented and can therefore act as bridges for knowledge transfer between domestic organisations and abroad (Birkinshaw and Hood 2000; Lorenzen and Mahnke 2002).

We now turn to potential challenges for host countries that emerge from the presence of foreign-owned firms. One interesting aspect of the literature on spillovers from FDI is the considerable number of studies that report negative effects of the foreign presence on domestic firms (see, for example, Aitken and Harrison 1999; Konings 2001; Castellani and Zanfei 2002; Damijan et al. 2003). An example is a recent study by Wang (2010) investigating the determinants of R&D investment at the national level for 26 OECD countries from 1996-2006. Wang (2010) finds that foreign technology inflows through trade and FDI had a robust and negative impact on domestic R&D. One explanation put forward for this negative impact is that increased competition in product and factor markets can have a negative impact on a domestic firm's productivity (Aitken and Harrison 1999; Konings 2001). These negative effects are predominantly found in developing or transition economies. A stronger competition from foreign-owned firms may also reduce R&D activities of domestically owned firms, because it decreases expectations of future demand.

Concerns that foreign presence may lead to a downgrading of domestic R&D are nurtured by more general doubts against MNE activities (see Barba Navaretti and Venables 2004; Jensen 2006; Forsgren 2008 for a summary of this discussion). One concern is that decisions on R&D of foreign-owned firms may not be taken by the subsidiaries themselves, but by corporate headquarters abroad. Others fear that MNEs are 'footloose', because they mainly pursue economic activities that can be easily transferred between countries; foreign-owned enterprises act in ways that are not in accordance with the national interest; they show rent-seeking behaviour in selecting locations and try to undermine national labour standards. Another fear is that foreign ownership may change the nature of business R&D in terms of novelty and originality. R&D of foreign-owned firms may be associated with a higher degree of adaptation and less basic, strategic research, leading to fewer radical innovations than in the case of domestic ownership.

Empirical evidence that supports these concerns, however, is thin. Internationalisation certainly leads to a shift of control from domestic headquarters to organisations abroad. However, we also have to consider that domestic ownership does not necessarily mean that enterprises act in best national interest. Moreover, domestic policy does not necessarily have a higher ability to influence R&D decisions when enterprises are domestically owned (Dunning and Lundan 2008, p. 249 ff).

The question if foreign ownership is associated with a downsizing of R&D activity has been evaluated both for take-overs as well as for all foreign-owned and domestically owned firms. In the case of take-overs, there are both examples of downsizing as well as examples of expansion, depending on the complementarity between acquiring and acquired firms and other factors (Cassiman et al. 2005; UNCTAD 2005). Studies that compare innovation input and output of domestically owned and foreign-owned firms find no negative effect of foreign ownership after controlling for firm characteristics such as size, sector, export intensity etc.

R&D internationalisation may also lead to a separation of R&D and production. Multinational firms do not necessarily do research, development and production at the same place. They have various choices in locating their activities, which may lead to a separation of innovation, R&D and production (Pearce 2004; Pearce and Papanastassiou 2009). MNEs may find it useful to develop products in one country and manufacture those products in another country where conditions for production seem more favourable. As a consequence, policy measures to foster R&D and product development may yield only few jobs and give only a weak stimulus to growth, when foreign-owned firms decide to produce abroad.

To our knowledge, no empirical study so far has thoroughly examined the effects from the separation of R&D and production. It is, however, plausible that this leaking-out effect may be stronger in small countries and in countries with a high share of foreign-controlled R&D, and weaker or even reverse when foreign-owned firms have a high degree of autonomy and strong mandates in their enterprise groups, because these firms may try to concentrate not only R&D, but also production at their location of maximise influence. The effect may level out when studied at the EU instead of the national level.

Foreign-owned firms may also compete with domestically owned firms for resources. Foreign-owned subsidiaries are attractive employers for researchers and other R&D staff. This demand for skilled personnel is beneficial for the host country in the short run when there is unemployment among scientists, engineers and technicians and alternative employment opportunities (for example at universities) are scarce (Marin and Sasidharanb 2010). Additional demand by foreign-owned firms, however, may have negative consequences for the host country when the supply for research personnel is inelastic and foreign-owned firms and domestic organisations compete for qualified staff (Figini and Görg 1999; Driffield and Taylor 2000).

In the long run, the effects of the demand by foreign-owned subsidiaries on the labour market for R&D staff look more positive. Stronger demand for high-skilled labour due to market entry of foreign-owned firms and structural change may foster academic training and increase the number of graduates in science and technology in the long run. A higher skill intensity in the economy, in turn, may foster locational advantages and further increase the attractiveness of the country for inward investment. Barry (2004) illustrates such a 'virtuous circle' for the case of Ireland.

2.3. Impacts of overseas R&D and innovation activities on home countries

The internationalisation of R&D has implications for the home country of the multinational firm (Dunning and Lundan 2009). Before we briefly discuss the literature on home country effects, two remarks are important. First, as Kokko (2006) points out, the decision to engage in foreign activities is typically a voluntary decision and it thus can be assumed that overseas activities benefit the MNE. More specifically, it can be expected that the MNE will grow larger than what would have been possible if it had remained a purely national firm.

Second, as discussed above, a main reason 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 is the transfer of knowledge resulting from overseas R&D activities which brings new knowledge into the home country. Various studies provide evidence for such reverse knowledge transfers (Fors 1997; AlAzzawi 2004; Feinberg and Gupta 2004; Rabbiosi 2005; Todo and Shimizutani 2005; Ambos and Schlegelmilch 2006; Piscitello and Rabbiosi 2006; Narula and Michel 2009; Rabbiosi 2009).

Reverse knowledge transfer can increase the overall technological capacity, 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). The degree these benefits occur depends on the motives for overseas R&D activities of domestic firms, as well as on the degree of complementarity between overseas and home activities (Arvanitis and Hollenstein 2009), and the absorptive capacities and other firm characteristics of the parent company (Schmiele 2009). Moreover, there seems to be a positive relationship between internationalisation and the returns from R&D at home (Añón Higón and Manjón Antolín 2009; Criscuolo and Martin 2009) which may further increase the benefits for the home country.

Todo and Shimiztuani (2005) find for Japan that the scope for positive reverse technology transfer effects on the productivity of firms in the home country is large when foreign-owned affiliates undertake R&D that tap into advanced knowledge abroad. Adaptive R&D however was found to improve productivity in the host country, but did not contribute to enhanced productivity in the home country. Griffith et al. (2004) find that R&D by UK firms in the USA have resulted in benefits from reverse technology with the effects being larger in the case of R&D units set up to source technology. Results for Sweden, however (Fors 1997; Braconier et al. 2002) indicate that there have not been significant spillovers to the home country, possibly because much R&D has been of the adaptive type. AlAzzawi (2004) find that outward-FDI-induced R&D had a positive impact on the home country's level of innovation activity in both developed and newly industrialized countries, but productivity benefits were found for newly industrialized countries only.

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 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[1] , empirical results that confirm negative effects from overseas R&D on the home country are rare. A reason for this is the fact that the most R&D activities of domestic firms is still located in the home country (see section 4.3). We also know that tight bounds between a firm's knowledge base and its surrounding innovation system exist, including institutions and universities (Patel and Pavitt 1999; Narula 2003).

1 An example is the June 2010 issue of the Journal of Technology Transfer which discusses production offshoring and its effects on US manufacturing R&D in detail.

These linkages make the offshoring of R&D difficult, and most overseas R&D activity complements domestic activity. Data on R&D expenditure or patent inventions give no indication for a substitutive relationship between foreign-based and home-based R&D activities. This data suggests that countries which increased their overseas R&D activities saw also considerable gains in domestic R&D activities in the past (Dachs et al. 2010). A 'hollowing out' (Criscuolo and Patel 2003) of domestic R&D has not been observed so far. This finding is also supported by empirical evidence that points to the complementarities between domestic and foreign production and sales activities, at least in the long term (Lipsey 2002; Barba Navaretti and Falzoni 2004). Here, a main argument is that the home economy benefits in the long run because internationalisation creates a new division of labour within the firm, where home country units specialize in innovation, R&D and other headquarter activities, which generate a greater value added to the economy.

3. ISSUES IN COLLECTING DATA ON THE INTERNATIONALISATION OF R&D

This chapter summarizes the results of the data collection process. After presenting some basic definitions of R&D and innovation in the context of internationalisation of R&D a summary of the available data is provided and still existing data gaps and other important pitfalls that have to be taken into account when analysing data on foreign-owned R&D are discussed.

3.1. Definitions of R&D and innovation

For the analysis of the internationalisation of business R&D a first important step is to clearly define business R&D and distinguish R&D from other aspects of the innovation.

The OECD Frascati Manual defines R&D as 'creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications' (OECD 2002, p. 30). Compared to innovation, the term R&D rather refers to scientific discovery and knowledge creation than to the economic application of new knowledge. In practice, however, many firms may find it difficult to distinguish between innovation and R&D activities. Both terms are overlapping: R&D financed and performed by enterprises is always an innovation activity; in fact, R&D expenditure accounts for around half of innovation expenditure. The share is higher in countries with high average R&D intensity, such as Finland, Austria, France or Sweden, where R&D expenditure accounts for more than 60% of total innovation expenditure.

But not all R&D performed in a country is innovation activity, because a considerable part of total R&D is performed by universities which do not introduce new products or processes to the market. Moreover, some activities which are not R&D may be innovation activity; examples are design activities, staff training activities related to market introduction or production preparations. In a number of service industries, these activities comprise the bulk of innovation expenditure.

The focus of this project is on business R&D. Following the OECD Frascati Manual (OECD 2002, p. 54), the business enterprise sector includes 'all firms, organisations and institutions whose primary activity is the market production of goods or services for sale to the general public at an economically significant price' and 'the private non-profit institutions mainly serving them'. This definition excludes the government sector, the private non-profit sector and higher education, no matter if privately or publicly funded. Public enterprises are included if they are mainly engaged in market production.

Data on R&D expenditure is usually collected separately for intramural R&D and extramural R&D. The OECD Frascati Manual (OECD 2002, p. 21) defines intramural R&D expenditures as 'all expenditures for R&D performed within a statistical unit or sector of the economy during a specific period, whatever the source of funds'. In contrast, extramural R&D expenditures are defined as 'the sums a unit, organisation or sector reports having paid or committed themselves to pay to another unit, organisation or sector for the

Table 2: Main definitions

Business Enterprise R&D	
Total BERD	Total business enterprise research and development (BERD) by domestically owned firms and foreign-owned affiliates performed in the reporting country
Inward BERD	BERD by foreign-owned affiliates in the reporting country
Domestic BERD	BERD by domestically owned firms in the reporting country
Outward BERD	BERD of domestically owned firms outside of the reporting country
Sector and industry classification	
Sector	A NACE 1.1 section (mainly two-digit level)
Industry	The data aggregated into high-, medium-high-, medium- low-, low-technology manufacturing sectors, knowledge-intensive and less knowledge-intensive services

performance of R&D during a specific period' (OECD 2002, p. 21). Generally, R&D expenditures include both, intramural and extramural R&D expenditures and follow the definition of R&D as stated above to distinguish them from other innovative activities like design or staff training (OECD 2002).

This project frequently uses some key terms and abbreviations for different types of R&D which are summarized in Table 2. An important distinction is between business R&D expenditure of domestically owned firms (domestic BERD) and business R&D expenditure of foreign-owned firms (inward BERD) in a particular country. Outward BERD refers to all business R&D expenditure of domestically owned firms performed outside their home country.

3.2. Methodology, data sources and challenges

The increasing interest in the internationalisation of economic activity during the 1980s and 1990s brought forward various initiatives to collect data on the internationalisation of R&D, to the largest part organized by the OECD (Godin 2004). These efforts have been intensified after the year 2000, pushed forward by the OECD Working Party of National Experts on Science and Technology Indicators (NESTI), and the OECD Working Party on Innovation and Technology Policy (TIP) (OECD 1998; Colecchia 2005; OECD 2005a; Colecchia 2006; Colecchia 2007; OECD 2008a).

Another impetus for the collection of data on the internationalisation of R&D came from the European Union. Regulation (EC) No 716/2007 requires EU member states to collect data on intramural R&D expenditure by foreign-owned affiliates for every second year and, to a limited degree, on outward R&D expenditure starting with the year 2007. The methodology used is in line with the OECD Frascati manual. Foreign-owned affiliates are defined as 'enterprises resident in the compiling country over which an institutional unit not resident in the compiling country has control, or an enterprise not resident in the compiling country over which an institutional unit resident in the compiling country has control' (Regulation (EC) No 716/2007, Article 2 a)). The concept of the ultimate controlling institutional unit (UCI) is used to determine foreign control of an enterprise. The UCI is the institutional unit in a chain of control which is not controlled by another institutional unit (Eurostat 2007). In their Foreign Affiliates Statistics (FATS), EUROSTAT distinguishes between inward FATS data, statistics describing the activity of foreign-owned affiliates resident in the compiling country, and outward FATS data, statistics describing the activity of foreign-owned affiliates abroad controlled by the compiling country (Eurostat 2007). Values for a reporting firm are allocated completely to the majority owner's country; splitting of values according to owner shares or double counting is not recommended.

Most major non-OECD countries, including Brazil, China, India and Russia, follow the guidelines for the collection of R&D data provided by the OECD Frascati Manual. The Frascati Manual, however, offers only little guidance for collecting data on R&D internationalisation. Hence, the availability of data and the level of aggregation vary significantly across these countries (OECD 2010).

Despite increasing efforts to collect data and harmonize survey methodologies, some open methodological issues remain that have to be kept in mind when interpreting the data (Colecchia 2005; Colecchia 2006; Colecchia 2007; Cozza 2010; OECD 2010):

A first critical issue is the correct identification of the 'ultimate controller' and the ultimate country of ownership. Multi-level ownership structures of multinational corporations make is sometimes difficult to identify the ultimate controller of a firm.

A second critical issue are accounting practices. R&D internationalisation takes place to a considerable degree within large multinational firms with a presence in many countries. Thus, data on R&D expenditure of affiliates in different countries may be distorted by internal transfer pricing, non-priced transfers of R&D personnel and possibly problems in dividing flows of funds for R&D within the group across borders.

Another challenge for statistics on foreign-owned R&D is institutional separation. Responsibilities for collecting data on R&D expenditure and on the activities of foreign-owned firms (FDI or FATS surveys) are divided between statistical agencies and the central banks in some countries. This may result in different samples for both surveys. The collection of data on R&D expenditure of domestic firms abroad (outward R&D) seems to be a challenge in particular.

The problem of institutional separation and different samples of foreign-owned firms multiplies when R&D inward and outward data is compared bilaterally. A study by OECD NESTI (Colecchia 2006) compared outward BERD of the US and some European countries with corresponding data for inward BERD in several European countries. The comparison showed considerable differences both in the number of foreign-owned firms surveyed and in R&D expenditure between the two data sources.

With increased efforts put into the identification of foreign-owned firms, additional issues arise for the analysis of this data over time. We have to be careful in the interpretation of time series, because increasing levels of internationalisation for a given country or industry over time may be (partly) rather the result of increased efforts put into the collection of this data than of increased levels of internationalisation.

Data on the R&D expenditure of foreign-owned firms in a detailed sectoral disaggregation should be interpreted with care as well. Data reported by the OECD (Colecchia 2006, p. 10) indicate that a handful of MNE subsidiaries account for a major share of foreign-owned R&D expenditures in smaller countries. A change in the classification of only one of these firms may result in shifts in the sectoral composition of inward BERD.

The statistical unit of R&D surveys is the enterprise and all R&D expenditure of the enterprise is assigned to the sector of the main economic activity of the enterprise. Some countries, however, further split R&D expenditure if enterprises are active in more than one product field, for example chemicals and pharmaceuticals. This may be a source of inconsistencies in international comparisons of total BERD and inward BERD at the sectoral level. Another challenge related to the sectoral classification of foreign-owned firms is the classification of non-producing affiliates. If a foreign-owned affiliate generates the majority of its value added by selling the products of its parent company, it is classified as wholesale and retail trade, even if it belongs to a parent company from the manufacturing sector.

Finally, another relevant issue is the treatment of non-R&D performers. R&D surveys only report information on R&D active firms. If a regional headquarter of a multinational firm sponsors R&D abroad, but does not have own domestic R&D activities, it is unlikely that this R&D expenditure enters the survey results.

3.3. Experiences from the data collection

A main task of the project was the collection of data on R&D expenditure of foreign-owned firms from national statistical offices, EUROSTAT and the OECD. We collected data on inward BERD which captures R&D expenditure of foreign-owned firms in a particular host country, as well as outward BERD data which includes R&D expenditure of domestic firms abroad.

Over the last two years there has been a noticeable increase in attention of national statistical offices for R&D internationalisation, in particular in EU member countries. As mentioned before, a major impetus for the extension of survey programmes is EU regulation on FATS statistics starting with (EG) No. 716/2007 which requires EU member states to collect data on the R&D expenditure of foreign-owned firms every two years. Data from national statistical offices is considerably more actual and much more detailed in a number of countries than it was some years before. However, this is not yet fully reflected in the OECD AFA and EUROSTAT databases. Thus, we can expect a better coverage of these databases in the near future.

Data on the inward BERD is available at the aggregate and the sectoral level and by the home country of the foreign-owned firm for most European countries. In contrast, there is considerably less data available for non-European countries: Only rudimentary data on inward BERD could be collected for China and Israel. No data was available for South Korea, Russia, India, and Brazil. This is a major shortcoming and a serious obstacle to a global analysis of R&D internationalisation, since emerging economies may rapidly gaining importance in the process.

In most countries, inward BERD data is collected by business sector R&D surveys. From our perspective, this is the preferred organisational form, because it ensures the comparability of the data with total BERD or sectoral BERD. Separate R&D surveys for multinational firms (like in Israel) should only be considered as a second strategy.

Sectoral data is mostly available at NACE two-digit level. For a few selected industries (mainly pharmaceuticals and aeronautics), some statistical offices also provide data at the NACE three-digit level. The availability and quality of inward BERD data is better for manufacturing than for service industries. In our opinion, this is a second major shortcoming of the available data. Some countries exclude the service sector for some or all years (Denmark, Spain, Finland, the Netherlands, Bulgaria, Hungary and Turkey), while others only report data for broad service sector aggregates. Moreover, there are considerable differences in the share of service industries on inward BERD, and their development over time between countries which may also raise concerns about data quality. From our perspective, it is difficult to tell if these differences reflect a different economic structure or different survey designs.

In many countries, inward BERD data is also available in a split by the home country of the foreign-owned firm. National statistical offices tend to offer this data in more detail than OECD and EUROSTAT databases. Some smaller countries do not fully publish inward data in a home country split due to data confidentiality when there are only a few R&D active foreign-owned firms from a particular country. This is a considerable obstacle for the analysis of cross-country patterns of R&D internationalisation. Inward BERD data is also provided in a home country x sector dimension by many EU countries. Confidentiality issues are even larger in this case, and even medium-sized countries like the Netherlands have to omit data due to data confidentiality.

In some countries large changes in the shares of different home countries between two years can be observed. This may be the result of the concentration of foreign activity in a few large firms. It may, however, also be the result of a better identification of the 'ultimate controller' and the ultimate country of ownership. This is often hard to capture because of the multi-level structure of many multinational companies.

There is much less data on outward BERD than on inward BERD. Detailed outward BERD data is available only for two countries, the US and Japan. One reason for this poor coverage is the fact that collecting outward BERD data is more difficult than collecting inward BERD data. 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 firm population located within a country.

3.4. The most pressing data needs

The experiences from the data collection allow us to identify four areas where improvements in data quality and availability can considerably increase our knowledge of the internationalisation of business R&D:

First, we believe that less – not more - detailed data may give a more complete picture of R&D internationalisation. With an increasing level of detail of the data reported by EU member states over the last years, confidentiality issues further increased and became a main constraint when analysing data on R&D of foreign-owned firms. Inward BERD from non-European countries (except the US), for example, is only poorly available in many small EU member states because there is usually only a handful of R&D active foreign-owned firms from a particular home country and, as a result, many results are confidential. Another example is inward data in a country x sector split, which may very useful for analytical purposes, but also leads to a large number of confidential values, even in medium sized reporting countries. Thus, we propose to publish (but not collect) data in larger aggregates to avoid confidentiality issues.

Statistical agencies can overcome this issue by providing data in higher country group and sectoral aggregations. Rather than reporting inward BERD data for individual countries of origin (at the risk of suppressing data due to confidentiality), the statistical agencies should publish country aggregates, specifying the countries included in these aggregates. An aggregate for foreign-owned firms from Asian countries excluding Japan, for example may provide much more valuable information than data for individual countries where most information has to be suppressed because of the low number of firms. Moreover, several country aggregates at the EU-27 level prepared by EUROSTAT based on the national data would be extremely helpful. Such aggregates will provide valuable information on the role of the EU in the process of R&D internationalisation. It is not possible for researchers to generate such aggregates by summing up national data; though it seems very unlikely that confidentiality is an issue at the EU level.

Second, there are some serious data gaps in the service sector. In some countries the service sector is not included at all. More complete data on inward BERD in services, in particular in knowledge-intensive services, would enhance our picture of R&D internationalisation where most attention still focuses on manufacturing.

Third, we see a considerable difference in data quality and availability between EU and non-EU member countries, in particular emerging economies. Any measure to increase the awareness for the topic in these countries may help to improve our understanding of R&D internationalisation. Some of these countries, in particular China and India, may already be major host locations for overseas R&D of European firms – however, data to test this assumption is not available.

Finally, the outward perspective remains poorly covered and is not included in most reporting countries. Outward data can be substituted by the corresponding inward data (mirror flows). This is feasible for some large countries like Germany or France, which appear in nearly all inward BERD data as home countries. But even in these cases big numerical differences between reported inward and outward BERD are visible.

Constructing outward data by the corresponding (mirrored) inward data in a home country split may be helpful to see which countries have large R&D activities abroad and which have not, or to observe shifts in the distribution of outward BERD between the US, Europe and Asia. However, such an approach is only a second-best solution to outward data from enterprise surveys.

4. CURRENT STATUS AND FUTURE DIRECTIONS OF R&D INTERNATIONALISATION

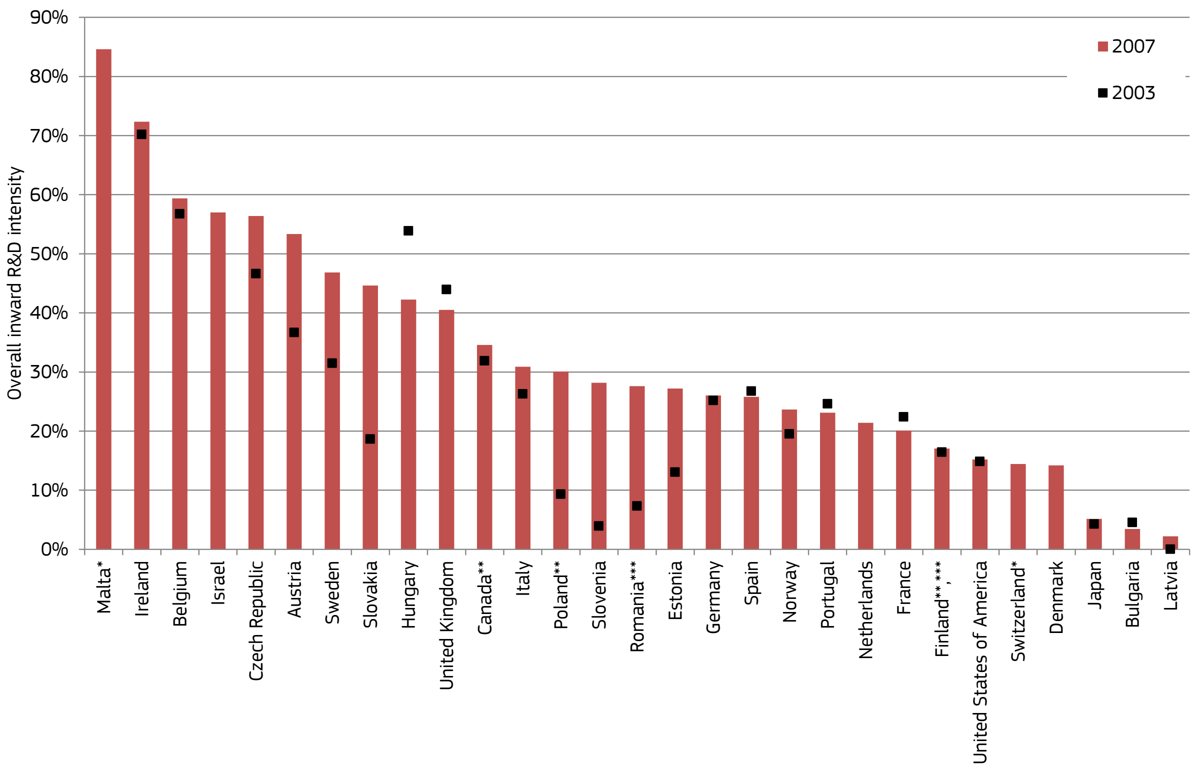
This chapter investigates variations in the degree of R&D internationalisation across countries and sectors. The first section looks at differences in inward BERD across countries and over time to identify the countries which are most internationalised. Section 4.2 gives insights in the shares of various home countries in total inward BERD of the EU countries. In particular, we focus on the question in which countries EU- or non-EU firms have the largest share on inward BERD. Whereas Section 4.3 proceeds with a cross-country analysis of the existing outward BERD, section 4.4 investigates the sectoral perspective of business R&D expenditure. Section 4.5 analyses the relationship between the European Union and The United States of America in R&D internationalisation. Section 4.6 closes this chapter with a look at new players from emerging economies in the internationalisation of R&D.

4.1. Inward BERD across countries and over time

We measure the intensity of R&D internationalisation by 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 relative importance of foreign-owned firms in different national innovation systems.

Figure 2 depicts overall inward R&D intensity for different countries. The figure reveals that the internationalisation of R&D is increasing in the majority of countries. Only Hungary and the United Kingdom experienced a decrease in overall inward R&D intensity between 2003 and 2007. However, the internationalisation of R&D emerges only slowly, as inward R&D intensities remained stagnant in a number of countries, including large countries such as France, the US, Japan or Germany. Huge changes between 2003 and 2007 are only observable in small countries.

Figure 2: Overall inward R&D intensity in the business sector (inward BERD / total BERD, 2003 and 2007)



Note: No 2003 data for Malta, Israel, Netherlands, Switzerland and Denmark; * 2008 instead of 2007; ** 2006 instead of 2007; *** 2004 instead of 2003

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

There is a large variation in overall inward R&D intensity across countries – ranging from over 80% in Malta to less than five percent in Japan, Bulgaria and Latvia. As a general rule, the level of R&D internationalisation is highest in small countries such as Austria, Belgium or Ireland. In some of these small countries, R&D expenditure of foreign-owned firms is even higher than R&D expenditure of domestic firms. Smaller countries exhibit also a higher degree of openness in trade or foreign direct investment. In addition, it only takes a handful of multinational firms and their R&D investments to substantially raise overall R&D expenditure in a small country.

Large and medium-sized countries, in contrast, have considerably lower levels of R&D internationalisation. In the United States, around 15% of all business R&D expenditure comes from foreign-owned firms. The share of foreign-owned firms is around 25% in Germany. Japan is considerably below the US value. But there are also exceptions to this rule. The United Kingdom and Canada, on the one hand, have high levels of R&D internationalisation compared to other countries of similar size. The UK benefits from its role as the preferred location for the European headquarters of US, Asian and other non-European firms. Canada owes its high degree of R&D internationalisation to its strong economic ties with the US.

There is no official number for R&D expenditure of foreign-owned firms for the whole EU-27. Based on the data from the member states, we estimate that R&D expenditure of foreign-owned firms in the EU-27 is more than 42.6 billion EUR in 2007. Around half of this amount can be attributed to foreign-owned firms from non-EU countries, mostly US and Swiss firms.

A general increase in the level of R&D internationalisation can also be observed over the long run. Table 3 shows the overall inward R&D intensity as well as the level and the trend between 1998 and 2007. For years prior to 1998, data is only available for a handful of countries. It is evident that overall inward R&D intensity has been growing or at least remained stable in almost all countries over the last decade. A decline of inward R&D intensity can only be found in Hungary, Spain and to a lesser extend in Italy. Large increases and decreases are mostly found in small countries and EU-12 countries.

This might be due to the fact that inward BERD in absolute terms is lower in these countries (see also Figure 3). That is to say, there may only a few R&D intensive foreign-owned affiliates in these countries and R&D expenditure of an additional foreign-owned subsidiary strongly affects inward R&D intensity. This is for example the case in Slovakia, the Czech Republic, Slovenia, Poland and Romania. However, there is no general convergence trend towards one level of internationalisation; inward R&D intensity remains remarkably stable in Belgium, Finland or Canada between 1998 and 2007. In order to get an impression of the magnitude of the process of R&D internationalisation, it is important to consider not only at relative, but also absolute inward BERD. Total inward BERD (see Figure 3), is highest in the largest countries, even if these countries have low inward R&D intensities. Although data for a number of countries is missing, it is very likely that the United States account for the lion's share of total world inward BERD.

In absolute numbers, inward BERD increased in every single country of Figure 3 between 2003 and 2007, except France and Sweden, although decreases in these countries are vanishingly small. Inward BERD also grew in Hungary and the United Kingdom where we found a decreasing overall inward R&D intensity.

Another way to look at the internationalisation of business R&D is to relate inward BERD to GDP (Figure 4). Gross R&D expenditure as a percentage of GDP is the most widely used indicator in science and technology policy studies. The EU 2020 strategy sets the goal that at least 3% of EU GDP should be spent on R&D in the year 2020.

Foreign-owned firms already contribute considerably to this goal in a number of countries. In the European Union, the share of their R&D expenditure on GDP is highest in Sweden, Austria, Belgium, where R&D expenditure of foreign-owned firms amounts to around one percentage of GDP. All countries with an inward BERD share of more than 0.5% of GDP are small and medium sized countries.

The non-EU countries included - Canada, Switzerland, the United States and Norway - have medium levels of inward BERD as % of GDP. The only exception is Israel, which has by far the highest contribution of foreign-owned firms. Israel is an important host country for R&D activities of US computer and software firms.

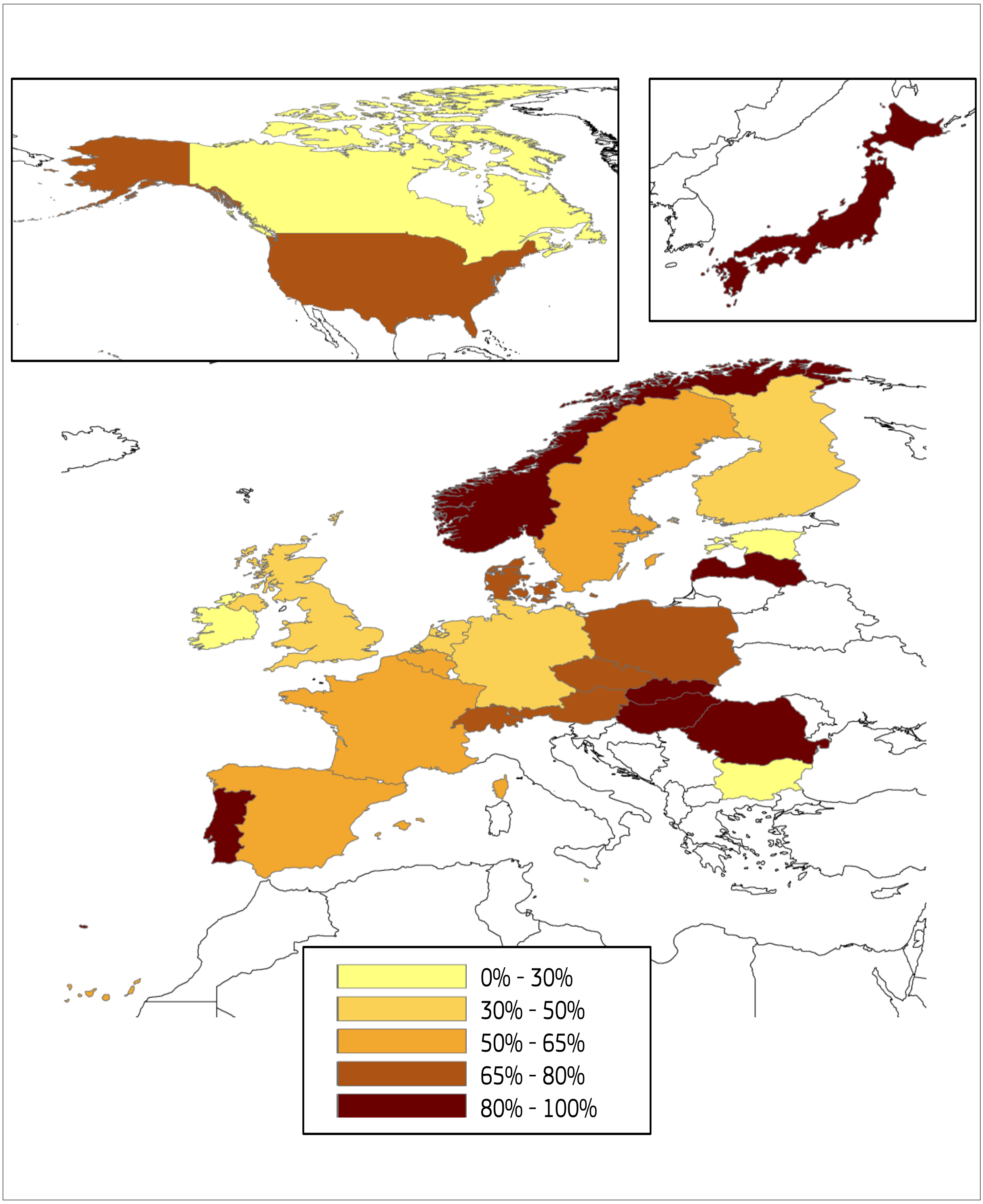
Table 3: Overall inward R&D intensity (inward BERD / total BERD. 1998 to 2007)

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Level	Trend
Ireland		63.8%		66.4%		70.2%		70.3%		72.4%	High	+
Belgium			59.7%	58.9%	58.0%	56.8%	57.2%	56.8%	59.7%	59.4%	High	=
Israel									59.0%	57.0%	High	=
Czech Republic	30.6%	27.4%	36.9%	45.2%	43.3%	46.6%	49.6%	52.5%	59.6%	56.4%	High	+
Austria						36.7%	44.9%			53.3%	High	+
Sweden		43.0%		44.7%		31.5%		41.0%		46.8%	High	=
Slovakia						18.6%	20.7%	22.7%	33.1%	44.6%	High	+
Hungary						53.9%	38.1%	43.7%	40.8%	42.3%	High	-
United Kingdom	30.4%	31.2%	31.3%	42.8%	40.7%	43.9%	40.4%	40.4%	39.1%	40.5%	High	+
Canada	33.2%	32.0%	29.2%	28.8%	31.8%	31.9%	33.5%	33.5%	34.6%		Medium	=
Italy				33.0%	27.7%	26.3%	25.8%	25.2%	26.6%	30.9%	Medium	=
Poland	12.3%	22.6%	12.1%	4.6%	10.6%	9.3%	16.8%	30.4%	30.1%		Medium	+
Slovenia						3.9%	36.6%		27.6%	28.2%	Medium	+
Romania							7.3%	3.9%	18.4%	27.6%	Medium	+
Estonia						13.0%	26.1%	26.6%	28.5%	27.2%	Medium	+
Germany		15.4%		22.1%		25.2%		27.5%		26.0%	Medium	+
Spain		32.8%		31.0%		26.7%	27.4%	26.5%	26.1%	25.8%	Medium	-
Norway						19.5%	21.4%	21.5%	21.9%	23.6%	Medium	=
Portugal		18.0%		30.8%		24.6%		34.0%		23.1%	Medium	+
Netherlands	21.2%	21.6%	26.1%	24.7%						21.4%	Medium	=
France	16.4%			23.1%	20.4%	22.4%		23.5%	22.2%	20.1%	Medium	=
Finland	13.2%	14.9%	12.7%	13.6%			16.4%	16.1%	17.0%		Low	=
USA	13.2%	13.0%	13.0%	13.1%	14.2%	14.8%	14.4%	13.8%	14.0%	15.2%	Low	=
Turkey	8.4%	7.3%	10.6%		6.6%						Low	=
Japan	1.7%	3.9%	3.6%	3.4%	3.6%	4.3%	5.1%	5.1%	5.4%	5.1%	Low	=
Bulgaria						4.5%	10.2%	4.4%	4.9%	3.4%	Low	=
Latvia						0.0%	3.4%	2.0%	1.2%	2.2%	Low	=

Note: High intensity is defined as an intensity of more than 40% in the last year with data available, medium intensity as intensit between 20% and 40% and low intensity as intensity of less than 20%.

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

Figure 3: Total inward BERD (2007, PPS EUR Mio)



Notes: Malta and Switzerland 2008; Finland 2006

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

4.2. The main countries of origin of inward BERD

Countries vary considerably in the degree foreign-owned firms contribute to total R&D expenditure of the business sector. Moreover, there are also major differences between countries in the sources of inward BERD, or, more precisely, in the relative importance of foreign-owned firms from different countries of origin. In particular, we are interested in the relative importance of EU vs. non-EU firms, which are mainly US firms.

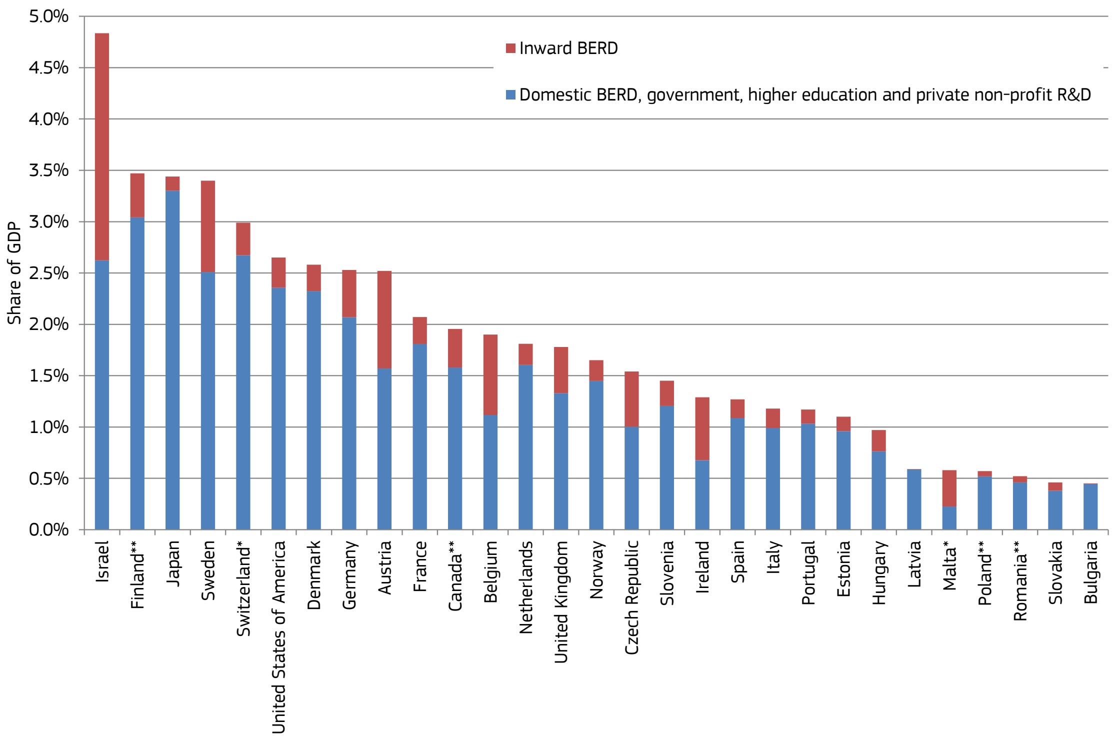
The share of different countries of origin on overall inward BERD is measured by the simple inward country penetration. The indicator shows the share of inward BERD from a particular country in total inward BERD. We distinguish between EU-27 and non EU-27 member countries. If a firm from an EU country performs R&D in another EU country, we speak of intra-EU internationalisation. Further, Germany and the United States, the two single most important countries of origin, are listed separately.

There are huge differences between countries in this indicator, as can be seen in Figure 5. Countries such as Romania, Hungary, Latvia, or Portugal have virtually no inward BERD from non-EU firms, while the opposite is true for Malta, Ireland and Bulgaria. Between these two extremes, virtually every distribution of inward shares between EU and non-EU firms can be observed with Belgium, France and Sweden ranging in the middle.

Inward BERD in EU-12 countries mostly stems from EU countries. The role of non EU countries is vanishingly small for most of the EU-12 countries. Exceptions are Estonia, Bulgaria and Malta, which show considerably high shares of inward BERD from the United States. One should however keep in mind that although Estonia shows a high share of inward BERD from the US, inward BERD in absolute terms is very small: This pattern should thus not be over-interpreted and may be traced back to only one or a few firms. This might likewise be the case in Bulgaria, where data only allows us to differentiate between EU and non-EU countries of origin. Similarly to most EU-12 countries, the major shares of inward BERD in Portugal and Denmark are from EU countries.

These variations in the importance of various countries of origin point to the importance of geography, a common language or cultural ties for the internationalisation of R&D. We will investigate these factors in detail in chapter 5 and 7. Proximity - may it be socio-cultural or geographic prox-

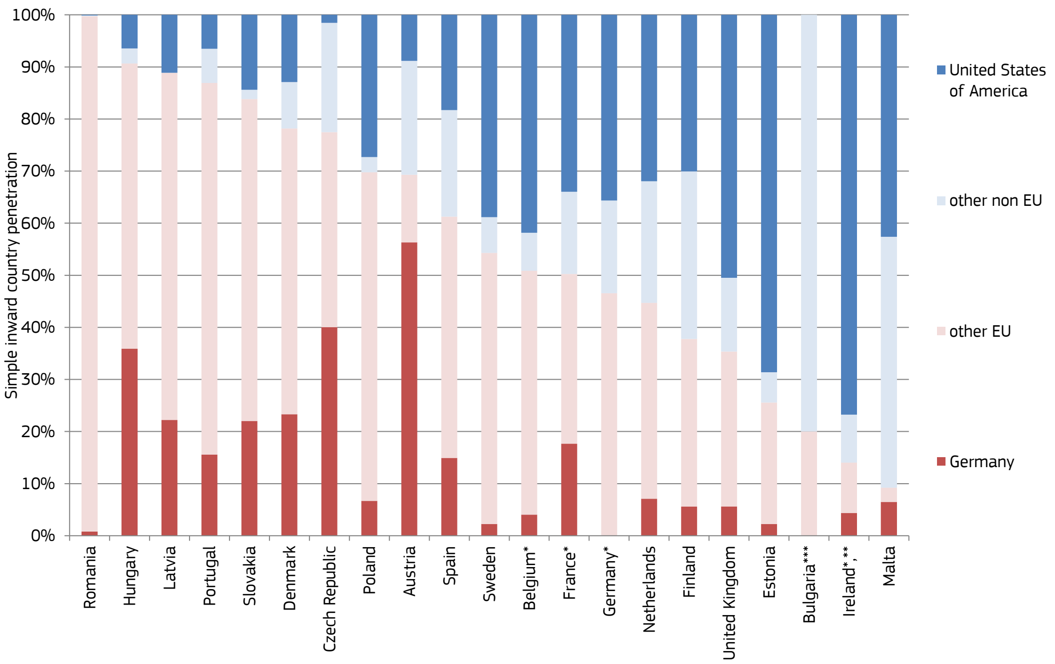
Figure 4: Total inward BERD and gross domestic expenditure on R&D as a % of GDP, 2007



Note: No 2003 data for Malta, Israel, Netherlands, Switzerland and Denmark; * 2008 instead of 2007; ** 2006 instead of 2007; *** 2004 instead of 2003

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

Figure 5: Simple inward country penetration (inward BERD from country X / inward BERD, 2007)



Note: * only manufacturing; ** 1999 (Greece) and 2005 (Ireland) instead of 2007; *** Germany included in other EU and the US included in other non EU. Source: OECD, Eurostat, national statistical offices, own calculations

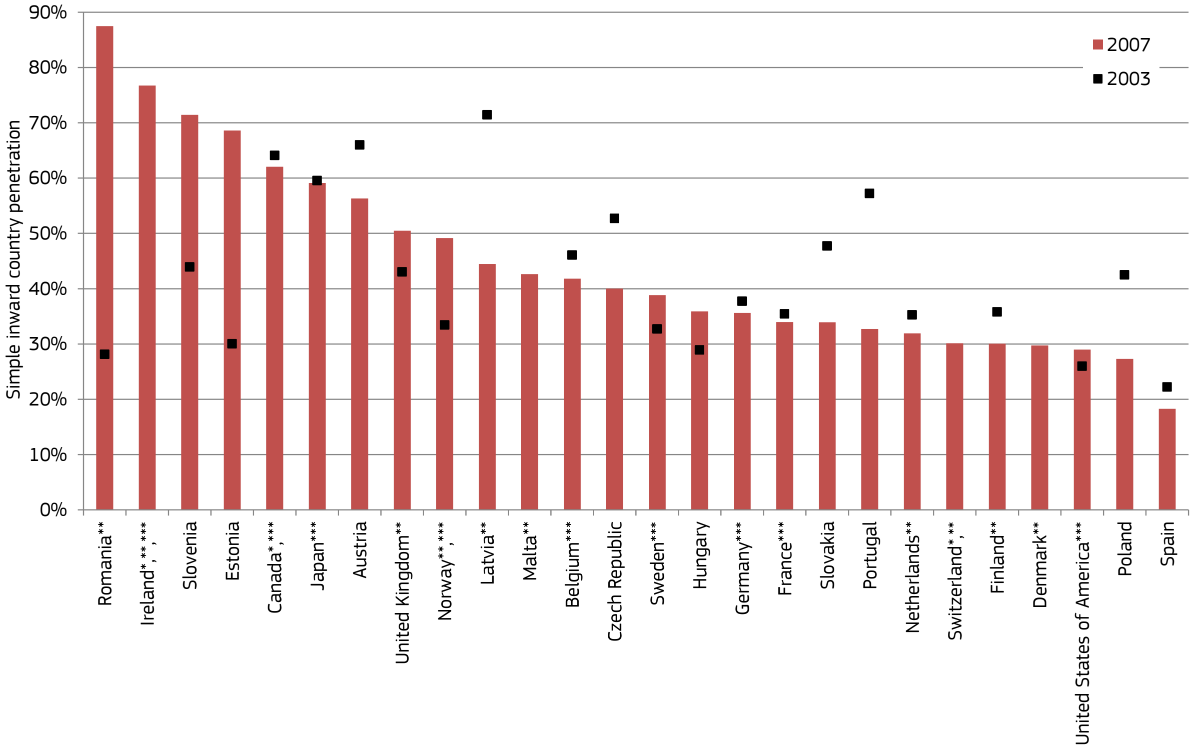
Note: * only manufacturing; ** 1999 (Greece) and 2005 (Ireland) instead of 2007; *** Germany included in other EU and the US included in other non EU. Source: OECD, Eurostat, national statistical offices, own calculations

imity – and language is relevant for countries like Austria, Hungary and the Czech Republic, where the largest shares of inward BERD come from Germany. Large shares of inward BERD from the United States in Ireland, Malta or the United Kingdom might be explained by the same language.

Figure 6 further investigates the role of single countries of origin by showing the simple inward country penetration rate of the top investor country, which is defined as the share of the top investor country in total inward BERD. In eight countries inward country penetration is above 50% indicating strong relationships between single countries.

It is striking that between 2003 and 2007 simple inward country penetration declined in the majority of countries. This indicates that the internationalisation of R&D becomes more geographically dispersed and evolves from regional to international integration where dependencies on a single country are declining and the concentration of controlling countries is decreasing. Similar results are also provided by a concentration index of inward R&D (Herfindahl-Index) across countries. For the majority of countries, concentration decreased which indicates a tendency towards a greater variety, a larger number of source countries and reduced dependencies on single countries.

Figure 6: Simple inward country penetration (inward BERD from country X / inward BERD) of top investor country 2003 and 2007



Note: * 2004 (Canada), 2005 (Ireland) and 2008 (Switzerland) instead of 2007; ** 1999 (United Kingdom), 2001 (Netherlands), 2004 (Latvia, Finland) and 2005 (Romania, Norway) instead of 2003; no data for 2003 (Ireland, Malta, Switzerland, Denmark); *** only manufacturing

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

4.3. Outward BERD across countries and over time

We now turn to the outward perspective and look at R&D activities of firms outside of their home countries. There is considerably less data available for outward BERD than for inward BERD. Therefore, the comparison is limited to only a small number of countries. Data for France, the United Kingdom, the Netherlands, Spain, but also for some Asian countries is missing in particular.

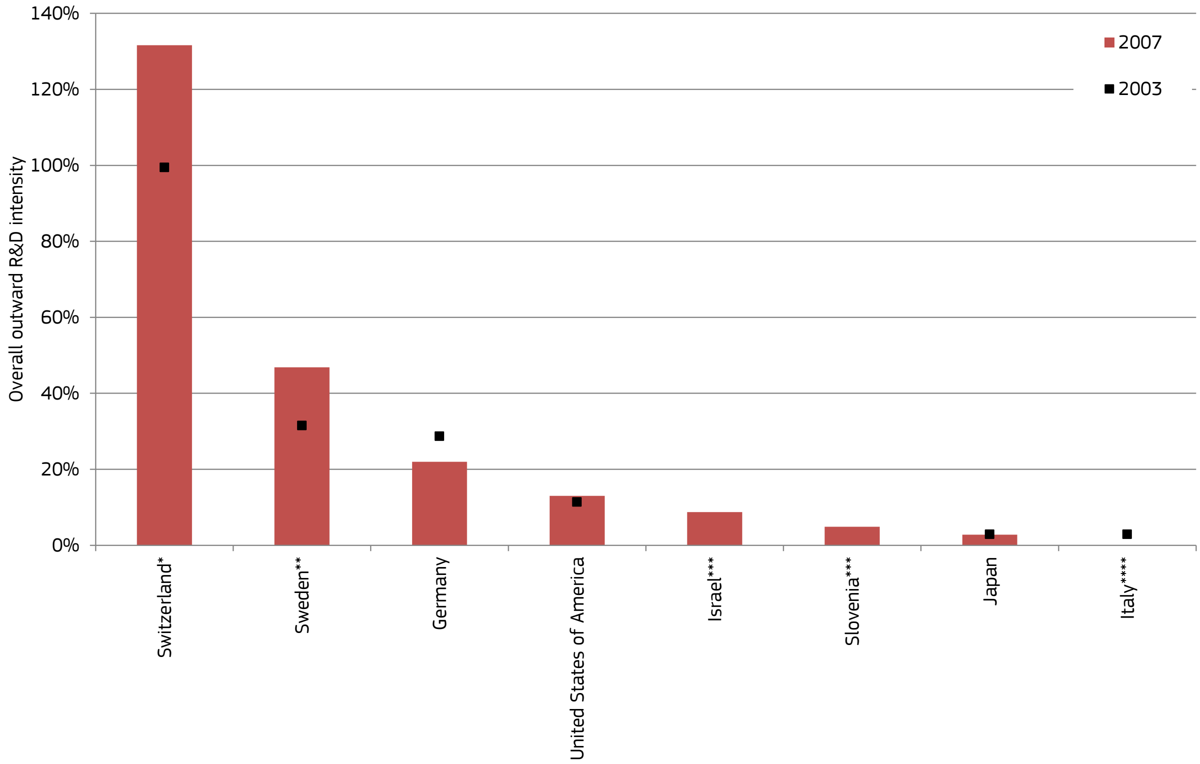
Corresponding to the overall inward R&D intensity, Figure 7 displays overall outward R&D intensity for all countries where data is available. This indicator is defined as outward BERD as a share of total national BERD (including domestic and inward BERD).

Similar to inward R&D intensity, the share of overall outward R&D intensity has increased in nearly all countries between 2003 and 2007. Particular attention should be given to Switzerland, where outward R&D intensity amounts to more than 130%. In other words, R&D expenditure of Swiss firms abroad is higher abroad than in Switzerland. Another country with a large outward R&D intensity is Sweden; the volume, however, is considerably lower than in Switzerland.

How can we explain the exceptional values of Switzerland and Sweden? Both countries have only a limited domestic market, but a large stock of foreign direct investment abroad and host a number of large multinational firms. These firms have a need to delocalize R&D to bring it closer to larger markets. Moreover, foreign R&D can augment and complement the domestic knowledge base, provided that knowledge flows sufficiently towards the MNEs' headquarters.

In contrast to Sweden and Switzerland, Germany and the United States, ranked third and fourth, have large domestic markets. For these countries, the second argument may be of greater importance; i.e. to use R&D abroad to augment and complement the domestic knowledge base. The level of outward R&D intensity of Germany and the United States is similar to their respective level of inward R&D intensity. This indicates that the magnitude of investment in R&D abroad is similar to the level of inward R&D in both Germany and the United States.

Figure 7: Overall outward R&D intensity (outward BERD / total BERD, 2003 and 2007)

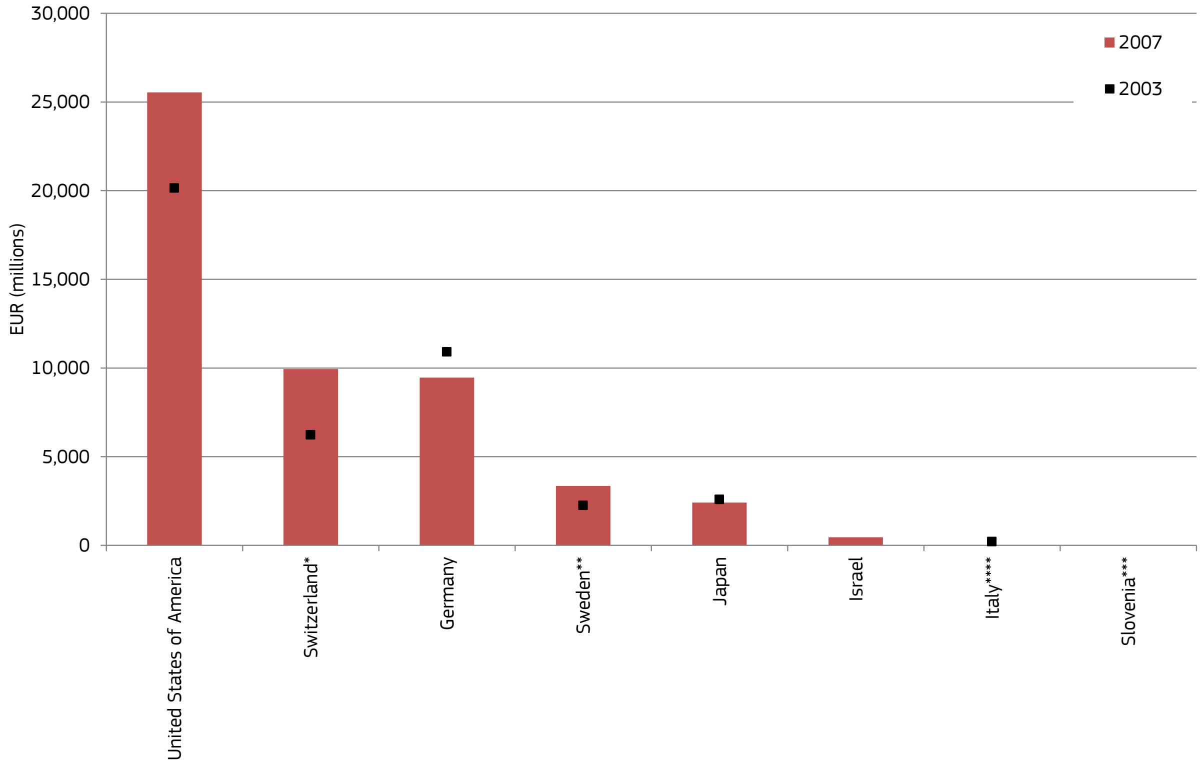


Note: * 2008 instead of 2007 and 2004 instead of 2003, ** only manufacturing included; *** no data for years before 2007; **** 2003 only year with data

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

Total outward BERD in absolute terms is depicted in Figure 8 below. It does not come as a surprise that total outward BERD is largest for the United States, as its stock of FDI abroad is the largest of all countries observed here. Switzerland whose outward R&D intensity is largest (see Figure 7) is ranked second, right before Germany and Sweden. Total outward BERD has increased significantly in the United States, Switzerland and Sweden since 2003 (Switzerland 2004) but at the same time slightly decreased in Germany and Japan. The largest increases can be found for the United States; Switzerland showed considerable increases as well.

Figure 8: Total outward BERD (EUR, 2003 and 2007)



Note: * 2008 instead of 2007 and 2004 instead of 2003; ** only manufacturing included; *** no data for years before 2007; **** 2003 only year with data

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

4.4. Inward BERD across sectors and industries

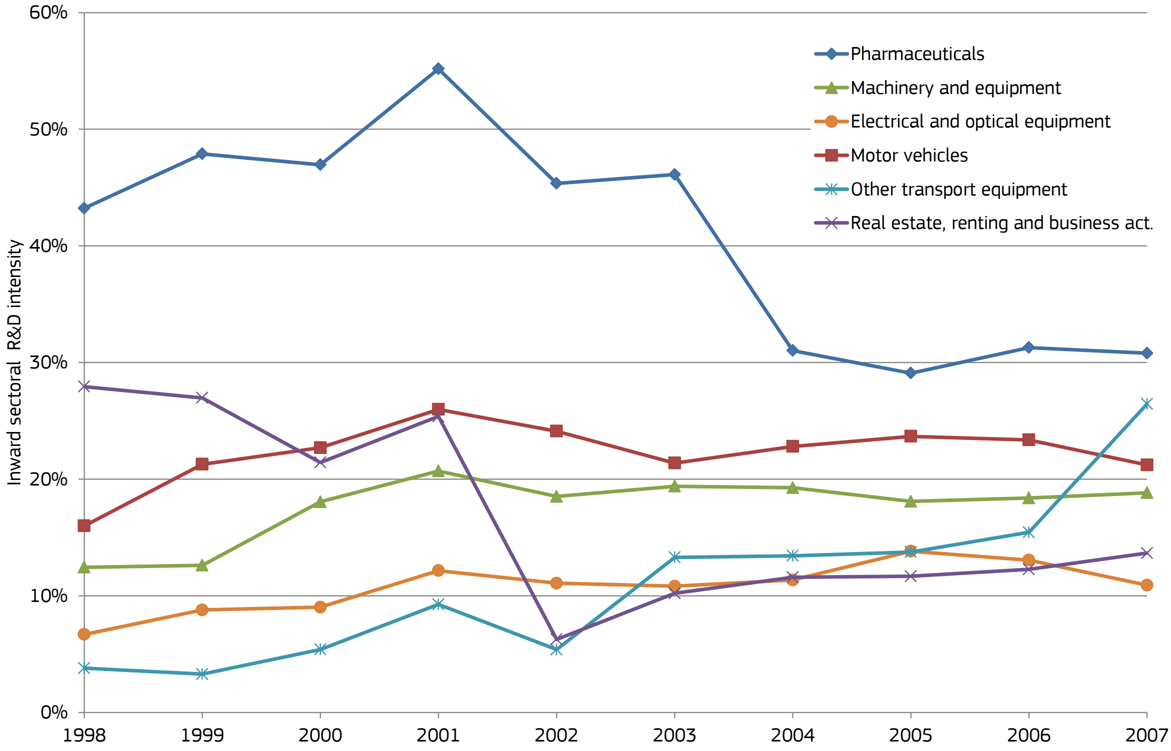
Due to data constraints, the analysis the internationalisation of business R&D across different sectors and industries is limited in two respects: first, the data only allow an analysis of inward BERD data. Second, the countries for which data is available differ across sectors and over time. As a result, the analysis is only feasible for the six largest sectors – five manufacturing sectors and knowledge-intensive services - and results have to be interpreted very cautiously.

All five manufacturing sectors included are high technology or medium-high technology sectors: pharmaceuticals, machinery and equipment, electrical and optical equipment (including office, accounting and computing machinery; electrical machinery and apparatus; radio, TV and communications and medical, precision and optical instruments) motor vehicles and other transport equipment (including aircraft and spacecraft). The only non-manufacturing sector considered is real estate, renting and business activities. It includes most knowledge intensive services (KIS) which in most countries make up a huge proportion of inward BERD in services. As mentioned before, these six sectors are of outstanding absolute importance, each of them attracting between 5.2 billion PPS EUR (machinery and equipment) and 16.4 billion PPS EUR (pharmaceuticals) inward BERD in 2007 worldwide.

Figure 9 compares inward sectoral R&D intensities for these six sectors over time. This intensity is defined as the ratio of total sectoral inward BERD to total sectoral BERD.

The pharmaceutical sector is the sector with the highest inward R&D intensity and thus the most internationalised sector over the whole period. However, there is a sharp decline in inward intensity from about 45% in 2003 to about 30% in 2004. This decline is not caused by a reduction in inward BERD but by a massive increase of domestically owned BERD in the US from 6.2 billion PPS EUR in 2003 to 19.2 billion PPS EUR in 2004, an increase of 12.8 billion PPS EUR or 199% within one year. As a result, global total sectoral BERD in pharmaceuticals increased by almost exactly the same amount, 13.3 billion PPS EUR. Combined with a fairly stable worldwide inward BERD (11.9 billion PPS EUR in 2003 and 12.1 billion PPS EUR in 2004), this leads to the observed decrease in sectoral R&D intensity.

Figure 9: Inward sectoral R&D intensity (inward BERD / total BERD, 1998 to 2007)



Note: Data includes **Belgium** (2000-2007), **Czech Republic** (1998-2007), **Germany** (2001-2007 except pharmaceuticals 2003-2007 and electrical and optical equipment 2005-2007; inward values in 2002, 2004 and 2006 own calculations), **Estonia** (only machinery and equipment 2006-2007, electrical and optical equipment 2003-2007 and real estate, renting and business act. 2003-2007), **Spain** (2003-2007 except pharmaceuticals 2003-2005), **France** (1998-2007 except electrical and optical equipment 2001-2007 and real estate, renting and business act. no data; inward values in 1999, 2000 and 2004 own calculations), **Ireland** (2003-2005 except pharmaceuticals 1999-2001 and 2005, machinery and equipment 1999-2005 and real estate, renting and business act. 2005; inward values in 2000, 2002 and 2004 own calculations), **Italy** (2001-2007 except pharmaceuticals no data, other transport equipment included in motor vehicles; inward values in 2003 and 2004 for real estate, renting and business act. own calculations), **Hungary** (only machinery and equipment 1998-1999 and electrical and optical equipment 2003-2007 and motor vehicles 1998-1999), **Netherlands** (1998-2001 and 2007 except pharmaceuticals 1999-2001, other transport equipment 1998 and real estate, renting and business act. no data), **Austria** (2003-2007, except pharmaceuticals, electrical and optical equipment and real estate, renting and business act. 2004-2007; inward values in 2005 and 2006 own calculations); **Poland** (1998-2007, except pharmaceuticals no data, real estate, renting and business act. 2005-2006; inward values in 2002 and 2002 for other transport equipment own calculations); **Portugal** (1999-2007, except pharmaceuticals no data; inward values in 2000, 2002, 2004 and 2006 own calculations), **Romania** (only machinery and equipment 2004-2005, motor vehicles 2004-2006, other transport equipment 2005 and real estate, renting and business act. 2005-2007), **Slovenia** (only machinery and equipment 1998-1999 and real estate, renting and business act. 1998 and 1999), **Slovakia** (only machinery and equipment 2003-2007, electrical and optical equipment 2004-2005, real estate, renting and business act. 2003-2004 and 2006-2007), **Finland** (pharmaceuticals 1998-2001 and 2005-2006, machinery and equipment 1998-2001 and 2005-2007, 30-33 1998-2001 and 2007, motor vehicles 2000 and 2005-2006, other transport equipment 1998-2001 and 2007, real estate, renting and business act. no data), **Sweden** (1998-2007, inward values in 2004 and 2006 own calculations), United Kingdom (1998-2007, inward values in 2005 and 2006 own calculations), **Turkey** (1999-2000 and 2002 except other transport equipment and real estate, renting and business act. no data), **Norway** (2007, excl. pharmaceuticals), **Japan** (1998-2007, excl. pharmaceuticals, real estate, renting and business act. 2003-2007), **United States of America** (1998-2007, except real estate, renting and business act. 2002-2007; electrical and optical equipment only includes NACE sections 30 and 31 in 1998, 31 in 1999 and 2000, 30-32 in 2001, 31 and 33 in 2002, 30 and 33 in 2004, 33 in 2005, 31 and 33 in 2006, inward value in 1999 for motor vehicles and other transport equipment own calculations), **Canada** (1998-2001 and 2006-2007, except pharmaceuticals 1998-2001)

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

The second most important sector in terms of inward R&D intensity is real estate, renting and business activities which also experienced a massive drop in sectoral R&D intensities from 2001 to 2002. Again, it is not caused by a decrease in inward BERD but an increase in total BERD caused by an increase in domestic BERD. US data for this sector is not available before 2002, and the inclusion of US data boosts total sectoral BERD from 7.4 bn to 45.7 billion PPS EUR while inward BERD only increases from 3.3 billion to 6.0 billion PPS EUR.

The third outstanding annual change in intensity levels, the increase in other transport equipment from 2006 to 2007, is again caused by a change in US data. However, in this case the movement is caused by a massive increase of inward BERD in the aircraft and airspace sector in the US, which is included in other transport equipment. This may be due to a takeover of a US aircraft company. The three remaining sectors all have stable and comparable low intensity levels between 10 and 20% for the most recent years.

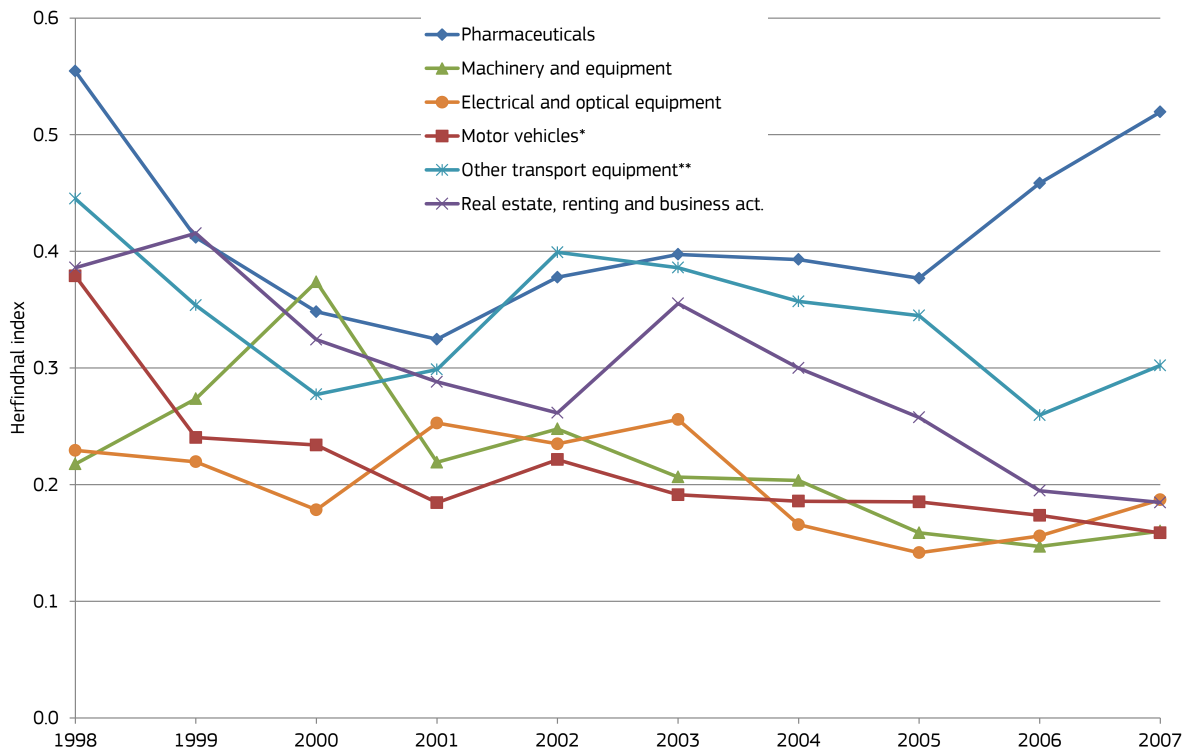
Figure 10 displays the concentration of inward BERD across destination countries for the six sectors considered measured by the Herfindahl-Index. A low Herfindahl value indicates that inward BERD in the sector is more equally distributed across different countries, and a high value indicates a concentration of sectoral inward BERD in one or a few countries.

Four of the six sectors considered, machinery and equipment, electrical and optical equipment, motor vehicles and real estate, renting and business activities, show decreasing and converging concentration levels as already observed for total inward R&D (see Section 4.2 above), indicating a diminishing skewness of the distribution of inward BERD, i.e. greater variety and a larger number of countries of destination.

Pharmaceuticals, and to a smaller extent other transport equipment, have sustained higher concentration levels. The concentration in the pharmaceutical industry increased considerably over the last years. This increase is caused by the growing role of the US as a destination for inward BERD in the pharmaceutical industry, increasing from 7.3 billion PPS EUR in 2005 to 11.6 billion PPS EUR in 2007. At the same time, inward BERD in this sector in all other countries together slightly decreased from 5.1 billion PPS EUR to 4.8 billion PPS EUR. As a result, more than 70% of worldwide inward BERD in this sector in 2007 is located in the US.

A different perspective on R&D internationalisation at the sectoral level emerges if we look at the contributions of different host countries to global inward BERD in a sector. This perspective reveals the preferred host countries in different sectors.

Figure 10: Concentration of inward BERD by host country and sector (1998 to 2007)



Source: OECD, Eurostat, national statistical offices, own calculations, for included countries see Figure 9

Figure 11 illustrates simple inward country penetration, defined as the shares of inward BERD from a certain host country in total inward BERD in the sector considered, for each of the six sectors. All simple inward sector penetration values therefore add up to 100%.

Besides the US, which plays a dominant role as location for inward BERD in pharmaceuticals, only two more countries, Germany and Belgium, account for more than 5% of the total sectoral inward BERD in the sector. All other countries of the world together only account for about 15% of total sectoral inward BERD, explaining the high concentration in that sector mentioned before.

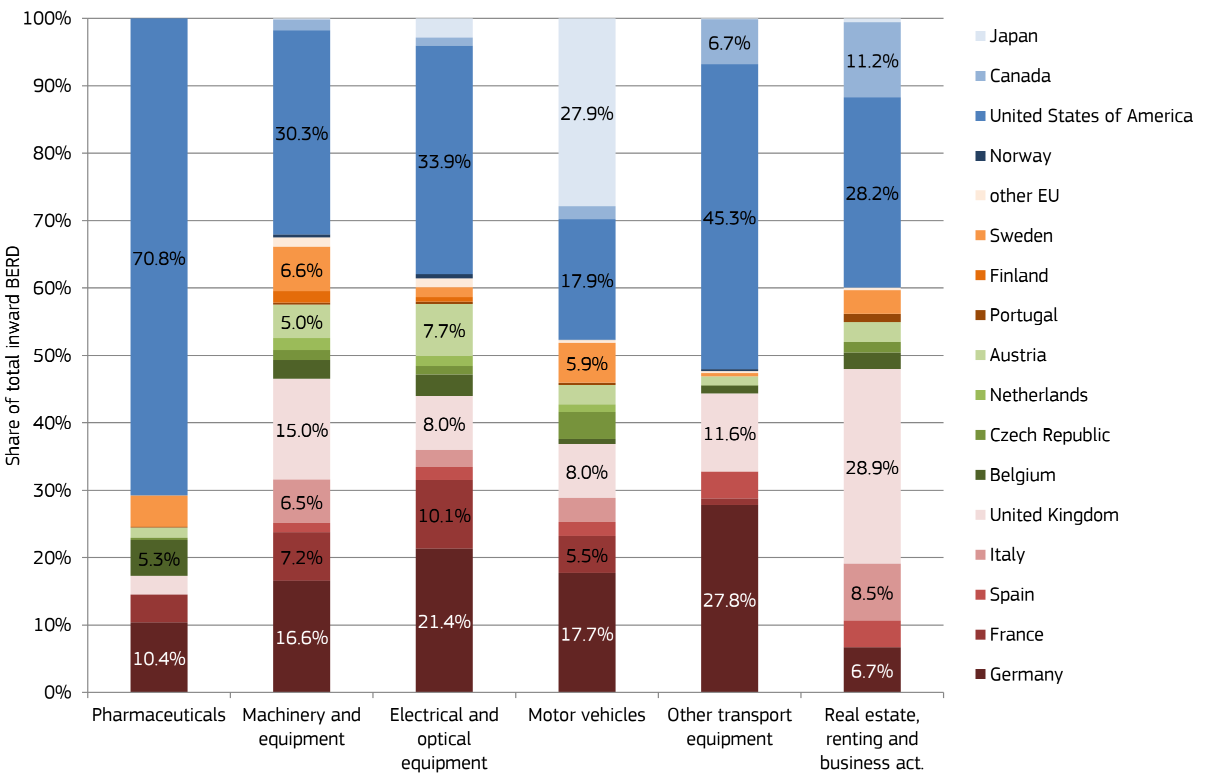
Machinery and equipment, one of the sectors with the lowest concentration by controlling country, is the sector with the highest cumulated value for all EU countries. All EU member countries together attract more than 2/3 thirds of global inward BERD in this sector. While the US plays a much smaller role, with more than 30% it still accounts for the lion's share of the remaining inward BERD. Interestingly, inward BERD in machinery is widely distributed across different EU countries. While two of the largest EU economies, Germany and the United Kingdom, are ranked second and third worldwide, also smaller economies, including Sweden (6.6% of total inward BERD) and Austria (5%) play a certain role. With seven countries each attracting more than 5% of total inward BERD, this sector has the highest number of host countries above this threshold.

The overall picture is similar for the electrical and optical equipment sector. With more than 20% of total sectoral inward BERD, Germany clearly leads the EU. In contrast, small and medium sized EU countries with large domestic MNCs, including the Netherlands, Finland and Sweden, attract significantly less inward BERD in this sector.

Motor vehicles differ in one important aspect from all other sectors as it is the only manufacturing sector where Japan, and not the US, is the largest attractor of inward BERD. However, the important role of Japan as a destination of inward BERD is mainly caused by the alliance between Renault, a French carmaker, and Nissan.

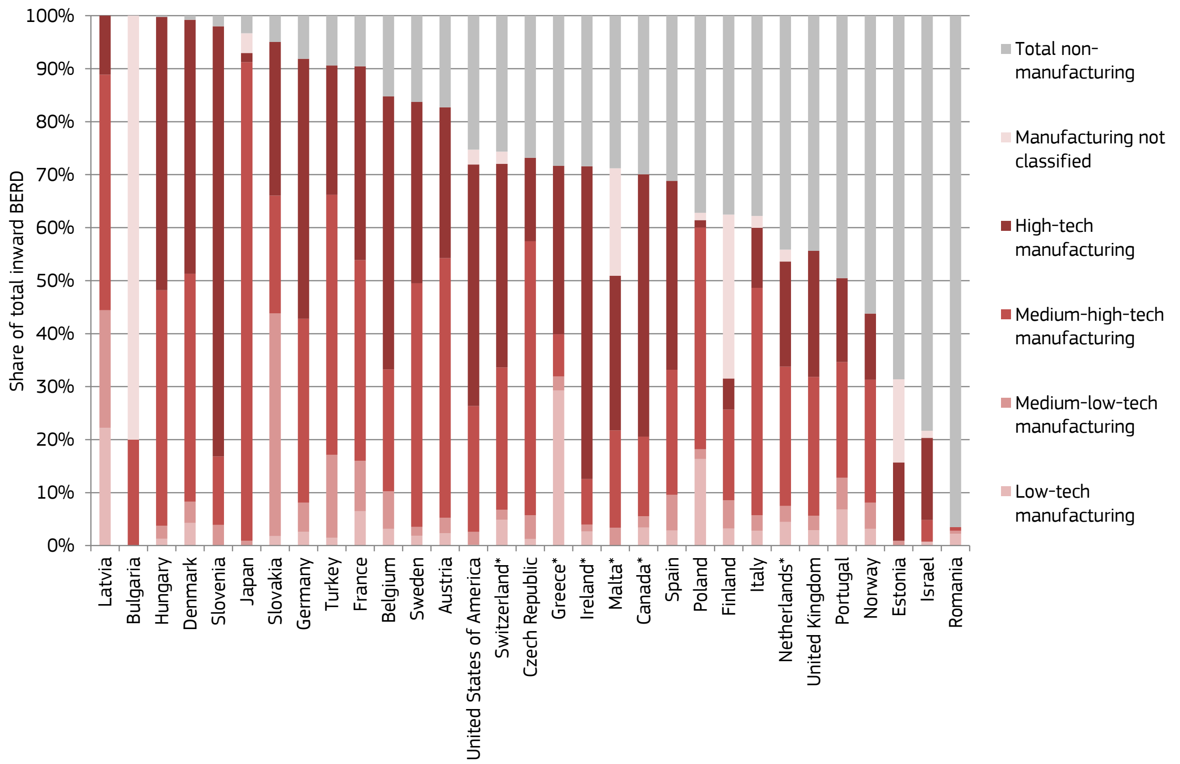
Internationalisation in other transport equipment, the sector with the second highest concentration of inward BERD, is again dominated by the US with a share of more than 45% in 2007. The second most important country is Germany with another 28%. Two more countries, the United Kingdom (11.6%) and Canada (6.7%) are of importance as well whereas all remaining countries play only a limited role with a share of only 8.7% in total.

Figure 11: Share of total inward BERD by host country and sector (inward BERD in country X in sector Y / total inward BERD in sector Y, 2007)



Source: OECD, Eurostat, national statistical offices, own calculations, for included countries see Figure 9.

Figure 12: Inward BERD by type of industry (2007)



Note: * 1999 (Greece), 2001 (Canada, Netherlands), 2005 (Ireland) and 2008 (Malta, Switzerland) instead of 2007; Due to data constraints in the services sector, we only consider five industries: four manufacturing industries and total non-manufacturing (including KIS and LKIS but also all other non-manufacturing sectors).

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

Real estate, renting and business activities is the only sector with an EU country, the United Kingdom, attracting most inward BERD. Germany and France play only minor role while Canada is ranked third worldwide with a share of 11.2% on total inward BERD. With the US ranked second, all top three countries are English speaking countries and share a similar cultural background. Unfortunately there is no data available for Ireland in 2007; however, in 2005 Ireland attracted another 3% of worldwide inward BERD in this sector.

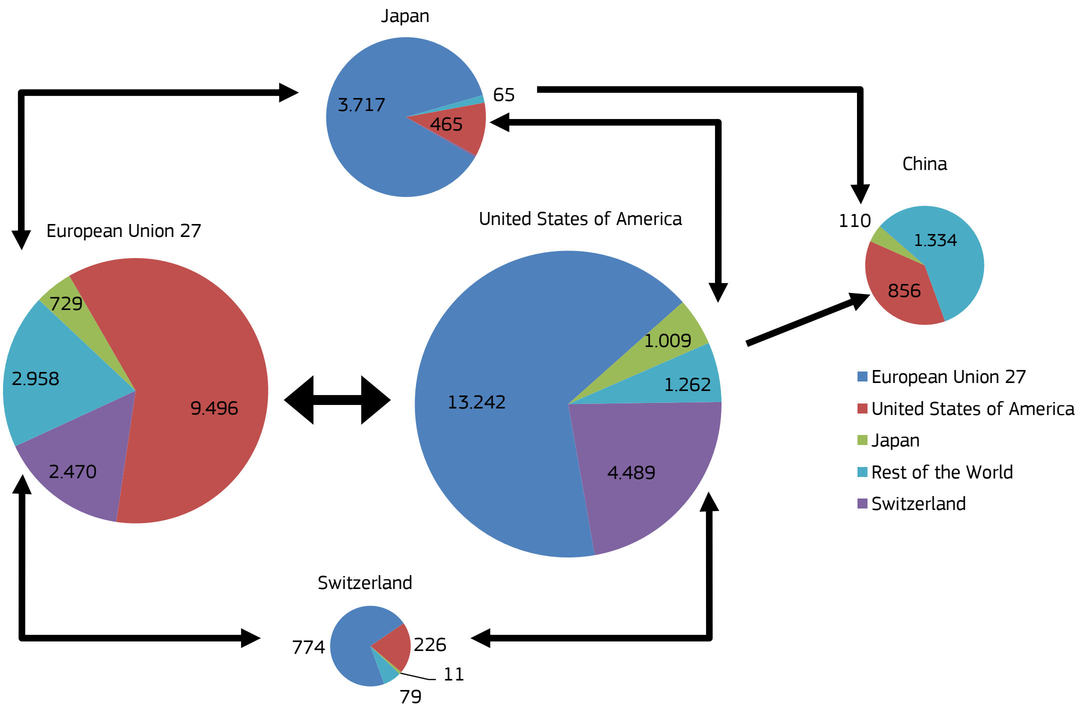
Finally, inward BERD by type of industry (Figure 12) confirms the outstanding role of high and medium-high technology manufacturing for total inward BERD in almost all countries. Non-manufacturing sectors are only relevant in a few small and medium sized countries such as Estonia and Israel, where foreign-owned firms in computer and commercial R&D services have a huge share on total inward BERD. In some other countries the results of Figure 12 may at least partly be caused by the poor coverage of service sectors.

4.5. The relationship between the European Union and United States of America

The EU and the US play an outstanding role in the internationalisation of business R&D, both as countries of origin and as locations for the R&D activities of foreign MNEs. The linkage between the US and the EU is the single most important bilateral relationship in the internationalisation of business R&D. This section therefore looks in detail at business R&D of EU firms performed in the US and compares it with the business R&D expenditure of US firms in the EU.

Figure 13 illustrates the global inward BERD relationships for the manufacturing sector of the EU-27, the US, Japan, China and Switzerland. The service sector is excluded due to missing data. The size of the pie chart for each country indicates the total amount of inward BERD in this country, while the pie slices represent inward BERD from one particular country of origin. The major relations between the countries are illustrated with arrows. The figure reveals the outstanding importance of the relationship between the US and the European Union. Inward BERD of US firms in the EU

Figure 13: Inward BERD relations between the EU, the United States, China, Japan and Switzerland by location (2007, EUR Mio current prices)



Reading note: Firms from the European Union have spent 774 Mio EUR on R&D in Switzerland in 2007; Swiss firms have spent 2,470 Mio EUR on R&D in the EU-27 in 2007. Swiss data include also the service sector; data for China is estimated based on national sources and US and Japanese outward data.

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

and inward BERD of EU firms in the US together account for 2/3 of total inward BERD in manufacturing world-wide[2]. The US is also the largest investing country in the majority of the EU member states. US firms account for more than 65% of the total inward BERD in manufacturing in the EU or more than 90% when we exclude other European, but non-EU countries (mainly Switzerland and Norway). The figures are very similar if we look at R&D performed by US firms abroad. In 2007, 62% of US outward BERD is located in the EU member countries. Asia ranks second with a share of only 13%.

In recent years, China has emerged as a new location for R&D of foreign-owned firms. However, Chinese data is incomplete and plagued by some methodological issues which render a comparison with data from OECD countries difficult (see also Box 1). We only included the R&D expenditure of wholly foreign-owned companies in China in Figure 13, which is 2.4 billion EUR for the year 2007. A breakdown of this amount into different countries of origin is not available.[1]

2 The European Union is considered as one entity, and intra-EU relationships (for example R&D of German firms in France) are not taken into account

In a next step, we take a closer look at the distribution of the R&D expenditure of EU firms in the US by country of origin (Figure 14). The figure has to be interpreted very carefully due to several data constraints. First, we can only employ US inward data, since there is no outward BERD data available for most EU countries. Second, the US statistical office does not provide a value for the whole EU-27, but only for 'total Europe'. The EU total used for the analysis therefore includes total Europe, excluding Switzerland.

Simple inward country penetration, the ratio of inward BERD from a certain EU country to total inward BERD from the EU in the US, reveals that three countries account for 80% of R&D expenditure of EU firms in the US: Germany, France and the United Kingdom. In all but the last year Germany is the largest of these three countries. In 2006, the United Kingdom overtakes Germany as the most important foreign investor in business R&D in the US.

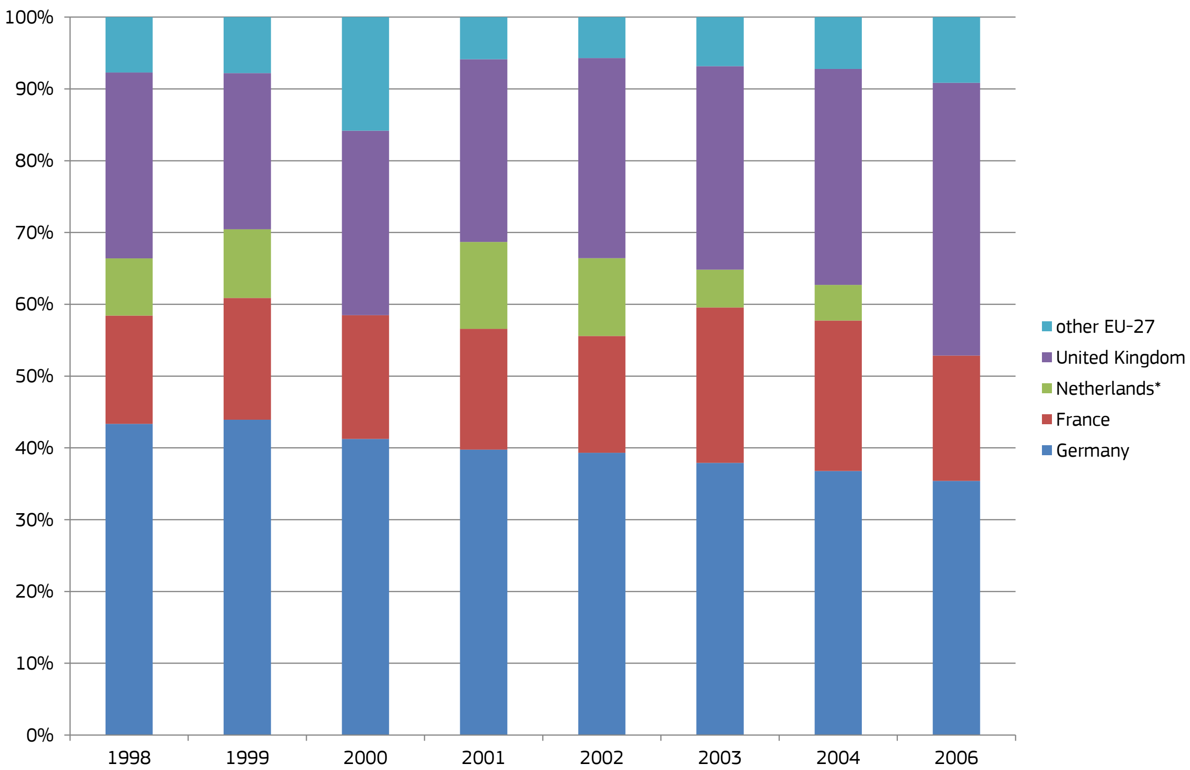
Figure 15 illustrates in a similar way the distribution of R&D expenditure of US firms across EU member states. Again, the United Kingdom, Germany and France receive the highest shares. However, the relative importance of the three top countries declined over time while the total amount of

Box 1: What is the true amount of inward BERD in China?

In 2007, inward BERD in China amounted to 61.5 billion RMB (around 6.1 billion EUR) according to Chinese statistics. The sum of all available outward BERD (including the US and Japan) for that year, however, amounts to only 1.1 bn EUR, or 18% of total reported inward BERD. Thus, outward BERD to China may be significantly under-reported or inward BERD over-estimated, or both.

There are several reasons for a possible over-estimation of China's inward BERD. A first reason is the reporting of Joint Ventures which still comprise more than half of all foreign-owned enterprises in China. Some researchers argue that Joint Ventures between Chinese and foreign partners may often report their full R&D expenditure as inward BERD to the Chinese Statisti¬cal Office. If we only consider R&D expenditure of wholly foreign-owned companies to avoid over-reporting, inward BERD comes up to 2.3 bn EUR instead of 6.1 bn EUR in 2007. Moreover, there may be also deliberate over-reporting, since R&D activities are a sign of commitment to the host country and often a necessary condition for government support. Finally, firms may report planned R&D ex¬penditure as realized R&D in the surveys.

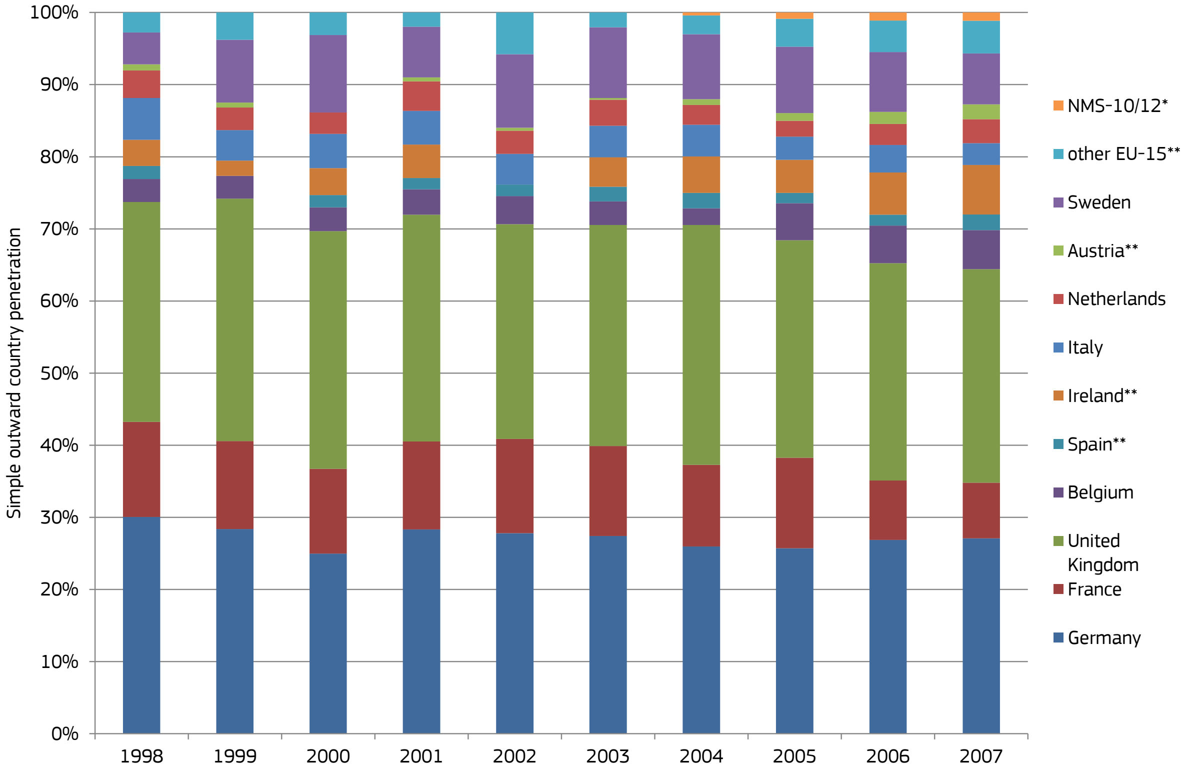
Figure 14: Countries of origin of EU inward BERD in the US (inward BERD from EU-27 country X in US / inward BERD from total EU-27 in US, 1998-2006)



Note: * included in other EU in 2000 and 2006; Total EU-27 includes all European companies except Swiss companies. No country breakdown possible for 2005 and 2007.

Source: OECD based on US data by the US Bureau of Economic Analysis, own calculations

Figure 15: Location of US inward BERD in the EU (US outward BERD in EU-27 country X / US outward BERD in total EU-27, 1999-2007)



Note: * EU-10/12 includes from 2004-2007 the Czech Republic, Estonia, Cyprus, Latvia, Lithuania, Hungary, Malta, Poland, Slovenia and Slovakia and in 2007 additionally Bulgaria and Romania; ** other EU-15 includes Greece, Ireland (only 2002), Denmark, Luxemburg, Portugal and Finland, Austria (only 2000) and Spain (only 1999)

Source: OECD based on US outward data by the US Bureau of Economic Analysis, own calculations

US inward BERD in the EU increased. As a result, an increasing share of US inward BERD is not located in the UK, Germany or France. In 2007 more than 1/3 of US inward BERD in the EU is located outside the top three countries.

A comparison of Figure 14 and Figure 15 also reveals that US inward BERD in the EU is much less concentrated than EU inward BERD in the US, and small and medium sized countries are by far more important as locations for R&D by US companies than as home countries of MNEs performing R&D in the US. Each of the Top Ten ranked EU countries account for more than 2% of the total US outward BERD in the EU, highlighting again the decreasing concentration of business R&D internationalisation patterns.

4.6. New players in the internationalisation of R&D

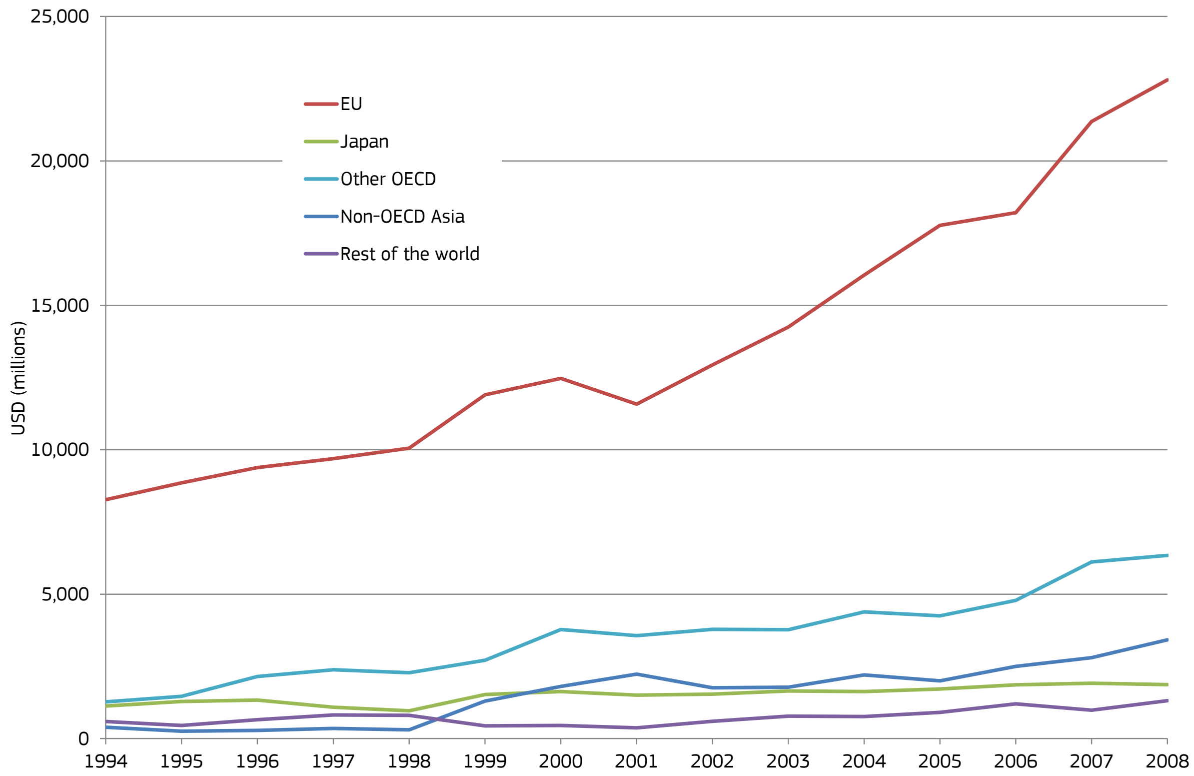
According to Pearce (1995, p. 23), MNEs from the US and UK pioneered the establishment of overseas R&D units. Some smaller European countries (in particular Switzerland and Sweden) started to internationalise R&D relatively early as well, while firms from France, Germany, Italy, or Japan, started much later (UNCTAD 2005, p. 122).

Since the beginning of the new millennium, new players are entering the stage. Asian countries, particularly China and India became host countries for R&D activities of US and European firms (Asakawa and Som 2008, Baskaran and Muchie 2008). Moreover, Chinese, Indian or Brazilian firms are starting to set up their own R&D activities in Europe and the US (Zhang and Filippov 2009, Di Minin and Zhang 2010).

According to UNCTAD (2005, p. 139), “the rise of developing Asia and Oceania has been the most dramatic development in the global landscape of R&D”. There is considerable evidence that supports this claim:

By 2004, foreign MNEs have established 700 R&D centres in China (Baskaran and Muchie 2008, p. 14). In 2005, their number increased to 750 (Walsh 2007). In India, between

Figure 16: Overseas R&D expenditure of US firms in Mio USD, 1994-2008



Source: OECD based on US outward data by the US Bureau of Economic Analysis, own calculations

35 and 40 new foreign R&D centres per year were established after 2000, with a total number of 200 international R&D centres in 2007 (Krishna and Bhattacharya 2009, p. 7-8). R&D investment in India has more than doubled between 2003 and 2008 and at the end of the period it came up to 25% of total FDI in the country. US MNEs account for above 70% of the total FDI in R&D in India, but also South Korea, Germany, Denmark and the UK have significant shares. Particularly in India, some small and medium enterprises (SMEs) started to engage, together with MNEs, in inward R&D investment (Baskaran and Muchie 2008, pp. 14-18).

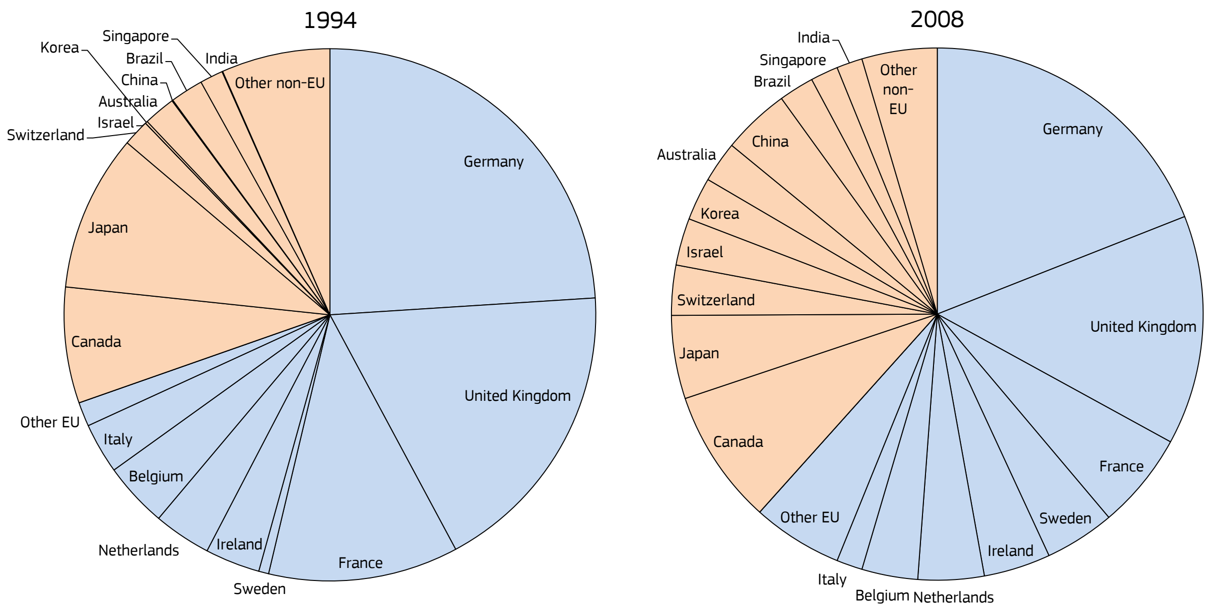
According to an IBM survey (IBM 2009), India ranked at first place, measured by the number of new jobs created from foreign investment in stand-alone R&D projects in 2008 (albeit with a strong focus on software development). China ranked second, surpassing the USA (IBM 2009, p. 17). Cincera et al. (2009, p. 4) describe particularly China and India as "the two biggest net-importers of R&D". An UNCTAD survey among the world's largest R&D spending MNEs, asking for the most attractive prospective R&D locations 2005-2009, indicates that the growing preference for emerging countries as R&D locations is expected to continue. China ranked as the most attractive future R&D destination, India ranked third, right after the United States. The Russian Federation also appeared at the sixth rank (UNCTAD 2005, p. 153).

The emergence of China and India looks impressive from these sources; however, a few caveats have to be noted; first, the studies cited here usually cover less than 200 large MNEs and their results may be biased by this selection.

Second, the surveys often attempt to measure future plans and the perception of various R&D locations, not the actual investments. There may be a gap between what executives think are important locations and the realisation of these plans some years later. This can be observed, for example, in the annual EU Survey on R&D Investment Business Trends organized by DG Research and Innovation and JRC-IPTS (European Commission 2010): expected changes in R&D expenditures in India and China reported by the firms are constantly higher than the actual growth rate two or three years later.

Third, R&D internationalisation is not a zero-sum game. Our data show that R&D expenditure has increased in all world regions in the years until 2007. There is no substitution of inward BERD in the EU by activities in Asia. As a result, the gap between the EU and Asia closes only slowly. Similar evidence is given by the DG Research and Innovation and IPTS survey of EU MNEs (European Commission 2010). Growth of R&D expenditure, however, will be much faster in emerging economies.

Figure 17: Share of various countries on overseas R&D expenditure of US firms, 1994 and 2008



Source: OECD based on US outward data by the US Bureau of Economic Analysis, own calculations

A much more reliable source to study the emergence of new players in R&D internationalisation in detail is data on US outward BERD (Figure 16). This is the only data source which results from a large-scale survey and provides continuous time series on outward BERD over a longer period. The data was already used in the previous section.

Between 1994 and 2008, outward BERD of US firms more than tripled in nominal terms from 11.8 billion USD to 36.1 billion USD. The share of non-OECD Asia (China, India, and Singapore to name the most important countries of this group) increased nearly tenfold, from 391 Mio to 3,423 Mio USD. This was a very impressive growth in relative terms; however, in absolute terms, most of increases in US outward BERD have been spent in the EU-27, in particular in Germany, the UK, and France. Outward BERD of US firms to the EU-27 grew from 8,271 Mio USD to 22,803 Mio USD in 2008. Outward BERD of US firms in Japan, in contrast, grew only moderately from 1,130 Mio USD 1,872 Mio USD.

But new players are not only emerging in Asia. As a consequence of the preoccupation of many observers with China and India, the emergence of some other countries as locations for R&D of MNEs is often missed. Examples are Australia, Canada, Israel, Korea and Switzerland, which are included as 'other OECD countries' in Figure 16. Some of these countries could attract considerable amounts of US outward BERD since 1994. Korea and Israel, for example, grew from virtually no US inward BERD in 1994 to around 1 billion USD of US outward BERD in 2008, and also Canada and Australia could considerably increase their share on total US outward BERD in this period.

US outward BERD increased in all country groups depicted in Figure 16, so there was no shift of R&D expenditure from EU or OECD countries to emerging economies in absolute terms. However, we find some shifts in relative terms, which are shown in the following Figure 17. In short, there is a significant decrease in the share of US outward BERD to developed countries and the EU-27 in particular, and rising shares of East Asian economies, especially of China, Singapore, India and Malaysia.

Further increases of US outward BERD to China, India and other emerging countries are likely as US multinational firms will further increase their turnover and production in these countries. Past experience, however, also teaches that there is no reason to fear that the EU-27 will lose US outward BERD to these countries – as long as the EU can preserve its growth prospects, locational advantages for R&D, and a favourable business environment.

5. THE CROSS-COUNTRY STRUCTURE OF R&D INTERNATIONALISATION

5.1. The network perspective

We now move one step further and analyze the structure of R&D internationalisation from a network perspective. In this perspective, we look at the whole set of countries and relationships between these countries as measured by inward BERD. The aim of this approach is to make sense of the structure of this network, to identify the countries which are well connected with all other countries, or have no connection with parts of the network. In addition, we will identify the strongest links at the level of individual countries, as well as analyse if there are sub-groups of countries in the network which are well-connected with each other, but have only weak linkages with other countries. We consider the inward BERD linkages between countries as an indicator for international technology diffusion (Keller 2004, 2010). R&D activities of foreign-owned firms inevitably lead to transfers of information and knowledge from foreign-owned firms to domestic organisations.

Social network analysis (SNA) has come into wide use for the analysis of social systems in the recent past. SNA offers a wide range of analytical tools disclosing the structure of large social systems. Central to network analysis is identifying, measuring, and testing hypotheses about the structural forms and substantive contents of relations among actors (Knoke and Young 2008), in our case firms aggregated to the country level. This distinctive structural-relational emphasis sets social network analysis apart from individualistic, variable-centric traditions in the social sciences. The main underlying assumption in this context is that structural relations are often more important for understanding observed behaviour than are attributes of the actors.

This subsection presents various network indicators and the visualization of the network of inward BERD linkages. All countries where sufficient data is available are included. We will describe the cross-country network of inward BERD as a whole, and shed light on the position and roles of different countries in this network. Further we will visualize the spatial structure of the network under consideration by means of spatial network maps. After that we will identify the relative most important country pairs in terms of their pair wise R&D investment intensity, providing important insight into the geographical patterns of R&D investments.

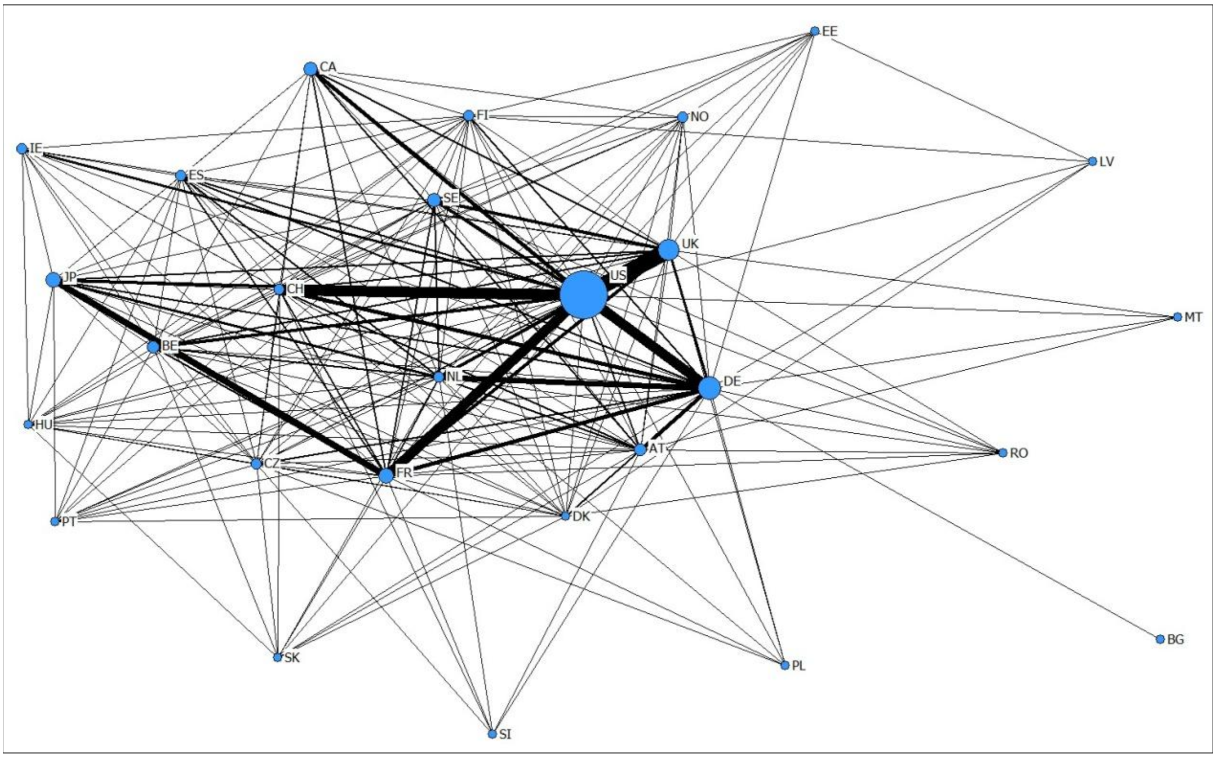
5.2. Some descriptive analyses from a social network perspective

A network can be viewed in several ways. In our context, the most useful view is as a graph consisting of nodes (vertices) and edges (links). A familiar representation is obtained by letting V be a set of nodes representing countries participating in the inward BERD network, and E be a set of edges where elements of E are unordered pairs of distinct nodes v_i, v_j representing a link in the form of R&D investment flows between a pair $\{v_i, v_j\}$. The two sets together are called a simple graph $G_1=(V, E)$ where all pairs $\{v_i, v_j\}$ are distinct; the number of edges incident on a vertex $i=1, \ldots, n$ is called the degree k_i. Note that G_1 represents an unweighted graph by definition. In our case, it is natural to consider the weighted form given by $G_2=(V, E, W)$ where $W=\{w_1, w_2, \ldots, w_n\}$ represent weights between two nodes v_i and v_j denoting the magnitude of inward BERD. In the current analysis, we will draw on both types of graphs for different kinds of indicators and descriptive statistics. Readers should further note that we symmetrize G_2 by taking the sum of R&D inward flows between two countries as weights between them, i.e. both G_1 and G_2 represent undirected graphs. This is more appropriate to handle in a social network analysis framework.

In a first step, Figure 18 visualizes the inward BERD network using G_2. Countries that show a relatively higher intensity of bilateral inward BERD flows are positioned nearer to each other. The node size corresponds to the weighted degree centrality of a country that is defined as the sum of a country´s inward and outward BERD. Outward BERD is approximated by the corresponding inward BERD of the partner country.

The United States represents the central hub in this network in terms of absolute size showing the highest interaction intensity with other countries. The most important partners in terms of absolute size are the UK, Germany, Switzerland and France. The graph visualization reveals that the UK shows striking higher interaction intensity with the US than with Germany or France in this network. Germany has the highest interaction with the US followed by the Netherlands, while France shows comparably high interactions with Japan. A surprising result is also that Switzerland is more connected with non-European countries, particularly the US and Japan, than embedded in the European sub-network.

Figure 18: Network of inward BERD relationships between 27 countries, 2007



Note: Vertex positions were determined so that countries that are strongly interconnected are positioned nearer to each other. 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 correspond to total R&D investment between any two countries.

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

We will further investigate the structure of the inward BERD network between the 27 countries with indicators that investigate the connectedness and cohesion of this network, or, in other words, how well-connected the countries in this network are (Figure 18). Table 4 comprises respective SNA measures also used in similar empirical works based on other forms of R&D interactions (see, for instance, Breschi and Cusmano 2004). Details on the mathematical definition of the indicators listed in Table 4 are given in Wasserman and Faust (1994). For comparison purposes we relate the SNA indicators calculated for the network of inward BERD with those calculated for a random graph using the same number of nodes (n = 27).

The results from Table 4 indicate that the connectedness and cohesion of the inward BERD network is comparably high. The density of the inward BERD network shows a value of 0.554, i.e. more than 50% of all possible links between any two countries are established; a much higher value than is usually found for real-world social networks as indicated by the density for the random graph. The true density may be even higher, because some data are not available due to confidentiality. The high degree of connectedness and cohesion is also reflected by the average path length – given by the average of the shortest paths between all pairs of nodes – that is much smaller as for the random graph. This is confirmed by the clustering coefficient which measures the likelihood that two associates of a country are associates themselves, for example country A and country B are connected under the condition that country A is connected to a country C to which also country B is connected. In our case, we can speak of a very 'cliquish' network showing explicitly a so-called small world character (see Watts and Strogatz 1998).

Connectedness and cohesion of the network is also reflected by the diameter – referring to the highest path length observed in a network – showing a value of 2 for the inward BERD network as compared to a value of 5 for the random graph. The mean degree, i.e. the mean number of partner countries for any country, shows a value of 14.9 while for the random graph the mean degree is 4.1. The number of nodes that have a higher degree than the mean is more than 50%, indicating that most countries have many interaction partners while the minority of the countries has very few interaction partners.

A central point in the context of the structural analysis of the network is the role that different countries take in this network. The concept of centrality is a useful approach to investigate this issue. We shortly introduce this concept; the mathematical specification of the indicators is given in Wasserman and Faust (1994). In this analysis we focus on four different types of centrality measures that are calculated for each country:

First, degree centrality is defined as the ratio of the degree of a node and the maximum degree in a network of the same size (i.e., the total number of edges connected to a node). Second, eigenvector centrality accords each vertex a centrality that depends both on the number and the quality of its connections by examining all vertices in parallel and assigning centrality weights that correspond to the average centrality of all neighbours. Third, closeness centrality of a vertex is defined as the inverse of the mean geodesic distance (i.e., the mean length of the shortest path) from this vertex to every other vertex in a connected graph. Fourth, betweenness centrality is measured by the frequency of one actor positioned on the shortest path between other groups of actors arranged in pairs. Those actors, who are located on the shortest paths between many actors, therefore hold a key position for controlling the flow of information within the network (gatekeeper function).

Table 5 presents the results on the centrality rankings of our 27 countries participating in the inward BERD network. The first column contains the calculated values for degree-based centrality. Germany shows the highest degree centrality among the countries under consideration, followed by the US. This means that Germany has the highest number of partner countries. The Netherlands has a higher number of partner countries than France or the UK. The Czech Republic shows more partner countries than Austria, Switzerland, Belgium, Finland and Sweden though it has a lower magnitude of inward BERD in total, pointing to a comparably spatially dispersed partner structure of the Czech Republic. The number of partner countries of Japan is just slightly higher than the average, i.e. the partner structure of Japan is more concentrated than, for instance, the one of France, Germany, the UK and the US. Readers, however, have to bear in mind that some of the effects we see here may explained by the data quality rather than the propensities of the network.

If we turn to eigenvector-based centrality, the ranking changes significantly. The US shows the highest eigenvector centrality indicating that its partner structure is focused on countries that show a high centrality by themselves. Obviously the high eigenvector-based centrality of the US and the UK is also to a large extent related to the quite high interaction intensity between them. Further interesting changes in the ranking as compared to the degree-based centrality are subject to Switzerland, Japan and Canada. Switzerland changes from rank 8 to rank 5, i.e. though it has a lower number of partners than, for instance, Austria, it is connected to more partners that also have a relatively higher centrality. The same is true for Canada that even changes from rank 17 for the degree-based centrality to rank 8 for the eigenvector-based centrality mainly related to its comparably high magnitude of investments with the US, and Japan changing from rank 14 to rank 6. In contrast the Netherlands, Austria, the Czech Republic and Denmark that show a comparably high degree-based centrality take a lower ranking for the eigenvector-based centrality, indicating that on average these countries have more interactions with partner countries showing a low centrality, such as the Eastern European countries.

Table 4: Indicators for cohesion in the network of inward BERD relations, 2007

Indicator	Network of inward BERD	Random graph*
Number of nodes n	27	27
Number of edges l	202	54
Density	0.554	0.148
Clustering-coefficient	0.762	0.116
Diameter	2	5
Average path length	1.466	2.437
Mean degree	14.961	4.120
Number of nodes higher than mean degree (in %)	55.555	33.124

Note that we use the unweighted graph G1 for these indicators

* Erdös-Renyi conceptualization of random graphs

Source: own calculations

Table 5: Centrality of countries in the network of inward BERD relations, 2007

Country	Degree	Country	Eigenvector	Country	Betweenness	Country	Closeness
DE	1.00	US	92.04	DE	15.15	DE	100.00
US	0.92	UK	68.24	US	5.99	US	92.86
NL	0.88	DE	54.49	NL	3.74	NL	89.66
FR	0.85	FR	43.09	UK	3.73	FR	86.67
UK	0.85	CH	32.20	FR	2.96	UK	86.67
CZ	0.81	JP	18.58	AT	2.81	CZ	83.87
AT	0.77	NL	14.58	CZ	2.31	AT	81.25
CH	0.77	CA	11.64	DK	1.99	CH	81.25
BE	0.73	SE	11.55	CH	1.94	BE	78.79
DK	0.73	BE	8.80	FI	1.75	DK	78.79
FI	0.73	AT	7.60	SE	1.16	FI	78.79
SE	0.73	ES	5.11	BE	0.75	SE	78.79
ES	0.65	IE	3.51	ES	0.31	ES	74.29
JP	0.65	FI	2.28	JP	0.31	JP	74.29
HU	0.58	DK	1.41	EE	0.31	HU	70.27
NO	0.54	CZ	1.17	HU	0.27	CA	68.42
CA	0.54	NO	0.77	NO	0.25	NO	68.42
IE	0.46	HU	0.51	CA	0.05	IE	65.00
PT	0.46	PT	0.35	LV	0.03	PT	65.00
SK	0.38	RO	0.26	IE	0.02	SK	61.90
EE	0.35	PL	0.23	SK	0.02	EE	60.47
RO	0.31	SI	0.13	BG	0.00	RO	59.09
PL	0.23	EE	0.09	MT	0.00	PL	56.52
SI	0.23	SK	0.08	PL	0.00	SI	56.52
LV	0.19	MT	0.05	PT	0.00	LV	55.32
MT	0.15	LV	0.00	RO	0.00	MT	54.17
BG	0.04	BG	0.00	SI	0.00	BG	50.98

Source: own calculations

The results for the closeness and the betweenness-based centrality are similar to those for the degree-based centrality ranking. This points to a low modularity of the network, or, in other words, there are no separated groups of countries in the network which are connected only via specific countries that take the role of 'gatekeepers'.

Figure 19 complements the network visualization of Figure 18 by focusing on the spatial structure of the inward BERD network in Europe. Here, we do not position the nodes according to methods from spectral graph theory, but according to their spatial location, i.e. nodes representing participating countries are positioned at the location of the capital city of the respective country. Again node size corresponds to the weighted degree centrality of a country that is defined as the sum of a country´s inward and outward flows.

The spatial network map presented in Figure 19 clearly reveals a clustering of inward BERD and a high degree of interaction in the centre of Europe. Germany now appears as the central hub showing high interaction intensity in particular with the direct spatial neighbours Netherlands, Switzerland and Austria. It can also be seen that the UK shows particular high interaction intensity with Sweden and France, Spain shows the strongest connections with France and Belgium. Finland appears to have a diverse set of partner countries but in terms of absolute size the interactions are comparably low.

Figure 19: Inward BERD relationships between European countries, 2007

Note: Node size corresponds to the sum of R&D expenditure of foreign-owned firms in a country and R&D expenditure of domestic firms abroad. The strength of the lines between countries A and B correspond to the sum of R&D expenditure of firms from country A in country by and vice versa.

No data available for Italy and Greece

Eastern European countries are in general connected to the core of the inward BERD network in Europe, but with comparably low magnitudes. The Czech Republic shows the highest degree of embededdness. EU-12 countries are mostly connected to Western Europe. Connections between the EU-12 countries are weak, despite the strong integration in the communist era. This can be explained by the fact that there are still only a few multinational companies originating from the EU-12 which could set-up R&D in neighbouring countries.

Further, the results show that integration of business R&D is far less developed than the integration of academic research, including universities and research organisations, as shown by a similar representation of a spatial network map based on international collaboration in the European Framework Programmes (FPs - see Scherngell and Barber 2011). In the FPs EU-12 countries seem to be rather well integrated in pan-European research collaborations, while this is not the case for the inward BERD network.

5.3. The strength of inward BERD links between individual countries

The exploratory analyses from above sheds some light on the structure of cross-country inward BERD from a social network perspective, in particular on the existence of links and their size. However, from social network analysis we know that we should consider the relative strength of the links between individual nodes or countries in our case. One appropriate measure to capture the relative size of the cross-region collaborative links is the Jaccard index (see, for instance, Leydesdorff 2008).

In our study the index is defined as

$$J_{ij} = \left(y_{i\bullet} + y_{\bullet j} - y_{ij}\right)^{-1} y_{ij} \qquad i, j = 1, \ldots, n \qquad (5.1)$$

where

$$y_{i\bullet} = \sum_{\substack{j=1 \\ j \neq i}}^{n} y_{ij}\,,\ y_{\bullet j} = \sum_{\substack{i=1 \\ i \neq j}}^{n} y_{ij} \qquad i, j = 1, \ldots, n \qquad (5.2)$$

The Jaccard index relates the strength of the connection between country A and B to the total number of connections of countries A and B. The idea is that a certain amount of inward BERD, say 100 Mio EUR, between two small countries has a larger magnitude than between two large countries compared to overall inward BERD.

The calculation of the Jij coefficient for our (i, j)-country pairs leads to interesting results concerning the spatial structure of R&D investment flows. Table 6 presents the top 20 links in terms of the Jaccard index. First, it comes out that the relative strongest links are different from the highest links when taking absolute numbers on total R&D investments between two countries. Second, the by far highest relative interaction intensity is identified for the country pair UK and US. Organisations that are located in the US relatively most often invest R&D in the UK and receive R&D investments from the UK. The same is true for organisations located in the UK. The second highest Jaccard index is observed for Germany and the US. Interestingly France seems to have the relative highest interaction intensity with Japan which is quite surprising considering the R&D investment structure of all 27 countries. We have discussed this case in the country fiches. The same result is obtained for the Netherlands also showing the highest relative interaction intensity with Japan. Also Switzerland has the highest Jaccard index with an extra European country, namely the US.

As mentioned above, the structure of the network of R&D investment points to some geographical logic in that we find high interaction intensities between countries that are located close to each other in geographical space. This is also reflected by the results obtained for the Jaccard index in Table 6. 50% of the Top 20 country pairs in terms of their relative link size are direct spatial neighbours (10 country pairs). When we leave out the US and Japan, the results become even more striking as all non-direct-neighbour interactions of the Top-20 country pairs refer to pairs that consist of the US or Japan. This is a particularly interesting result and will be further evaluated in section 7 by means of a gravity approach.

Table 6: Top-15 country pairs in terms of their relative link size

Country pair	UK US	DE US	FR JP	FR US	CH US	DE NL	DE AT	DE CH	DE FR	NL JP	SE UK	US CA	SE NO	FR UK
Jaccard index	0.27	0.16	0.15	0.12	0.11	0.09	0.08	0.07	0.07	0.06	0.05	0.05	0.05	0.04

Source: own calculations

6. R&D ACTIVITIES OF NON-EUROPEAN COMPANIES IN THE EUROPEAN RESEARCH AREA

6.1. Evidence from inward BERD data

The following section analyses R&D activities of non-European companies in the European Research Area (ERA). Due to data constraints, only Swiss and Norwegian data have been added to the EU-27 aggregate. Data from other ERA countries are not available.

Non-European firms in the European Union and US firms in particular have already been discussed in the context of chapter 4. Section 4.5 already illustrated the outstanding role of US firms which account for 82.5% of the BERD of all non-European companies in the ERA in 2007.

The remaining 17.5% or 2.9 billion EUR of inward BERD in the ERA are contributed by firms from very diverse countries of origin (Figure 20). Besides the US, only two countries account for a significant share of total inward BERD investments in the ERA: Japan with more than 1.1 billion EUR or a share of 6.8% of total non-European (including US) BERD, and Canada with more than 600 million EUR or a share of 3.8% in 2007. The US, Japan and Canada together account for more than 93% of total inward BERD in the ERA.

The next ranked country, India, is comparably small with 132 million EUR or 0.8% of total inward BERD in the ERA. The remaining countries, South Korea (37 million EUR) Israel (35 million EUR), the Russian Federation (27.3 million EUR) and China (8.7 million EUR) together account for less than 1% of total inward BERD in Europe by non-European firms. Also the offshore financial centres aggregate with a total of 133 million EUR or 0.8% share is of limited importance.

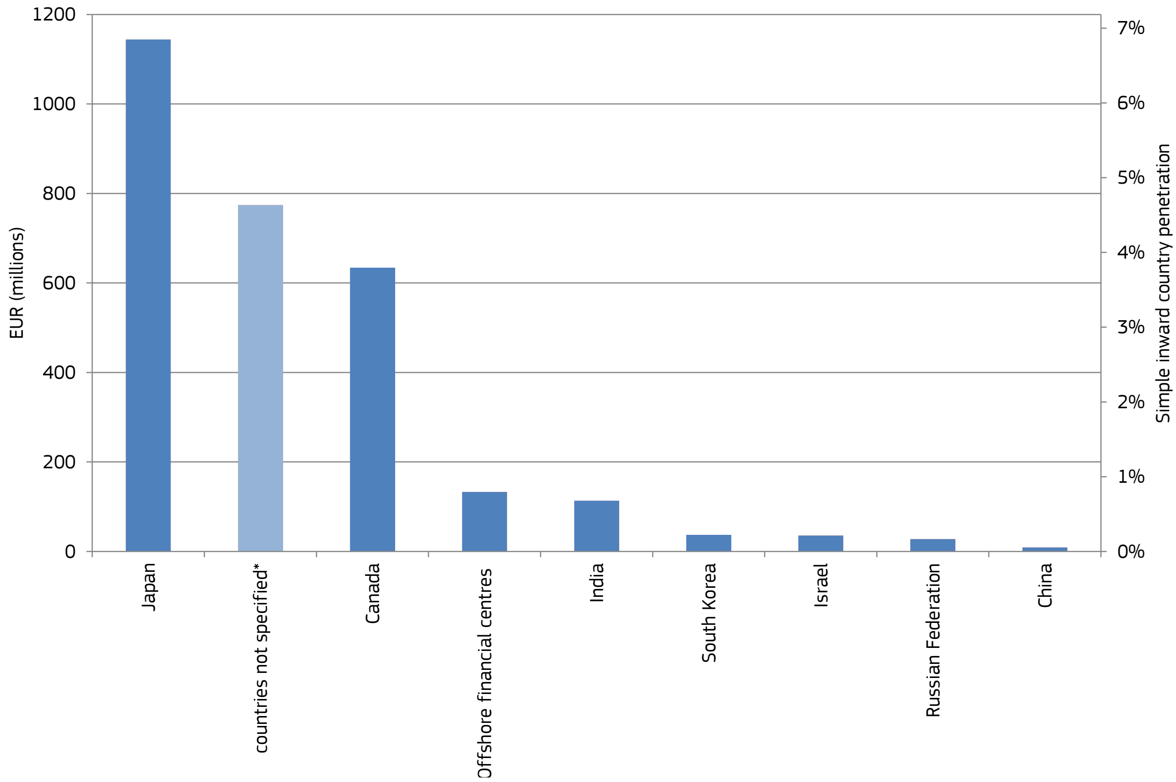
The figure also reveals one main limiting factor for the analysis of BERD by non-European firms: the huge portion of inward BERD summarized as countries not specified, which accounts for 4.6% of total inward BERD or almost 800 million EUR. Countries not specified include all inward BERD which has not been allocated to any specific country by national statistical offices because of missing or confidential data. Technically speaking, this is equal to the difference between total inward BERD and the sum of the values for the countries of origin in a reporting country, summed up over all reporting countries.

This limitation is important to keep in mind when looking at the values of all countries except Japan and Canada. China, for example, only accounts for 8.7 million EUR of inward BERD in Figure 20. This value is equal to the inward BERD of Chinese firms in Germany because no other European country reports data for Chinese firms. Inward BERD by Indian firms (see also Box 2) is reported for Belgium (14 million EUR), the Czech Republic (1.5 million EUR), Germany (21 million EUR), and the United Kingdom (77 million EUR). However, the values for a number of countries including France, Switzerland, Austria, Netherlands, Poland, Ireland, Hungary, Malta, Portugal, Finland and Sweden are not available.

Even inward BERD of Canadian firms - the third most important non-European BERD country of origin in Europe - may be underestimated in Figure 20. The values for Canada are missing in the data sets of Malta, Ireland, Poland and Sweden and are confidential in Slovenia and Estonia.

Besides the United States, only Japan appears to be large enough to be covered in inward BERD statistics of all European countries. Thus, a common EU-27 aggregate for inward BERD by country of origin would be highly appreciated. The publication of one aggregated inward BERD value for all EU-27 countries would circumvent the issue of confidential data at the level of individual member states and could give a more appropriate picture of R&D activities of non-European firms in the EU.

Figure 20: Countries of origin of inward BERD from non-European firms (EUR Mio, 2007, excluding US firms)



Note: * countries not specified includes all other non-European countries but also all confidential and missing values; The simple inward country penetration is defined as inward BERD from county X / inward BERD from all non-European countries (including the US); Excl. IT, only data for manufacturing are included in BE, DE, FR, IE, NO, PL, SE, FI; IE 2005 instead of 2007; CH and MT 2008 instead of 2007

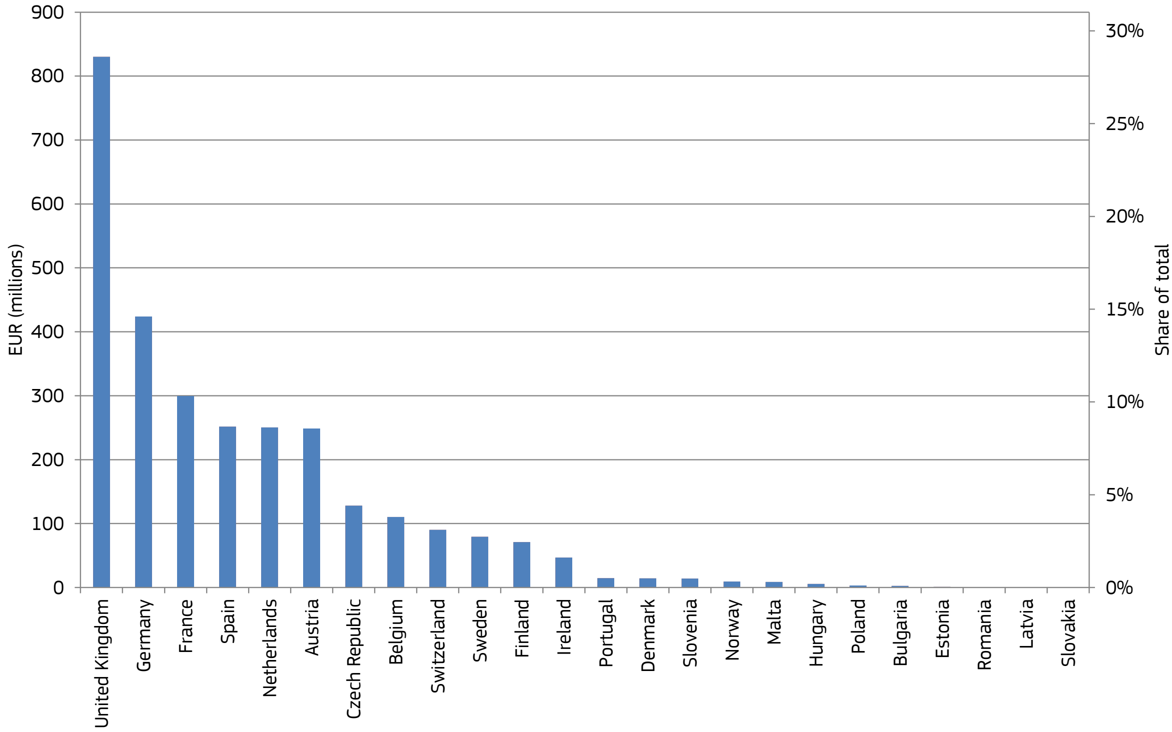
Source: OECD, Eurostat, National statistical offices, own calculations

Figure 21 changes the perspective from the countries of origin to the host countries. It shows the distribution of inward BERD of non-European firms (also excluding US firms) in the ERA by host country.

The United Kingdom stands out with inward BERD of more than 800 million EUR in 2007, a share of almost 30% on total BERD investments in Europe by non-European firms. This makes the UK Europe's gateway or hub for inward BERD from outside Europe. Almost half of the total inward BERD of Japanese firms in Europe is performed by subsidiaries in the United Kingdom, and about 2/3 of all inward BERD of Indian companies in Europe is located in the UK.

Germany, the largest attractor of both, intra-EU inward BERD and total inward BERD, is the second largest host country of non-European inward BERD and accounts for more than 400 million EUR or nearly 15% of inward BERD by non-European firms. However, compared to inward BERD from other EU countries (almost 5 billion EUR), Switzerland (1.4 billion EUR) and the US (3.7 billion EUR) these investments are of relative small relative importance. Domestic, European and US companies together account for more than 99% of Germany's BERD, non-European firms only account for less than 4% of total inward BERD.

Figure 21: Host countries of inward BERD from non-European firms (EUR Mio, 2007, excluding US)



Note: Only data for manufacturing are included in BE, DE FR, IE, NO, PL, SE, FI; IE 2005 instead of 2007; CH and MT 2008 instead of 2007; BG and SI inward from US and CH included; MT and RO inward from CH included

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

France, Spain, the Netherlands and Austria each report between 250 and 300 million EUR of inward BERD from outside the ERA (excluding the US). This is equal to 8 to 10% of total non-European inward BERD in the ERA. The top six host countries account for a cumulative share of almost 80%. The US is excluded in all these numbers.

There are also considerable differences between European countries in the relative importance of inward BERD from non-European firms. In the Czech Republic 18.8% of total inward BERD and 10.6% of total BERD are by non-European firms. Non-European firms have also a high absolute and relative importance in Austria (9.6% of total inward and 5.1% of total BERD) and Spain (13.1% of total inward and 3.4 of total BERD).

Japan, the largest inward BERD investor in Europe, is also the largest investor in most countries if we exclude the US. There are some exceptions to this rule: Canadian firms are more important than Japanese firms in Spain, in France and in particular in Austria. In the Czech Republic neither Japan nor Canada but the Russian Federation is the most important BERD investor country out of the non-European countries considered.

Box 2: Motives of Non-EU Firms to do R&D in Europe: A Case Study of two Indian Multinationals in Germany

There is a small but growing number of corporations from emerging economies such as Brazil, China or India that take up R&D activities in Europe. Tatra, an Indian conglomerate which acquired the British car manufacturer Jaguar in 2007 is the best known example for this group of firms. Defiance Technologies Limited and Suzlon Energy Limited are two other Indian companies which recently established R&D activities in the EU.

Defiance is an Indian company offering engineering and information technology services. The main geographical markets of Defiance are India, the EU and the US. Currently, 20% of Defiance's R&D staff is located in the EU. The firm has established a wholly-owned subsidiary in Germany as part of its global expansion plan. The EU is seen as a growing market for engineering services since outsourcing is considered to be still in a 'nascent stage' in many EU countries. Thus, market demand is the single most important factor for Defiance to locate R&D in the EU. Seeking access to skilled personnel is also regarded as a key driver for outsourcing by potential clients and is expected to play an important role in any future developments.

Suzlon is a producer of wind turbines headquartered in Pune in Western India. Suzlon's key geographical markets are the US, India, China, Spain, Portugal and Australia. R&D locations of Suzlon outside India include Berlin, Hamburg and Rostock in Germany, Århus in Denmark, and Hengelo and The Hague in the Netherlands. For Suzlon, the attractiveness of the EU as a location for R&D lies in its role as the 'lead market' for wind energy. Germany and Denmark are regarded as the leading countries in wind energy technology but also in terms of sophisticated clients in particular. Hence, the intention of doing R&D in the EU is to access and create knowledge and technologies. The firm stresses the role of knowledge co-creation with universities and research organisations in particular.

6.2. The relationship between foreign direct investment and outward BERD

The economic literature as well as public debates both assume a close relationship between the internationalisation of production and the internationalisation of R&D. Going abroad with production precedes R&D internationalisation in many cases, and firms only rarely do R&D at one location without complementary production or sales functions. We therefore compared outward BERD and outward FDI stocks for the US in the year 2007 by host country and by sector. The available data allows such a comparison only for the US. The analysis employs two different data, outward BERD data and outward FDI stocks data. Both data differ in one important respect: BERD data makes use of the concept of the ultimate controlling unit. Therefore the host country of US outward activities is the country where the subsidiary performing the R&D activity is based. In contrast, the US outward FDI data does only provide the location of the direct subsidy of the US MNC. As a result, countries with favourable tax schemes or locations which are traditional hubs for investments abroad are overrepresented in the outward FDI statistics compared to the outward BERD data set.

The distribution of US outward FDI stocks and outward BERD shows some striking differences when looking at host countries and sectors. Some countries, in particular other English speaking countries, have about the same importance in terms of outward BERD and outward FDI stocks. In most countries, the share on outward BERD is considerably higher or lower than the corresponding share on outward FDI stocks. Offshore financial centres and a few European countries, most notable the Netherlands and Luxemburg, show by far higher shares on FDI stocks than on outward BERD, while most European countries, most notable Germany, and all Asian economies are more important locations for R&D activities of US firms than their FDI stocks would suggest. At the sectoral level, high- and medium-high-technology sectors, in particular pharmaceuticals tend to have higher shares on outward BERD than on outward FDI stocks, while all low- and medium-low-tech sectors contribute little to outward BERD but account for large shares of outward FDI stocks. However, some high- and medium-high-tech sectors including medical and optical instruments and office machinery, computers, also combine comparable little outward BERD with higher outward FDI stocks.

6.3. Evidence from the Community Innovation Survey 2008

In addition to R&D expenditure data we employ data from the Community Innovation Survey (CIS) 2008 to gain insight into the R&D and innovation activities of non-European firms in the ERA. The CIS is a survey based on a common questionnaire administered by Eurostat and national statistical offices or research institutes in all EU member states, Iceland and Norway. The CIS aims at assessing various aspects of the innovative behaviour and performance of enterprises and follows the definitions laid down in the OECD Oslo Manual (OECD 2005). This ensures that definitions of research and development are the same as in the datasets used for this study.

EUROSTAT provides access to CIS data at the firm level at their premises. We use the CIS 2008 sample which refers to the period 2006-2008. Data has been accessed at the EUROSTAT SafeCentre in December 2011.

The sample includes more than 170,000 firms from 23 European countries[3], 16,862 of them foreign-owned. While this is a large sample and enables us to perform a detailed analysis on the innovation behaviour of foreign-owned firms in the ERA, it should be noted that the United Kingdom and some small and medium sized EU countries are not included in the sample. Among the foreign-owned firms, the majority (more than 65%) is from other EU-15 countries. 16.8% originate from the US or Canada. The remaining 18% are from other European countries (6.3%), the EU-12 (2.9%), Japan (2.3%), and a range of other non-European countries (5.6%), including Australia, Israel, Russia, Korea, China and India. Affiliates of firms registered in offshore financial centres account for the remaining one percent of all foreign-owned firms in the sample.

A special focus of this section is on the R&D activities of firms from China, India and Japan in the ERA. The share of firms from China, India and other emerging economies is even smaller than the share of the aforementioned groups. Altogether, the combined share of the BRICs, Brazil, Russia, India and China, on the sample is a little less than 3% of all non-European firms, which is in the range of the share of FDI inflows from the BRICs on total Extra-EU inflows between 2002 and 2007 (Havlik et al. 2009). This clearly confirms the picture from aggregate inward BERD data that activities of firms from emerging economies in Europe are still at a very early stage. Exporting, not investment is the predominant form of presence of firms from emerging economies in the EU. This is a fundamental difference to the position of EU firms in emerging economies, which is based on equity investment to a considerable degree (Havlik et al. 2009). As the UK is not included in the sample as a reporting country, but at the same time is the most important attractor of inward BERD, the magnitude of extra-EU internationalisation may be underestimated.

Firm-level data allow some comparisons of the characteristics of Chinese, Indian and Japanese firms with other foreign-owned firms in the ERA. First, we see that the share of Chinese, Indian and Japanese firms in high- and medium-high-technology manufacturing sectors is higher than the average. 31% of the Chinese, 35% of the Indian and 40% of the Japanese firms are in high- and medium-high-technology industries, compared to 22% in the total sample of all foreign-owned firms. This means that foreign direct investment of firms from these countries is predominantly targeted towards firms in technology-intensive manufacturing sectors, which may indicate that R&D and innovation is an important determinant of these investments. Quite contrary, FDI from the EU-12 reveals much higher shares of medium- and low-technology sectors. We also see that the share of service firms is quite similar in the Chinese, the Indian and Japanese sub-group. This is surprising, given that the export of knowledge-intensive services has a much higher importance for India than for China and Japan. This different trade specialisation of India, however, did not turn into a different specialisation in foreign direct investment.

Another striking difference is size. Chinese firms in the sample are, on average, larger in terms of employment and turnover than Indian firms as well as the median or mean firm size of the total sample. Indian firms, in contrast, are smaller than the total sample median or mean firm size. Japanese firms are the largest of all groups considered in terms of turnover but only of about average size in terms of employment.

Differences in firm size are important, because firm size is related to innovation and R&D. It is thus not surprising that the share of Chinese firms which introduced product and process innovation is also higher than the sample average and the corresponding share of Indian and Japanese firms. 60% of the Chinese firms have introduced innovations, compared to 47% of the Indian firms, 47% of the Japanese and 43% of the EU-15 firms. Firms from offshore financial centres (38%) and the EU-12 (34%) have the lowest innovation propensity.

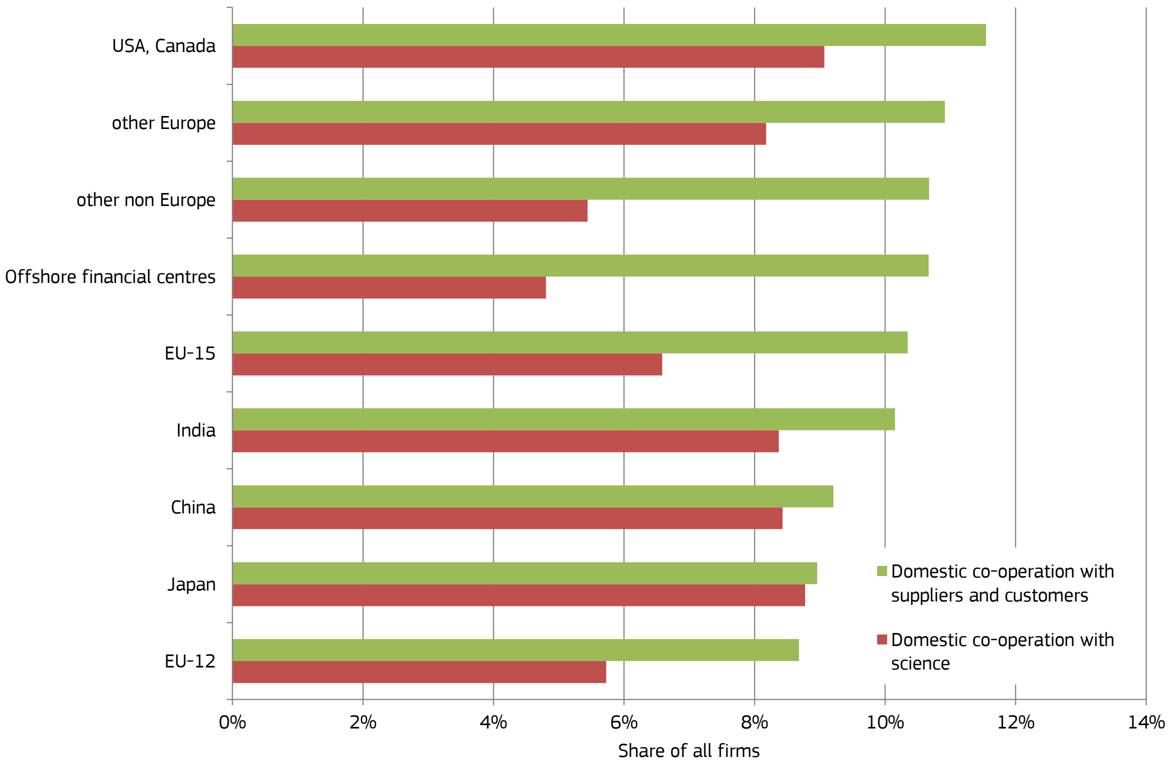
A higher share of innovative Chinese firms, however, does not mean that they also exhibit a higher R&D orientation. The share of Chinese firms with R&D activities (30%) is lower than any other group except firms from offshore financial centres (30%) and EU-12 countries (27%). The share of Japanese firms with R&D activities is only slightly higher (34%). Indian firms have a considerably higher share (43%), at the same level as firms from the US/Canada.

Another important aspect of R&D behaviour is co-operation. Firms rarely innovate alone, but are embedded in a network of clients, suppliers, competitors, university institutes etc. Spillovers between foreign-owned firms and domestic organisations may be transferred over the channel of co-operation. From the perspective of policy that tries to maximize the benefits from the presence of foreign-owned firms, it is thus important to know how closely foreign-owned and domestic organisations co-operate in innovation projects.

The CIS, unlike R&D expenditure data, provides insight into the co-operation behaviour of foreign-owned firms. US and Canadian firms are co-operating most frequently with suppliers and customers as well as with science in their host countries. Affiliates from EU-12 firms, like in the case of R&D intensity, are at the bottom of this ranking. However, the frequency of various forms of co-operation does not vary greatly between different groups of foreign-owned firms, as can be seen from the Figure 22.

3 BG, CZ, DE, EE, IE, ES, FR, IT, CY, LV, LT, LU, HU, MT, NL, PT, RO, SI, SK, FI, SE, NO, HR

Figure 22: Frequency of co-operation in the host country of various groups of foreign-owned firms in Europe (2008)



Source: EUROSTAT, CIS 2008

Chinese and Indian firms have a higher propensity for co-operation with suppliers and customers than Japanese and EU-12 firms, but a lower propensity than firms from the US, Canada, other European countries and the EU-15. However, these co-operate more frequently with universities and research centres in the host country than most other groups. This is an interesting finding, given that Asian firms co-operated significantly less frequently with science in a study based on CIS 2006 (Dachs et al. 2010).

The comparison of the shares of market and science co-operation gives also further insight into the motives for co-operation. We assume that market co-operation is a means to adapt existing products to markets in the host country, while science co-operation is a means to generate new knowledge. In this perspective, firms from offshore financial centres, the EU-15, EU-12 and other European countries mostly follow asset-exploiting motives when they co-operate in the host country. These firms reveal the highest gap between market and science co-operation. In contrast, the gap between market and science co-operation is smallest in Japanese, Chinese and Indian firms. We may therefore assume that co-operation in these firms is more frequently a means to generate new knowledge. Science-industry co-operation is difficult to maintain over distance, so the establishment of an affiliate in Europe may be a good way for these firms to co-operate with European universities.

7. DRIVERS OF R&D INTERNATIONALISATION

The previous chapters drew a detailed picture of the current status of business R&D internationalisation at the level of countries and sectors. The aim of this chapter is to explain the sectoral and cross-country patterns identified above. In particular, this chapter seeks to identify the key drivers of R&D internationalisation.

First, a descriptive analysis will i) analyse the relationship between R&D internationalisation and the internationalisation of production (section 7.1) and ii) compare the relative R&D intensities of domestic and foreign-owned firms across countries and sectors (section 0).

Additionally, econometric analyses are conducted to provide a broader and more general picture of the drivers of R&D internationalisation as identified in the literature. The analysis aims to identify a set of variables or indicators that determine the internationalisation decision of firms, indicators that may provide guidelines for science, technology and innovation (STI) policies. Specifically, section 7.3 identifies host country characteristics that drive business R&D expenditure of foreign-owned affiliates, while section 7.4 looks at both host and home country characteristics that drive and determine business R&D expenditure of foreign-owned affiliates.

The econometric analyses will be complemented by evidence from case studies on the drivers of inward BERD in various sectors and countries. The results of these case studies are briefly described in boxes throughout the chapter.

7.1. Internationalisation of production and R&D

In order to throw light on the relationship between production and R&D of foreign-owned firms across sectors and countries, the shares of inward R&D expenditure (defined as the share of business R&D of foreign-owned affiliates in total R&D of all firms in a sector) are compared with the shares of value added of foreign-owned affiliates (defined as the share of value added generated by foreign-owned affiliates to total value added generated by all firms in a sector). The analysis uses value added (instead of e.g. turnover) as a proxy for production since it more appropriately and precisely captures the value of firms' production activities. Specifically, the concept of value added explicitly excludes all inputs sourced from other sectors or from other countries and therefore captures the true value of production. In contrast, turnover clearly overrates the value of firms' production activities, particularly if foreign affiliates predominantly assemble parts and components obtained from other sectors or from abroad.

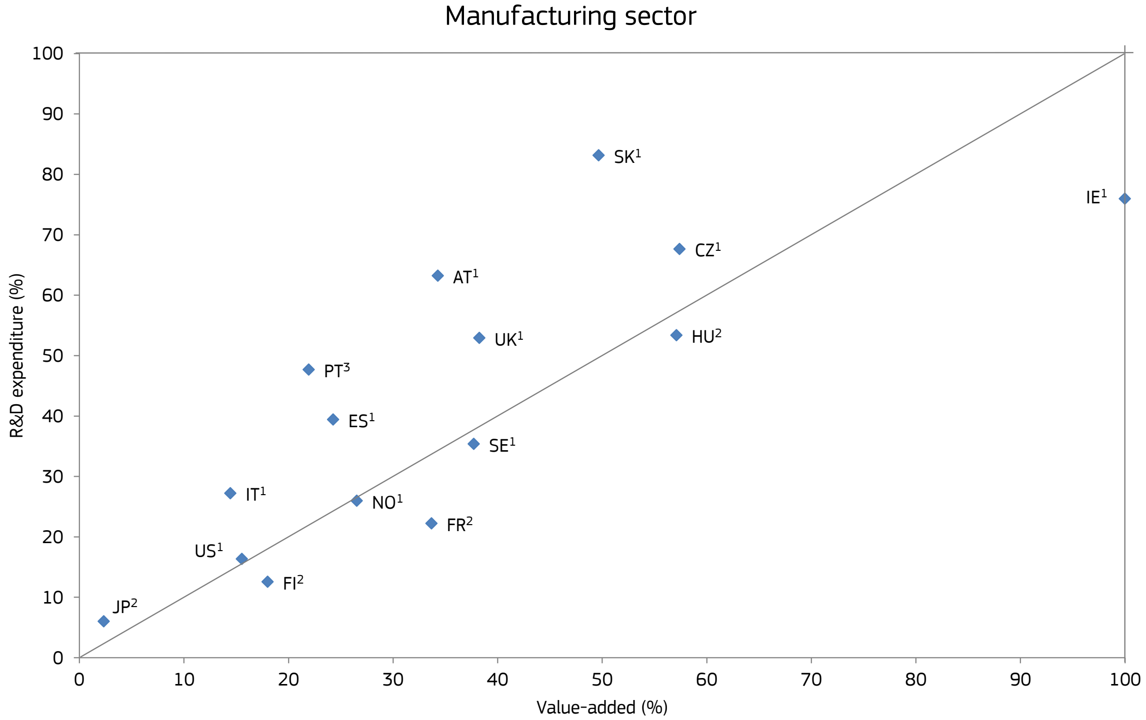
Specifically, we look at the following relation:

$$\frac{\mathrm{R\&D}_{\mathrm{inward}}}{\mathrm{R\&D}_{\mathrm{total}}} \overset{45^{\circ}}{=} \frac{VA_{inward}}{VA_{total}} \qquad (7.1)$$

Equation (7.1) emphasises that if the share of foreign-owned affiliates on R&D expenditure is equal or close to equal to their share of value added, host countries will align along or close to a 45 degree line. However, if the share of foreign-owned affiliates on R&D expenditure is larger than the value added share of foreign-owned affiliates, host countries are located to the north-west of the 45 degree line. A larger share of value added of foreign-owned affiliates (relative to the share of R&D expenditure of foreign-owned affiliates) will push host countries to the south-east. The analysis concentrates on the latter two cases and seeks to identify host countries off the 45 degree line as interesting cases to study. In particular, host countries positioned to the north-west of the 45 degree demarcation line mark countries or sectors with a high degree of internationalisation of R&D activities while the opposite corner (the area to the south-east of the 45 degree demarcation line) identifies host countries or sectors where production activities are more internationalised than R&D.

Data on R&D expenditure of foreign-owned affiliates ($\mathrm{R\&D}_{\mathrm{inward}}$) as well as total R&D expenditure ($\mathrm{R\&D}_{\mathrm{total}}$) has been collected by the Austrian Institute for Technology and the Vienna Institute for International Economic Studies (wiiw) from national contact points (national statistical offices, science policy offices etc.) in the course of the project. In contrast, the OECD Activities of Foreign Affiliates statistics (OECD AFA) exclusively provides information on value added of foreign-owned affiliates in a host country ($\mathrm{VA}_{\mathrm{inward}}$), while data on total value added ($\mathrm{VA}_{\mathrm{total}}$) exclusively originate from the OECD Structural Analysis Database (OECD STAN).

Figure 23: Share of R&D and value added of foreign-owned affiliates in manufacturing (2004-2007)



Notes: the share of value added for IE was rescaled to 100, [1] refers to the year 2007, [2] to 2006, [3] to 2005 and [4] to 2004

Source: Data collected from national contact points, OECD AFA, OECD STAN

In order to draw the most comprehensive picture and to provide a meaningful cross-country comparison, data points are identified by means of a backward-looking procedure. Specifically, the analysis predominantly focuses on the year 2007 as the last year covered in all datasets. However, if for a specific sector, no information on the R&D and value added shares are available for the year 2007; these shares are taken for the year 2006 instead. And in case a sector is not fully covered in 2006 (or 2005) either, shares are taken for the year 2005 (or 2004) instead. Moreover, due to lacking data for the service sector, the ensuing analysis focuses on the manufacturing sector only[4].

Figure 23 depicts the shares of business R&D and value added of foreign affiliates in the overall manufacturing sector. It points at a broad variation in the share of business R&D of foreign affiliates across countries which range between only 6% in Japan and 85% in the Slovak Republic. Specifically, the degree of internationalisation of R&D in manufacturing is highest in the Slovak Republic, Austria and Portugal. The opposite holds true for the Irish manufacturing sector whose production activities are comparatively more internationalised. Generally, with a few exceptions only, Figure 23 highlights that the share of R&D of foreign affiliates is consistently higher than the share of value added which suggests that, research and development expenditure is more internationalised than production in the manufacturing sector in the majority of countries considered, a finding that is in line with those of the OECD (2009b) for a comparable set of countries.

Furthermore, Figure 23 reveals that R&D shares and value added shares of foreign-owned affiliates are positively related. Moreover, in none of the sectors considered are all countries located either above or below the 45 degree line[5]. Hence, for the sample of countries considered, there is substantial within-sector heterogeneity across countries.

4 Belgium (BE), Bulgaria (BG), Canada (CA), Denmark (DK), Estonia (EE), Germany (DE), Israel (IL), Latvia (LV), Malta (MT), the Netherlands (NL), Poland (PL), Romania (RO), Slovenia (SI) had to be excluded due to insufficient data on value added of foreign-owned affiliates Moreover, lacking data on both value added and business R&D expenditure of foreign-owned affiliates led to the exclusion of Australia (AU), Greece (EL), Iceland (IS), Korea (KR), Malta (MT), Luxembourg (LU), Switzerland (CH) and Turkey (TR). As a result, 15 countries are included in the analysis: Austria (AT), the Czech Republic (CZ), France (FR), Finland (FI), Hungary (HU), Ireland (IE), Italy (IT), Japan (JP), Norway (NO), Portugal (PT), Spain (ES), Sweden (SE), Slovakia (SK), the United Kingdom (UK) and the United States of America (US).

5 Not shown here. See Chapter 3 in the full Analysis Report (Deliverable 7 of the project).

Table 7: Summary of emerging patterns – share of inward business R&D and value added of foreign-owned affiliates (2004-2007)

Sectors	Tech-intensity	No. of ob-servations	General pattern: **Higher inter-nationalisation in:**	Outliers		Missing observations for:
				above 45° line	below 45° line	
Total manufacturing		15	R&D	SK, AT, PT	IE	
Food, beverages and tobacco	LT	14	R&D	SK, PT	IE	AT
Textiles, fur and leather	LT	11	similar	IT, UK	IE	PT, JP, SK, FI
Wood, paper etc.	LT	12	production	AT	IE, HU, CZ	PT, JP, SK
Coke, refined petroleum etc.	MLT	6	data issues	IT, UK	SE, FR	PT, SK, IE, CZ, AT, HU, ES, NO, US
Chemicals & chemical products		13	R&D	SK, UK, AT, ES	FR, FI	NO, PT
Chemicals & chemical prod. (less pharma)	MHT	8	similar		FR, IE	NO, IT, PT, HU, AT, CZ, SK
Pharmaceuticals	HT	8	production		FR, FI	NO, IT, PT, HU, AT, CZ, SK
Rubber and plastic products	MLT	14	production	SK	HU, FR, SE	PT
Non-metallic mineral products	MLT	15	production	PT, SK, FI	CZ, HU	
Basic and fabricated metals	MLT	14	R&D	PT, UK, FR, IE		AT
Machinery and equipment	MHT	15	similar		NO	
Office, accounting and computing machinery	HT	9	production	IT	HU, IE, JP	AT, FI, PT, ES, NO, SK
Electrical machinery and apparatus	MHT	12	production		IE, SE	AT, FI, IT
Radio, TV and communications	HT	10	similar	NO		IE, AT, IT, FI, US
Medical, precision and optical instruments	HT	10	production	CZ	US	IE, AT, IT, FI, PT
Motor vehicles	MHT	12	similar	None		IE, AT, SK
Other transport equipment	MHT	10	production	ES	SK, CZ, FR, SE	IE, AT, PT, IT, FI
Furniture, other manufacturing	LT	13	similar	IT, UK	IE, HU, SE	SK, US

Note: areas highlighted in grey represent sectors with severe data issues, in which between 30% and more than 50% of all observations are missing; the last column captures the names of countries that are absent in the analysis.

Table 7 provides an overview of the relationship between the internationalisation of R&D and production for total manufacturing and for individual manufacturing industries. It highlights that, for the sample of countries considered, production (still) appears to be more internationalised than R&D in the majority of sectors. In contrast, R&D is more internationalised than production in total manufacturing as well as in the food, beverages and tobacco sector, the chemicals and chemical products sector and the basic and fabricated metals sectors only.

However, the emerging picture must be interpreted with care as it is plagued and partly driven by missing-data issues. Specifically, due to stringent confidentiality conditions, information on R&D and/or value added of foreign affiliates is not available for all manufacturing sub-sectors and missing in most service sectors. This missing-data problem is particularly true for medium-high-technology and high-technology sectors, which, by definition, are highly R&D intensive and whose research is expected to be more internationalised than production. In particular, with almost 50% of all country points missing, the missing-data problem is most severe in the coke, refined petroleum and nuclear fuel sector, followed by the chemicals and chemical products sector (less pharma), the pharmaceuticals sector, the office, accounting and computing machinery sector and the radio, TV and communications sector, the medical precision and optical instruments sector as well as the other transport equipment sector for which 30% of all country points are absent.

Moreover, the missing-data problem is also responsible for the apparent discrepancy in internationalisation patterns between the total manufacturing sector and all its sub-sectors. In particular, with mainly production as the more internationalised activity, manufacturing sub-sectors are unable to explain the higher degree of internationalisation of research in the total manufacturing sector. However, there is valid reason to believe that if all data were available, research would emerge as more internationalised (compared to production) in some or all of the above-mentioned medium-high-tech and high-tech sub-sectors.

7.2. The relationship between R&D intensities of domestic and foreign-owned firms

A comparison of R&D expenditure and value added shares of foreign-owned affiliates helps identify some characteristics of the process of R&D internationalisation; however it does not allow for a direct comparison of the R&D efforts of foreign-owned and domestic firms. Hence, a direct comparison of R&D intensities (as the share of R&D expenditure in value added) of foreign-owned and of domestic firms is drawn to identify and compare the relative size of R&D efforts undertaken by both types of firms.

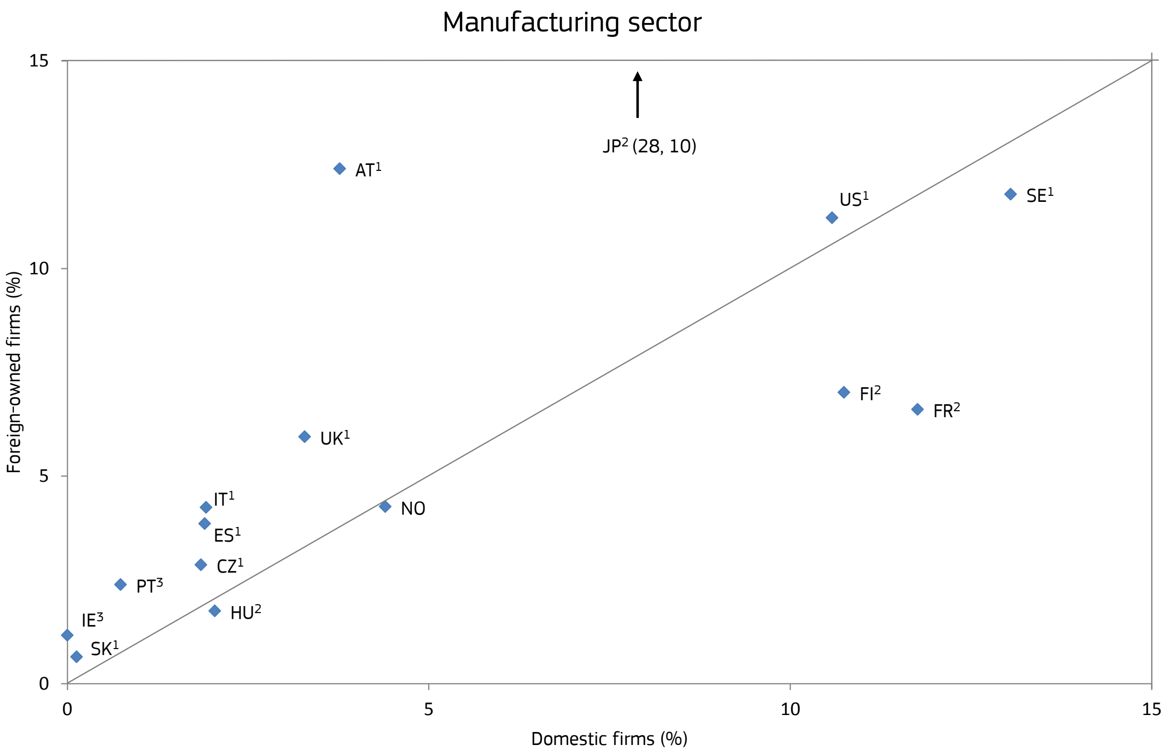
Methodologically, we draw the following comparison:

$$\frac{\mathrm{R\,\&\,D}_{\mathrm{foreign}}}{\mathrm{VA}_{\mathrm{foreign}}} \overset{45^\circ}{=} \frac{R\,\&\,D_{domestic}}{VA_{domestic}} \qquad (7.2)$$

Equation (7.2) emphasises that if R&D intensities of foreign-owned affiliates correspond to the R&D intensities of domestic firms, countries will align along or close to a 45 degree line. However, if R&D intensities of foreign-owned firms are higher than R&D intensities of domestic firms, countries will be located to the north-west of the 45 degree line. Larger R&D intensities of domestic firms (relative to R&D intensities of foreign-owned firms) push host countries to the south-east. The ensuing analysis again predominantly focuses on the latter two cases. Again, data points are identified by means of a backward-looking procedure (see section 7.1).

Figure 24 shows results for the manufacturing sector and highlights that R&D intensities of both foreign-owned and domestic firms range between 0% and 15%. Moreover, R&D intensities of foreign-owned and domestic firms are pretty similar across countries considered. The Japanese and the Austrian manufacturing sectors are the only exceptions as the R&D intensities of foreign affiliates is close to 30% in Japan and 12% in Austria and as such, almost three times as high as R&D intensities of domestic firms (10% and 4% respectively). This strong disparity in R&D intensities of foreign-owned and Japanese firms can be attributed to the strong concentration of foreign-owned affiliates in the motor vehicles, trailers and semi-trailers sector and their extensive investments in research and development.

Figure 24: R&D intensities in the manufacturing sector (2004-2007)



Notes: R&D intensity of domestic firms in IRL was rescaled to 0.

[1] refers to the year 2007, [2] to 2006, [3] to 2005 and [4] to 2004

Source: Data collected from national contact points, OECD AFA, OECD STAN

Table 8 provides an overview of findings for total manufacturing as well as all its sub-sectors. We find that, for the sample of countries considered, R&D intensities of both foreign-owned and domestic firms are similar in the majority of manufacturing sub-sectors.

Again, due to prevailing missing-data issues, emerging patterns must be interpreted with care. In particular, in some of the medium-high technology and high-technology sectors considered (the coke, refined petroleum and nuclear fuel sector, the chemical industry, the pharmaceutical sector, the office, accounting and computing machinery sector, the radio, TV and communications sector, the medical precision and optical instruments sector and the other transport equipment sector), between 30 to 50 % of all data points are missing, potentially providing a biased picture of the relative scale of R&D intensities of both domestic and foreign-owned firms.

Table 8: Summary of emerging patterns – domestic and foreign R&D intensities (2004-2007)

Sectors	Tech-intensity	No. of observations	General pattern: **Higher R&D intensity in:**	Outliers above 45° line	Outliers below 45° line	Missing observations for:
Total manufacturing		15	similar	JP		
Food, beverages and tobacco	LT	14	similar	FR	NO, JP	AT
Textiles, fur and leather	LT	11	foreign firms	IT, AT, ES	SE	PT, JP, SK, FI
Wood, paper etc.	LT	13	foreign firms	AT		PT, JP
Coke, refined petroleum etc.	MLT	5	similar	JP		PT, SK, FI, IE, CZ, AT, HU, ES, NO, US
Chemicals & chemical products		13	similar		FR, SE, FI	NO, PT
Chemicals & chemical prod. (less pharma)	MHT	8	similar	SE	JP, FR	NO, IT, PT, HU, AT, CZ, SK
Pharmaceuticals	HT	8	domestic firms	UK	FI, FR, SE	NO, IT, PT, HU, AT, CZ, SK
Rubber and plastic products	MLT	14	domestic firms		FI, FR, SE	PT
Non-metallic mineral products	MLT	15	domestic firms	FI, ES	CZ, JP	
Basic and fabricated metals	MLT	14	foreign firms	FR, IE	SE	AT
Machinery and equipment	MHT	15	foreign firms		NO	
Office, accounting and computing machinery	HT	9	similar	DATA ISSUES		AT, FI, PT, ES, NO, SK
Electrical machinery and apparatus	MHT	12	domestic firms		SE	AT, FI, IT
Radio, TV and communications	HT	10	similar	NO	FR, SE	IE, AT, IT, FI, US
Medical, precision and optical instruments	HT	10	domestic firms	CZ	JP, US	IE, AT, IT, FI, PT
Motor vehicles	MHT	12	similar	JP	FR	IE, AT, SK
Other transport equipment	MHT	10	domestic firms	ES	CZ, FR, SE	IE, AT, PT, IT, FI
Furniture, other manufacturing	LT	14	similar	IT, UK	IE, JP, SE	US

Note: areas highlighted in grey represent sectors with severe data issues, in which between 30% and more than 50% of all observations are missing; the last column captures the names of countries that are absent in the analysis

All in all, the graphical analysis of R&D intensities offers important lessons for the econometric analyses of drivers of R&D internationalisation. Specifically, it points out that:

- except for a few outliers per industry, countries locate along the 45 degree line. This highlights that R&D intensities of both domestic and foreign-owned firms are strongly related. High R&D intensities of domestic firms are (closely) matched by high R&D intensities of foreign-owned firms. Or, put differently: The scale of R&D intensities of domestic firms is an important driver of R&D expenditure of foreign-owned firms. This latter observation is substantiated by results of econometric analyses (which control for additional crucial characteristics) which point at robust complementarities between R&D intensities of domestic and foreign-owned firms (see section 7.3 and section 8.1).
- in none of the sectors considered are all countries located either above or below the 45 degree line. Hence, for the sample of countries considered, in none of the sectors are R&D intensities of foreign-owned affiliates consistently higher or lower than R&D intensities of domestic firms. Hence, there is evidence of non-negligible within-sector cross-country heterogeneity.

7.3. Host country determinants of R&D internationalisation

The ensuing analysis sheds light on and identifies potential drivers of business R&D expenditure of foreign-owned affiliates at both, country and industry levels. For that purpose the following model is estimated:

$$\ln RDinflow_{ikt} = \alpha_0 + \beta_z X_{zikt} + \varepsilon_{ikt} , \qquad (7.3)$$

where $RDinflow_{ikt}$ is the log of inward BERD for sector i in country k at time t and X_{zikt} is a matrix of z explanatory variables. The selection of variables is motivated by the literature review presented earlier in this report and comprises the following variables at both the country as well as sectoral level: country-specific variables include the log of total real national GDP to capture the size of the host economy, or equivalently, the host market. Since firms may have to adapt their products and production processes to local demand patterns, consumer preferences or to comply with legal regulations and laws, they may find it easier to cover their cost of adaptive R&D in larger markets with higher demand for their goods and services and consequently larger revenues.

Moreover, empirical studies have pointed at the pivotal role a skilled labour force has in successfully conducting R&D and in generating product and process innovations, rendering cross-country differences in the quality and size of a skilled workforce an important driver of cross-border R&D flows. Specifically, the shortage of highly skilled science and engineering talent explains the relocation of product development to other parts of the world (Lewin et al. 2009) while the abundance of graduates in science and technology and strong scientific and engineering capabilities in a host country account for the inflow of business R&D into a host country (e.g. Hedge and Hicks 2008). Hence, a highly qualified and skilled workforce in the host country with strong scientific and engineering capabilities is expected to increase inward BERD. This link between the quality and size of a skilled workforce and inward BERD is accounted for by the share of tertiary graduates in the fields of science, mathematics, computing, engineering, manufacturing and construction in the total labour force.

Finally, the attractiveness of countries for overseas R&D activities is shaped by public policy. Specifically, science, technology and innovation (STI) policy measures like public subsidies for R&D performing firms or measures to foster co-operation among firms or between firms and universities and other research organisations determine locational advantages and influence internationalisation decisions of firms in R&D (Steinmueller 2010). Hence, the share of government budgetary appropriations or outlays for R&D (GBAORD) in real GDP is included to capture the role STI policies play in driving R&D expenditure of foreign-owned affiliates.

Inward business R&D expenditure is also shaped by very specific characteristics of sectors in host countries which render them more or less attractive for inward R&D expenditure. In that respect, labour costs as percentage of value added is included as a proxy for unit labour costs (ULC) which captures the relative cost and productivity of labour of a sector in a host country. Since high ULC render both production and R&D relatively expensive activities, sectors with high ULC are expected to attract less inward business R&D.

Box 3: Drivers of inward BERD in Knowledge-Intensive Business Services: Clusters, start-ups and Skype

Knowledge-intensive business services (KIBS) include consultancy services, computer services and commercial R&D services. Their growth is largely fuelled by intermediate demand (the use of KIBS by other firms for the production of goods) and the usage of information and communication technologies (ICT) in services provision. KIBS account for the major share of inward BERD in the service sector.

Locational decisions of KIBS firms mainly rely on the presence of skilled workforce and proximity to their customers; additional drivers vary between countries:

UK: The attractiveness of the UK as a location for R&D in KIBS results from a large number of corporate headquarters, including the European headquarters of non-European firms, and the specialization of London as one of the largest agglomerations of financial services and KIBS in the world. The London KIBS cluster offers a large pool of skilled personnel, the potential for the development of specialized services and a high number of potential clients among financial services as well as corporate headquarters. Additional locational advantages are the English language as being the dominant language of international business, and English law being the most used contract law in international business. Moreover, the UK has a special relationship with the United States and strong ties with many countries in Asia, Africa and the Middle East.

Israel: KIBS account for about three quarters of inward BERD and about two thirds of total BERD in Israel. The large share of KIBS in inward BERD in Israel can largely be explained by takeovers of Israeli start-up firms in ICT by US multinationals. Israel has one of the most developed entrepreneurial cultures in the world and produces more start-up companies per inhabitant than any other country in the world; the availability of venture capital in Israel is the second best in the world.

Estonia: KIBS have also a high share on inward BERD in Estonia. This can mainly be traced back to the R&D strategy of one single company, Skype, founded in Estonia, bought by eBay in 2005 and by Microsoft in 2011. Its global development headquarter is located in Estonia, with about half of Skype's total workforce. Skype is responsible for the bulk of inward BERD in KIBS in Estonia. This example illustrates the role of single firms for overall patterns in R&D internationalisation.

Moreover, the extent of inward R&D expenditure crucially depends on a sector's attractiveness to foreign-owned investors in terms of FDI. In that respect, the sectoral FDI intensity, as the share of the inward FDI stock in total gross sectoral output, is included to capture the pivotal role FDI plays for R&D activities.

Furthermore, as pointed out by Athukorala and Kohpaiboon (2010), both the R&D intensity of production processes and the need to adapt products and production processes to local conditions and preferences differ widely across sectors. Hence, a sector's domestic R&D intensity defined as total sectoral domestic R&D expenditure as percentage of sectoral value added is included to capture that some host country sectors inherently require higher R&D expenditure which renders higher inward business R&D expenditure a necessary prerequisite for any successful adaptive or innovative R&D activities or production activities of foreign-owned affiliates. This hypothesis is also supported by findings of the graphical analysis (see section 0) which highlights that, on average, business R&D expenditure of foreign-owned affiliates are positively related to business R&D expenditure of domestic firms.

Additionally, sectors differ with regard to their size, as proxied by sectoral employment as percentage of the total labour force. Specifically, current sector size is the result of past employment expansions by successful and profitable firms. And since firm profitability crucially depends on its ability to continuously generate marketable innovations, sizeable resources are allotted to research activities and the development of new products and/or productivity-enhancing processes by both domestic firms as well as foreign-owned affiliates. Hence, inward BERD is expected to be higher in larger sectors. Account is also taken of the differences in the ability to attract inward business R&D across EU-15 and EU-12 member countries by including dummy variables for both groups (with non-EU member countries as reference). Finally, ε_{ikt} is the error term.

The data for the analysis are drawn from various sources. The dependent variable (i.e. inward business R&D expenditure) represents data both AIT and wiiw collected from national contact points in the course of the project. Moreover, country-level variables like real GDP or information on the number of tertiary graduates in the fields of science, mathematics, computing, engineering, manufacturing and construction come from different OECD sources. Furthermore, data on labour costs, value added and size originate

Box 4: Drivers of inward BERD in the pharmaceutical industry: Rising R&D costs and changes in the technological paradigm

The pharmaceutical industry accounts for the major share of inward BERD in the manufacturing sector and has one of the highest inward R&D intensities in the business sector. It is also one of the most internationalised sectors in terms of sales.

The internationalisation of R&D in the pharmaceutical industry is the result of a considerable number of mergers and acquisitions in recent years. These mergers can be explained, on the one hand, by the rising cost of R&D in the sector. Reasons for the increase of costs are manifold; e.g. a rising share of failure in clinical trials, advances in research technology, the growing commercialization of basic research, and strong regulations in all major functions.

On the other hand, the pharmaceutical industry has seen a change in its underlying technological paradigm, from chemistry to biotechnology. Large pharmaceutical companies acquire small biotechnology start-ups or enter into joint-ventures and partnerships with start-ups to get access to new knowledge and fill up their product pipelines.

As a result, horizontal mergers aiming to exploit potential economies of scale, scope and risk-pooling led to a concentration of the pharmaceutical sector across borders, and to a high degree of internationalisation in pharmaceutical research. This trend has been further fuelled by the trend towards global marketing of pharmaceuticals. The largest R&D spending pharmaceutical firms are located in the US, UK, Switzerland and France. Inventors are still concentrated in a relatively small number of countries (to a large part in Northern America and Europe). Some more routine activities have been outsourced to China and India.

Table 9: Results for host country determinants of R&D internationalisation (2004-2007)

Dep. Var.: log inward BERD	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	-10.724***	-10.303***	-6.942**	-11.091
	(5.97)	(4.32)	(2.50)	(0.93)
Country level				
Log real GDP	0.913***	1.005***	0.712***	0.528
	(7.94)	(5.72)	(3.79)	(0.40)
Share of tertiary graduates	1.070	0.576	-0.493	10.895**
	(0.72)	(0.39)	(0.29)	(2.59)
Share of GBAORD in real GDP	1.606***	0.627	-0.783	4.424*
	(2.84)	(1.02)	(0.86)	(1.84)
Sector level				
Labour cost over value added	-0.007	-0.011	0.023*	-0.031**
	(0.85)	(1.11)	(1.83)	(2.13)
FDI intensity	0.023***	0.019***	0.015***	0.096***
	(4.26)	(3.35)	(2.69)	(4.69)
Domestic R&D intensity	0.030***	0.034***	0.035***	0.035
	(3.23)	(3.06)	(3.07)	(1.26)
Size	0.098	0.218*	0.230	0.023
	(0.86)	(1.84)	(1.31)	(0.16)
Dummy: EU15	0.605*			
	(1.66)			
Dummy: EU12	0.459	0.051		
	(0.83)	(0.11)		
No of observations	229	181	106	75
Adj. R^2	0.570	0.499	0.272	0.525

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

Methodologically, a pooled OLS approach without time fixed effects is applied. Column (1) uses the overall sample, column (2) is based on the overall EU sample; column (3) uses the EU-15 sub-sample only, while column (4) uses the EU-12 sub-sample only.

Box 5: Drivers of inward BERD in the Automotive Industry of the EU-12: Path dependency, a skilled workforce and labour cost advantages

The automotive industry in the EU-12 benefitted strongly from the inflow of foreign direct investment since the collapse of communism in 1989, which in turn provided a strong impetus for inward BERD. In the Czech Republic, Hungary and Slovakia, the automotive sector is both the most important manufacturing sector and also a major recipient of foreign investment.

Some of the countries were already specialized in motor vehicles during the communist regime, and had skilled human resources in this industry. This specialisation still determines the competitive advantages of today, along with advantages in labour cost. After the system's collapse in 1989, transition encompassed the change to market systems, the opening up of trade and privatization. Framework conditions changed again through the EU-accession; e.g. support for science and research increased. Moreover, investment incentives for foreign and domestic investors are regarded to be one of the most important factors for the establishment of R&D activities.

Internationalisation of R&D is pronounced in the Czech Republic and Hungary; foreign-owned affiliates are responsible for nearly all R&D expenditure in the automotive industry. More recently R&D occurred in the automotive sector in Romania and Slovakia as well, so there is hope that in the long-run R&D is following FDI in these countries too.

Škoda Auto in the Czech Republic is the most successful of these ventures: Škoda holds more than 75% of total R&D in the sector. It is particularly due to this company that the Czech Republic has become a focal point for automotive R&D in the region, which is due to the integration in the structure of the parent company Volkswagen, retaining its brand and maintaining previous R&D facilities and the cheap and skilled R&D labour force. In contrast, in Romania, the main parent company Daewoo collapsed; the state took over shares which were sold to Ford between 2007 and 2009. Additionally, unlike the other countries which specialised in cars (Czech Republic), busses (Hungary) and light trucks (Slovakia) during the communist era, Romania tried to produce everything.

from the OECD Structural Analysis Database (OECD STAN), while information on government budgetary appropriations or outlays for R&D stem from the OECD Main Science and Technology Indicators. The OECD AFA statistics is the source for information on value added of foreign-owned affiliates, while inward stocks on foreign direct investments (FDI) are taken from the OECD International Direct Investment Statistics (OECD IDI). Due to missing data for the service sector in many countries, services are excluded.

Given data quality and availability, the econometric analysis uses the short unbalanced panel from 2004 to 2007 and analyses the overall sample comprising a set of OECD and non-OECD countries (OVERALL) on the one hand and three sub-samples on the other[6]. Methodologically, a pooled OLS approach without time fixed effects is taken as both Hausman test and Breusch-Pagan Lagrange multiplier test are rejected.

Table 9 presents results and highlights that the set of relevant drivers differs considerably between EU-15 and EU-12 countries. Specifically, with the exception of the EU-12 country sample, larger host markets that promise larger revenues to foreign-owned firms induce higher business R&D expenditure of foreign-owned affiliates. In particular, a 1% increase in the host country's real GDP is found to increase business R&D expenditure of foreign-owned affiliates by between 0.5% and around 1%.

Moreover, human capital, as proxied by the share of tertiary graduates in technology-related fields in the total labour force, is an important determinant of inward BERD only for the group of EU-12 countries (column (4)). Hence, for the group of EU-12 countries only, there is sound evidence that strong prevailing scientific and engineering capabilities attract inward business R&D expenditure. In contrast, no such role can be attributed to human capital in the group of EU-15 countries (column (3)).

As advocated by Steinmueller (2010), science, technology and innovation policy measures determine locational advantages and may therefore influence internationalisation decisions of firms in R&D. The analysis demonstrates that STI policies, as proxied by the share of government budgetary appropriations or outlays for R&D (GBAORD) in total national real GDP, is essential, but for the overall sample and the EU-12 sub-sample only. Hence, in EU-12 countries, STI policies are important drivers of inward R&D expenditure.

6 The three sub-samples consist of 22 EU member countries (EU), 13 of the EU-15 member countries (EU-15) (Austria (AT), Belgium (BE), Denmark (DK), Finland (FI), France (FR), Germany (DE), Ireland (IE), Italy (IT), the Netherlands (NL), Portugal (PT), Spain (ES), Sweden (SE) and the United Kingdom (UK) and 9 EU-12 member countries (EU-12) (Bulgaria (BG), the Czech Republic (CZ), Estonia (EE), Hungary (HU), Latvia (LV), Poland (PL), Romania (RO), Slovakia (SK) and Slovenia (SI)) to identify differences in drivers across sub-groups.

Box 6: Drivers of inward BERD in Aerospace: National interest vs. the need for a European consolidation

The aeronautics sector is regarded as a strategically important sector in many countries and enjoys widespread governmental support on grounds of military autarky, potential spillovers to other industries and the need to prevent monopoly power of other countries in this industry. Policy in different countries has a keen interest in national aerospace industries; the complexity of the underlying technologies, rising developing costs, long break even points and small national markets, however, lead to a situation where no single national aircraft manufacturer in Europe is able to survive on its own in the long run. These risks and obstacles can only be reduced through international collaboration.

Tensions between national interests vs. the need for a European consolidation paved the way to a concentration process in the European aerospace industry and the emergence of a complex network of relationships among firms. Policy has been an important driver of this process, although national interests are not always in line with the need for a European consolidation that enables the European aerospace industry to compete with the American aerospace and defence industry. In the beginning of the 1990s the aerospace sector included 30 companies from six European countries (Sweden, United Kingdom, France, Germany, Italy and Spain); today the number of major players has decreased to only eight. The European aerospace industry is concentrated in only a handful of countries, in particular France, UK and Germany, which together account for almost 70% of total employment in this sector in Europe. The high degree of internationalisation in aerospace R&D is a result of this concentration process.

Furthermore, some sectoral characteristics of host countries are of importance. Specifically, labour costs as percentage of value added have a significant positive effect on inward R&D expenditure in the group of EU-15 countries (column (3)) but a significant negative effect in the group of EU-12 countries (column (4)). Hence, high labour costs (relative to value added) are associated with higher R&D expenditure of foreign-owned affiliates located in EU-15 countries but with lower R&D expenditure of foreign-owned affiliates located in EU-12 countries. This might reflect the very specific R&D activities that are conducted in different country groups. The EU-12 is an attractive region for more routine and less demanding or sophisticated R&D activities of foreign firms. Hence, R&D expenditure tends to be lower if labour costs increase as routine R&D activities may be conducted more cheaply elsewhere. In contrast, the EU-15 is an attractive region for less routine but more sophisticated and novel R&D activities, activities which tend to be more expensive also.

Empirical results also consistently demonstrate that inward FDI and inward R&D expenditure are strategic complements. By comparison, the effect is considerably stronger among EU-12 countries (column (4)) than among EU-15 countries (column (3)).

Furthermore, a sector's domestic R&D intensity (as the share of R&D expenditure of domestic firms in value added of domestic firms) is positively associated with business R&D expenditure of foreign-owned affiliates, for all but the EU-12 sample. Specifically, industries that are inherently more R&D intensive are also found to experience significantly higher inward business R&D expenditure. The coefficient, however, is quite small, so huge changes in domestic R&D intensity are associated with only minor changes in the level of inward BERD.

In addition, sector size is an important driver of business R&D expenditure of foreign-owned affiliates in the overall EU sample only (column (1)).

Finally, some country-group dummies were included to capture in how far business R&D expenditure of foreign-owned affiliates are significantly higher (or lower) for the group of EU-15 or EU-12 countries (compared to non-EU countries). Column (1) highlights that - compared to non-EU member countries - EU-15 countries experience significantly higher inward business R&D expenditure. Furthermore, column (2) stresses that EU-15 and EU-12 countries receive similar amounts of inward business R&D expenditure.

7.4. Host and home country determinants of R&D internationalisation

In a next step, the analysis is extended to include both host and home country characteristics as drivers of inward BERD. For that purpose, a gravity model approach is used. In the empirical literature, gravity models are popular for their success in explaining international trade flows (see Anderson 1979 or Deardorff 1984 for a theoretical discussion and Breuss and Egger 1999 or Helpman et al. 2008 for some empirical results).

In essence, the gravity equation for trade says that trade flows between two countries are proportional to the size of the countries (as proxied by GDP), but inversely related to the distance between them. Moreover, gravity models also often account for physical or cultural proximity in terms of common borders, common language or colonial history, respectively. More recently, gravity models were also used to explain FDI flows (Brainard 1997; Jeon and Stone 1999 or Bergstrand and Egger 2007), migration flows (Lewer and Van den Berg 2008) or flows of workers' remittances (Lueth and Ruiz Arranz 2006) between countries. In contrast, empirical analyses on gravity-based cross-border R&D expenditure is still scarce, a shortcoming the ensuing analysis seeks to remedy[7].

pirical literature highlights the essential roles played by the economic size of countries as larger economies represent larger markets with a broad range of diversified products and superior market potentials and market prospects for foreign-owned affiliates.

Account is also taken of the effect a country's standard of living has on the extent of business R&D expenditure of foreign-owned affiliates. As such, economies that are on

Specifically, following the tradition of the gravity literature, the econometric model includes standard gravity-indicators but adds a set of technology or innovation related indicators to account for their pivotal role in explaining cross-country R&D expenditure:

$$\begin{aligned}\ln RD_{ijt} &= \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \ldots \\ &\ldots + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \delta_z X_{zijt} + \varepsilon_{ijt}, \qquad (7.4)\end{aligned}$$

and, to account for the role of the standard of living:

$$\begin{aligned}\ln RD_{ijt} &= \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \ldots \\ &\ldots + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \beta_6 \ln POP_{it} + \beta_7 \ln POP_{jt} + \delta_z X_{zijt} + \varepsilon_{ijt} \qquad (7.4')\end{aligned}$$

where $\ln RD_{ijt}$ is the log of business R&D expenditure of foreign-owned affiliates of country j in country i at time t, α_i and α_j are country-fixed effects for country i and j, respectively. $DIST_{ij}$ is the log of the geographical distance between country i and j as the simple distance between most populated cities (in km). As a proxy for additional costs (like the costs of co-ordinating geographically dispersed R&D activities, the costs of transferring knowledge over distance, and a loss of economies of scale and scope when R&D becomes more decentralised) firms have to shoulder when penetrating foreign markets, distance is expected to deter cross-country R&D flows.

$COMLANG_{ij}$ and $COMBORD_{ij}$ are dummies taking the value 1 if the two countries i and j share a common language and border, respectively, and are included to capture cultural and physical proximity between countries i and j. Specifically, strong cultural ties between countries (as proxied by common language) facilitate communication and the exchange of information and knowledge across borders while physical proximity (in terms of shared borders) is expected to further enhance cross-border flows in addition to distance. Furthermore, dummies for EU-membership are included which capture whether none, one or all two countries are EU-27 members. This will show whether effects from EU integration and the single market affect inward R&D flows.

In addition, $\ln GDP_{ij}$ and $\ln GDP_{jt}$ refer to the log of real gross domestic product in country i and j, respectively and are proxies for the market size of countries i and j. The em-

average wealthier than others (as proxied by real GDPs per capita, included in the equation as the sum of log real GDP and log population) may not only have a higher purchasing power, but may also be home to consumers with a stronger 'love for variety'. Hence, foreign-owned affiliates which develop or produce novel products or processes consider economies with higher standards of living attractive markets with promising market potentials and profit perspectives.

Moreover X_{zijt} is a matrix of z additional technology-related variables that are expected to affect inward R&D expenditure of foreign-owned affiliates to different degrees. Specifically, gross tertiary school enrolment rates in country i and j are included to account for the pivotal role the quality of human capital plays in research as firms may relocate product development to other parts of the world if faced with a shortage of skilled science and engineering talent or as an abundance of graduates in science and technology and strong scientific and engineering capabilities in a host country is able to attract business R&D into a host country.

To capture a country's general level of inventiveness, the ratio of patent applications of residents to total patent applications in country i and j is included to capture that more inventive host countries are attractive for foreign-owned affiliates seeking to harness prevailing local technology and innovation capabilities for the development of new products or processes.

7 Exceptions are Guellec and van Pottelsberghe de la Potterie (2001), Dachs and Pyka (2010) and Castellani et al. (2011).

Related to that, high-technology exports of country i and j (defined as the share of high-technology exports that are produced with high R&D intensity in total GDP) are included to capture the quality of indigenous R&D and technological capabilities foreign-owned affiliates can harness to successfully develop new products and processes or to adapt products and processes to local conditions and preferences.

In addition, as cross-country differences in the levels of technological development may also affect R&D flows across borders, the technology distance between country i and j is included, in terms of a correlation coefficient which, by construction, lies between [0, 1]. And the higher the coefficient, the smaller the technological distance between two countries, and the higher the countries' technological compatibility. And a high technological compatibility between countries is considered conducive to inward business R&D expenditures.

Data for the analysis are drawn from different sources. Data on inward R&D expenditure by investing country have been collected by AIT and wiiw in the course of the project. We included only data for the manufacturing sector. Furthermore, standard gravity indicators such as distance ($DIST_{ij}$), common language ($COMLANG_{ij}$), common boarder ($COMBORD_{ij}$) are taken from databases created by CEPII. Additional data sources are the World Bank's World Development Indicators (for GDP, tertiary school enrolment rates, high-technology exports and patent applications of resident and non-residents and total populations in country i and j) and the Austrian Institute of Technology (technology distance between country i and j).

The empirical analysis is based on an unbalanced sample for the period between 2001 and 2007. Results are provided for different estimation techniques: i) pooled OLS, ii) fixed effects for receiving and sending countries and iii) random effects specific for bilateral country pairs. The main shortcoming of the pooled OLS approach lies in its inability to allow for heterogeneity of host and home countries since it assumes that all countries are homogeneous. This is remedied by the fixed effects and random effects approaches which explicitly account for heterogeneity of individual both host and home countries as well as for heterogeneity of host-home-country pairs, respectively.

Relying on the econometrically appropriate specifications including country specific effects the results in Table 10 highlight that there is strong empirical support for the role of distance for the internationalisation of R&D. Inward R&D flows tend to decline with distance: in particular, a 1% increase in distance reduces inward R&D expenditure by between 0.4% and 0.8%. Moreover, common language and borders (which capture cultural and physical proximity, respectively) are conducive to business R&D expenditure of foreign-owned affiliates.

Additionally, a significant size effect emerges. Inward BERD increases by around 1% to 2% in response to a 1% increase in the host or home country's real GDP. Moreover, a high standard of living in both host and home countries is associated with higher R&D expenditure of foreign-owned affiliates. Specifically, a 1% increase in the host or home country's standard of living increases resources foreign-owned affiliates allot to research by around 0.7% and 0.8%.

Results also consistently stress that strong scientific and engineering capabilities in the host country attract business R&D into the host country, while a shortage of these crucial capabilities in the home country tends to foster the relocation of innovative activities to other parts of the world. However, no indication is found that the level of inventiveness of both home and host country, technological distance between home and host country in terms of patent specialisation, or the share of high-tech exports of home or host country is significantly related to inward R&D expenditure in the host country.

Table 10: Results on host and home country determinants of R&D internationalisation (2001-2007)

Dep. Var.: log of inward R&D expenditure						
Estimation technique	**Pooled OLS**	**Country FE**	**Country-pair RE**	**Pooled OLS**	**Country FE**	**Country-pair RE**
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Constant	-21.39***	-99.19**	-18.17***	-9.53***	103.43	-6.708**
	(16.86)	(2.06)	(10.01)	(4.99)	(0.51)	(2.54)
Log distance	-0.681***	-0.425***	-0.754***	-0.528***	-0.428***	-0.555***
	(6.64)	(3.96)	(4.78)	(5.29)	(3.99)	(3.60)
Common language	0.641**	-0.313	1.080***	0.079	-0.316	0.575
	(2.41)	(1.33)	(2.61)	(0.31)	(1.34)	(1.43)
Common border	0.454*	1.442***	0.453	1.037***	1.443***	0.986**
	(1.86)	(6.21)	(1.10)	(4.32)	(6.21)	(2.46)
Log real GDP HOST	1.078***	1.339	1.078***	1.485***	0.924	1.552***
	(18.26)	(0.64)	(11.99)	(13.08)	(0.43)	(9.83)
Log real GDP HOME	0.874***	5.544**	0.798***	1.915***	5.273**	1.610***
	(14.80)	(2.26)	(9.16)	(14.31)	(2.06)	(8.41)
Log population HOST				-0.700***	-9.059	-0.821***
				(4.72)	(1.20)	(4.05)
Log population HOME				-1.144***	-0.208	-0.911***
				(8.82)	(0.03)	(4.90)
Tertiary enrolment rate HOST	0.047***	0.014	0.029***	0.026***	0.007	0.010
	(8.79)	(0.54)	(4.13)	(4.17)	(0.26)	(1.28)
Tertiary enrolment rate HOME	-0.001	0.009	-0.007	-0.009**	0.008	-0.011**
	(0.32)	(0.45)	(1.35)	(2.13)	(0.44)	(2.13)
Share patent applications residents	-0.001***	0.000	0.000	-0.001***	0.000	0.000
HOST	(3.41)	(0.16)	(0.42)	(3.37)	(0.20)	(0.50)
Share patent applications residents	-0.001***	0.000	0.000	-0.001***	0.000	0.000
HOME	(4.11)	(0.67)	(0.91)	(5.16)	(0.62)	(1.03)
Share high-tech exports HOST	0.026	0.048	0.048*	0.022	0.061	0.041
	(1.21)	(0.53)	(1.88)	(1.04)	(0.66)	(1.64)
Share high-tech exports HOME	0.018	-0.070	-0.025	0.016	-0.073	-0.028
	(0.96)	(1.59)	(1.23)	(0.88)	(1.49)	(1.42)
Technology distance	-0.394	0.910	-0.627	0.905*	0.933	0.543
	(0.81)	(1.54)	(0.86)	(1.88)	(1.58)	(0.75)
Dummy: HOST EU-member	1.073***	0.459	0.530	0.592*	-40.722	0.251
	(3.22)	(0.03)	(1.01)	(1.84)	(1.16)	(0.50)
Dummy: HOME EU-member	1.765***	-0.152	1.439**	1.533***	41.029	1.205**
	(5.17)	(0.01)	(2.55)	(4.71)	(1.17)	(2.23)
Dummy: HOST and HOME EU-member	1.415***		0.519	1.296***		0.519
	(3.94)		(0.94)	(3.78)		(0.98)
Observations	910	910	910	910	910	910
Adj. R^2	0.562	0.773		0.605	0.773	
Number of i			309			309

Note: t-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1

8. IMPACTS OF R&D INTERNATIONALISATION

Host countries can benefit considerably from the R&D activities of foreign-owned firms. The literature reviewed in chapter 2 of this report lists different types of benefits: first, R&D expenditure of foreign-owned firms may increase aggregate R&D and innovation expenditure of the country; second, inward R&D expenditure may give rise to substantial information and knowledge spillovers; third, foreign-owned firms may boost the demand for skilled personnel including R&D staff; finally, inward R&D and the presence of foreign-owned firms may lead to structural change and agglomeration effects.

On the contrary, inward R&D may also entail negative effects for the host country. First, host countries may lose the control over their indigenous innovation capacity; second, if foreign-owned affiliates predominantly pursue adaptive innovation, this may lead to fewer radical innovations; third, multinational firms may separate research and production and their R&D may yield fewer jobs in the host country than in the case of a domestic firm; finally, increased presence of foreign-owned firms may increase competition with domestic firms for skilled personnel, which may lead to a crowding-out of R&D activities of domestic firms.

Against that backdrop, the ensuing analysis attempts to identify impacts and consequences the internationalisation of R&D and the presence of foreign-owned affiliates has on the host country. Section 8.1 looks at the effects on the level of domestic R&D expenditure, domestic R&D intensities (defined as the share of R&D expenditure of domestic firms in their value added), domestic labour productivity and domestic employment while section 8.3 throws light on the effects on domestic patenting activities.

8.1. The impact of inward BERD on domestic BERD and R&D intensity

With respect to host-country effects, the analysis follows the FDI spillover literature and examines the effects of R&D activities of foreign-owned affiliates on the level of domestic R&D expenditure as well as domestic R&D intensity (defined as the share of R&D expenditure of domestic firms in their value added). In view of that, the following models are estimated:

$$DOMVAR_{ikt} = \alpha_0 + \beta_1 FORRD_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt}, \qquad (8.1)$$

where DOMVAR_{ikt} is the log of domestic BERD or domestic R&D intensity, respectively of sector k in host country i at time t while FORRD_{jkt} refers to the log of inward BERD or R&D intensity of foreign-owned firms in sector k in country i at time t. Moreover, X_{zikt} is a matrix of z additional variables that captures sector and country level characteristics of host countries like sector size, sector growth, sector openness to international trade, sectoral investment rates or inward FDI intensities, host countries' real GDP per capita, real GDP growth rate or the log of real GDP, the share of tertiary graduates, the contribution of medium-high-tech-

Box 7: The impact of foreign presence on aggregate R&D expenditure in Austria and Canada

One of the main impacts of the internationalisation of R&D for host countries are increases in aggregate R&D expenditure. The decision of a multinational firm to take up or expand R&D activities in a country may lead to considerable increases in aggregate R&D expenditure in a short time, in particular in small countries.

To understand why multinational firms select which countries for their R&D activities, a couple of studies – including this one – have analyzed the drivers of R&D internationalisation. However, a potential impact of inward BERD on aggregate R&D expenditure in a country is not just a matter of presence of various drivers. This becomes obvious if we compare Austria and Canada. Both countries share a lot of characteristics which have been identified as drivers of inward BERD, including a high GDP per capita, political and economic stability, favourable business conditions, a large pool of skilled researchers, a high degree of internationalisation in terms of trade and FDI, a large R&D performing neighbouring country and a high degree of similarity in terms of culture and language with this country.

Despite these similarities, R&D expenditure of foreign-owned firms in Canada and Austria took different routes in recent years. Between 2003 and 2007, inward BERD doubled in nominal terms in Austria, but only grew by about 25% in Canada during this period. Thus, the impact of foreign presence on total BERD is not just a matter of presence of various drivers – the well-known drivers of inward BERD are all present in Canada as well as in Austria – but roots deeper into the structures and the institutional set-up of national innovation systems. Examples are, among other factors, by the economic structure including the share of resource-based industries, different developments of key industries such as the automotive industry, the role of indigenous multinational, or differences in the public support for R&D.

nology industries to the manufacturing trade balance or the share of government budgetary appropriations or outlays for R&D in real GDP.

The analysis is based on unbalanced samples for the manufacturing sector (2004-2007) and uses the following data sources: the OECD Activities of Foreign Affiliates statistics (OECD AFA), the OECD Structural Analysis Database (OECD STAN), the OECD STAN Bilateral Trade Database, the OECD Main Science and Technology Indicators and the OECD International Direct Investment Statistics (OECD IDI).

Results are summarised in Table 11. Except for the overall sample considered (column (2)), the levels of R&D expenditure of foreign-owned and domestic firms are unrelated[8]. Hence, for the EU, there is no evidence that R&D expenditure of foreign-owned affiliates substitutes (or crowds-out) domestic R&D expenditure.

In contrast, except for the overall OECD sample (column (1)), significant complementarities surface between R&D intensities of foreign-owned and domestic firms. This is consistent with findings of the graphical analysis of R&D intensities (see section 7.2 above) which highlight that apart from a couple of outliers, R&D intensities of both domestic and foreign firms are pretty similar.

Likewise, since the internationalisation of R&D may also have implications for the home country of the multinational firm, the analysis also looked at the reverse effect and analysed the impact of outward R&D expenditure of foreign affiliates on their home countries. A main benefit for home countries is the transfer of knowledge from domestic firms located abroad back to their home countries. Various studies provide evidence for such reverse knowledge transfers. Reverse knowledge transfer may increase the overall technological capacity and strengthen the growth of the parent company. But overseas R&D of domestic firms may also have negative consequences for the home country when firms replace domestic R&D activities with similar activities abroad

The analysis, though severely plagued by missing data on outward BERD, does not suggest such a 'hollowing out' of domestic R&D. Case study evidence (see Box 8 below) even suggests that domestic and overseas R&D complement each other, because they target different markets. This is in line with other studies which point at complementarities between domestic and foreign R&D activities, at least at the aggregate level and in the long term.

Table 11: Impact of R&D expenditure of foreign-owned firms on R&D expenditure and intensity in the host country (2004-2007)

	OVERALL (1)	EU (2)	EU-15 (3)	EU-12 (4)
Effect of inward BERD on domestic BE EU-member RD	–			
Effect of foreign R&D intensity on domestic R&D intensity		+	+	+

All regressions for R&D expenditure are based on fixed effects estimation procedures and include time fixed effects and country fixed effects plus additional sector and country controls. Blank cells indicate insignificant effects.

8 The complete regression results can be found in Deliverable 7.

Box 8: Implications of Overseas R&D for the Home Country: A Case Study of two German Multinationals in India

In recent years, emerging economies became host countries for R&D activities of EU firms. India and China in particular rank very high in surveys of the relative attractiveness of various R&D locations (see, for example, Thursby and Thursby 2006 or European Commission 2010). This attractiveness has raised concerns that emerging economies may compete with locations in the EU for R&D centres of multinational firms. This box examines the relationship between R&D abroad and R&D in the home country for two German multinational firms, Bosch and Siemens.

Bosch employs around 280,000 people world-wide and is a supplier of products and services in the areas of automotive & industrial technology, consumer goods and building technology. Siemens AG is a German multinational firm primarily active in technologies related to energy, healthcare, industry and infrastructure. Siemens employs around 360,000 people, 27,800 of them in R&D.

Both companies have large, long-standing business activities in India, including R&D, which experienced a steady and sustained growth in recent years. They have located R&D in India to participate in this fast-growing market, but also because of the availability of skilled personnel and the wish to anticipate new technology trends that emerge from India ('frugal innovation').

R&D activities in India complement, but not substitute R&D in Germany in both cases. Activities in India are targeted towards local demand, or fields which are not covered adequately by the German activities. Thus, the two cases do not provide evidence for an offshoring of R&D jobs to India. Rather, they indicate that the emergence of new markets in India had also positive effects on jobs growth in Germany.

8.2. The impact of inward BERD on domestic labour productivity and employment

Equation 8.1 is also used to estimate the impact of inward BERD on domestic labour productivity and employment. The results demonstrate that except for the group of EU-12 countries (Table 12, first row) R&D efforts of foreign-owned affiliates are positively related to labour productivity of domestic firms. Specifically, a 1% increase in R&D expenditure of foreign-owned affiliates is associated with a 0.05% increase in labour productivity of domestic firms, so the effect is rather small. In contrast, there is no evidence of any employment effect of inward R&D expenditure (Table 12, second row).

Table 12: Impact of R&D expenditure of foreign-owned firms on the labour productivity and employment in the host country (2004-2007)

	OVERALL (1)	EU (2)	EU-15 (3)	EU-12 (4)
Effect of inward BERD on domestic labour productivity	+	+	+	
Effect of Inward BERD on domestic employment				

All regressions are based on pooled OLS estimation procedures and include time fixed effects and country fixed effects plus a set of sector and country controls. Column (1) uses the overall sample, column (2) is based on the overall EU sample; column (3) uses the EU-15 sub-sample only, while column (4) uses the EU-12 sub-sample only. Blank cells indicate insignificant effects.

However, innovative activities are highly resource-intensive and uncertain, giving rise to only a small group of lucky winners while leaving the majority of firms unrewarded for their research efforts. In particular, there is no guarantee that substantial inputs into any innovative process translate into a successful and marketable new or modified product and/or process. Hence, the effects of R&D expenditure of foreign-owned affiliates on their own labour productivity or employment might be rather limited. Furthermore, in view of that, any effects on labour productivity or employment of domestic firms may be rather small also or absent altogether (as highlighted above).

Hence, against that backdrop, an alternative approach is taken, which more directly identifies the effects successful research activities of foreign-owned affiliates have on domestic firms. Numerous firm-level studies reveal that successful R&D activities translate into higher firm labour productivity and growth (both in terms of sales but also in terms of employment). Hence, the analysis determines whether higher labour productivity of foreign-owned affiliates (as a result of successful innovative activities) also translates into higher labour productivity of domestic firms or whether larger foreign-owned affiliates are matched by larger domestic firms. For that, the following specification is estimated:

$$DOMVAR_{ikt} = \alpha_0 + \beta_1 FORVAR_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt}, \text{ (8.2)}$$

where $DOMVAR_{ikt}$ is the log of domestic labour productivity or the log of domestic employment, respectively, in sector k in host country i at time t while $FORVAR_{jkt}$ refers to the log of foreign labour productivity or of foreign employment in sector k in country i at time t. Moreover, X_{zikt} is a matrix of z additional variables that captures sector and country level characteristics of host countries like sector size, sector growth, sector openness to international trade, sectoral investment rates or inward FDI intensities, host countries' real GDP per capita, real GDP growth rate or the log of real GDP, the share of tertiary graduates, the contribution of medium-high-technology industries to the manufacturing trade balance or the share of government budgetary appropriations or outlays for R&D in real GDP.

The results (Table 13) highlight that irrespective of sample considered, labour productivity of foreign owned affiliates is positively associated with labour productivity of domestic firms. In particular, a 1% improvement in the labour productivity of foreign-owned firms is associated with an increase in domestic labour productivity by around 0.4%. This relationship is strongest for the sample of EU-15 countries.

Moreover, employment in foreign-owned affiliates and domestic firms is positively associated. Specifically, a 1% increase in employment in foreign-owned affiliates is associated with a 0.6% increase in domestic employment. By comparison, this relationship is slightly stronger for the sample of EU-12 countries.

Table 13: Impact of labour productivity and employment of foreign-owned firms on labour productivity and employment in the host country (2004-2007)

	OVERALL (1)	EU (2)	EU-15 (3)	EU-12 (4)
Effect of foreign labour productivity on domestic labour productivity	+	+	+	+
Effect of foreign employment on domestic employment	+	+	+	+

All labour productivity-related regressions are based on pooled OLS estimation procedures and include time and country fixed effects while employment-related regressions are based on are based on FE estimation procedures and include time fixed effects to account for common time effects. Column (1) uses the overall sample, column (2) is based on the overall EU sample; column (3) uses the EU-15 sub-sample only, while column (4) uses the EU-12 sub-sample only. Blank cells indicate insignificant effects.

8.3. The impact of inward BERD on domestic patenting activities

R&D activities of foreign-owned affiliates may also be associated with more intense patenting activities in the host country. In particular, higher R&D efforts of foreign-owned affiliates may spur domestic patent activities by increasing domestic firms' inventiveness and innovativeness: either through i) knowledge spillovers which help domestic firms develop technological capabilities essential for any successful R&D activities or through ii) intensified R&D efforts of domestic firms so as to keep pace with and defy strong competition from abroad.

For that purpose, the following specification is estimated:

where lnDOMPATENTS$_{ikt}$ represents the log of patent applications to the European Patent Office (EPO) of domestic firms in sector k of country i in time t while FORRDint$_{jkt}$ and DOMRDint$_{ikt}$ are the R&D intensities of foreign-owned affiliates and domestic firms, respectively, (as the share of R&D expenditure in value added) in sector k of country i at time t.

Moreover, X$_{zikt}$ is a matrix of z additional variables that captures both sector and country level characteristics of host countries only. At the sectoral level, a sector's size as the share of a sector's employment in total labour force is included since larger sectors are expected to be very dynamic and innovative, hosting numerous firms that allot sizeable R&D expenditure to the development of new products or processes, which, for protective purposes, may be registered with the patent office. R&D efforts and success may

$$\ln DOMPATENTS_{ikt} = \alpha_0 + \beta_1 FORRD\mathrm{int}_{ikt} + \beta_2 DOMRD\mathrm{int}_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt}, \quad (8.3)$$

Table 14: Impact of R&D internationalisation on the host country (2004-2007) – domestic patenting activity

Variables	OVERALL (1)	EU (2)	EU-15 (3)	EU-12 (4)
FORRDint$_{jkt}$				
DOMRDint$_{ikt}$			+	

All regressions are based on fixed effects estimation procedures. Column (1) uses the overall sample, column (2) is based on the overall EU sample; column (3) uses the EU-15 sub-sample only, while column (4) uses the EU-12 sub-sample only. Blank cells indicate insignificant effects.

be higher in quickly expanding sectors, a sector's growth rate (in terms of employment) is included. Finally, the degree of openness to international trade (as the share of the sum of exports and imports in total gross output) is included to capture that faced with tougher international competition, firms may see the need to intensify their own R&D efforts in order to keep up with competition, to survive and thrive. As a consequence, new innovations may materialise which, for protective purposes, may be registered.

At the country level, a host country's real GDP per capita growth rate is included to capture the role a growing standard of living plays for sector level domestic patenting activities as well as the contribution of medium-high-technology industries to the manufacturing trade balance is included as a proxy for a country's capability to generate technologically sophisticated and internationally competitive products which may translate into more intense patenting activities. The analysis uses data from different sources.

The dependent variable stems from the OECD Patent Database, R&D expenditure of foreign-owned affiliates represent data collected in the course of this project, while R&D expenditure of domestic firms is calculated as the difference between total R&D expenditure (as collected in the course of this project) and R&D expenditure of foreign-owned affiliates. Furthermore, information on value added of foreign-owned affiliates is taken from the OECD Activities of Foreign Affiliates statistics (OECD AFA) while information on value added of domestic firms is calculated as the difference between total sectoral value added (as included in the OECD Structural Analysis Database (OECD STAN)) and value added of foreign-owned affiliates. Additionally, data on sector size, growth and openness are calculated from data included in the OECD Structural Analysis Database (OECD STAN). Finally, the real GDP pc growth rate and the contribution of medium-high-technology industries to the manufacturing trade balance are calculated from data taken from the OECD STAN Bilateral Trade Database.

The results are presented in Table 14 below and show that host country patenting activities appear unrelated to both foreign-owned affiliates' as well as domestic firms' R&D intensities. Hence, there is lacking evidence of either any knowledge spillover effect (that might spur domestic firms' inventiveness or innovativeness) or of any competition-driven effect (that induces domestic firms to intensify their R&D efforts and innovativeness to defy competition from abroad). The only exception is the group of EU-15 countries for which a positive and significant relationship emerges: hence, we find higher R&D intensities of domestic firms associated with higher EPO patent applications only for the group of EU-15 countries.

However, the absence of a significant relationship between (foreign-owned and domestic) R&D intensities (as inputs in the highly resource intensive and uncertain innovative process) and host country patenting activities (capturing the output-side of an innovative process) is not much of a surprise as patents are imperfect proxies for the output of research activities:

First, not all innovations are patented. Specifically, firms may consider the financial and/or administrative burden associated with any application procedure as too high or innovators may opt for other forms to maintain their competitive edge, like the exploitation of any first-mover advantage. Second, patents do not capture innovations of imitators. Hence, official patent statistics strongly underestimate a country's true innovativeness.

Third, any innovative process is highly complex, resource intensive and highly uncertain, characterised by a continuous trial-and-error process without any guarantee that all research efforts will eventually materialise in marketable product or process innovations. Hence, higher R&D expenditure is no guarantee for any innovative success and, consequently, for any new patent applications. Finally, there is a tendency that complex relationships vanish or become obstructed once higher levels of aggregation are analysed.

9. CLOSING REMARKS

Firms not only sell or produce their products and services abroad, but increasingly also do research and development (R&D) at locations outside their home countries. We call this development the internationalisation of business R&D.

This project has analyzed the internationalisation of business R&D in detail. The results indicate that the member countries of the European Union are active players in the internationalisation of business R&D and that the EU benefits from this process to a considerable degree.

First, there is evidence that the internationalisation of business R&D has strengthened intra-EU integration and the exchange of knowledge between EU countries. Around half of all R&D expenditure of foreign-owned firms in the EU can be assigned to firms from other EU member states.

Second, the data collected in the project indicates that the European Union is also an attractive R&D location for firms from outside the EU-27. Non-EU firms, in particular US firms, have continuously increased R&D expenditure in the EU since the 1990s. Multinationals from India, China, Brazil or other emerging economies are just about to make their first steps into the EU as a location for their R&D activities.

The literature as well as the empirical analysis identified various factors that are conducive to foreign R&D: developed markets with a sophisticated demand ('lead market'), the quality and quantity of its pool of skilled labour, a stable economic framework, and excellence in academic and business R&D. The EU countries score high on these factors.

Third, EU countries benefit from R&D activities of foreign-owned firms. Their R&D expenditure helps to raise overall R&D intensity in order to achieve the goal of 3% research and development expenditure on GDP as laid down in the Europe 2020 strategy. Moreover, R&D expenditure and labour productivity of foreign-owned affiliates is positively related to labour productivity of domestic firms which may indicate spillover and competition effects.

Fourth, EU firms are also very active in R&D abroad, in particular in the US, helping them to open up new markets and expand globally. The home countries may benefit from the global expansion and from reverse knowledge spillovers. Based on today's empirical evidence, it is unlikely that these overseas R&D activities are a substitution for similar domestic activities.

The analysis also identified some blind spots where more knowledge is needed to fully apprehend the drivers and consequences of the R&D internationalisation for the EU as well as its future prospects. One of these areas is the role of emerging economies, including China and India, for which considerable data gaps exist. Data on the activities of EU firms in these markets as well as on overseas R&D expenditure of firms from these countries is still very limited. Another blind spot is the service sector. Detailed data on R&D of foreign-owned firms in the service sector is missing in a number of countries. Moreover, there is only limited knowledge on what happens inside multinational firms, how knowledge and people move inside multinational firms between countries, or how specialisation, roles and mandates of subsidiaries change over time.

Policy can help in various ways to maintain Europe's favourable position in the internationalisation of business R&D. First, policy makers should try to create a research-friendly environment. Rather than trying to attract R&D intensive foreign-owned firms, results from the econometric analysis indicate that policy should look to maintain stable economic 'fundamentals', increase the skills of the workforce, strengthen university research and increase the innovative capabilities of firms. Second, in order to maximise spillovers from foreign-owned firms, policy should raise the capabilities of domestic organisations to absorb knowledge and help foreign-owned firms to integrate into domestic innovation networks. Third, policy makers should not be too worried about R&D activities of EU firms outside the European Union. There is no evidence that these activities substitute domestic research; in contrast, they are a means to open up new markets and may contribute to growth at home.

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Firms increasingly perform research and development (R&D) at locations outside their home countries. This development is referred to as the internationalisation of business R&D. The internationalisation of R&D has become an important trend that shapes the national innovation systems of all EU and OECD countries. Foreign-owned firms already account for 20% to 25% of total business R&D in France, Germany and Spain; between 30% and 50% in Canada, Hungary, Portugal, the Slovak Republic, Sweden and the United Kingdom; and more than 50% in Austria, Belgium, the Czech Republic, Malta, or Ireland.

The project "Internationalisation of business investments in R&D and analysis of their economic impact" has been launched by the Directorate General for Research and Innovation of the European Commission (Economic Analysis Unit) to examine this phenomenon in detail. This study is part of a set of projects providing key information for policy making in the perspective of contributing to growth in Europe through innovation policies

The study results indicate that EU member countries are active players in the internationalisation of business R&D. The internationalisation of business R&D has strengthened intra-EU integration and the exchange of knowledge between EU countries. Around half of all R&D expenditure of foreign-owned firms in the EU can be assigned to firms from other EU member states.

This report, as well as a short Summary report of the study, the detailed Analytical Report and 34 Country reports are available at: http://www.ec.europa.eu/research/innovation-union/index_en.cfm?pg=other-studies

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