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

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1. COMPARISONS ACROSS COUNTRIES AND SECTORS

The first chapter of deliverable 7 moves the focus of analysis from the perspective of individual countries (D6) to the „big picture“ of R&D internationalisation by examining variations in the degree of R&D internationalisation across countries and sectors. The first section of this chapter looks at differences in inward BERD across countries and over time to identify the countries which are most internationalised. Section 1.2gives 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. We proceed with a cross-country analysis of the existing outward BERD in section 1.3. Section 1.4analyses the relationship of business expenditure on the aggregate level between the European Union and The United States of America. Section 1.5 concludes this first chapter with a sectoral perspective on business expenditure R&D, and investigates the development of inward BERD in selected industries across time and countries.

The observations for EU countries rely mostly on Eurostat data and were complemented by OECD data for non-EU countries. In some cases national data was the main or only data source; this is in particular the case for Belgium, China, Spain and Switzerland. US outward data proved to be very useful for the big worldwide picture. Maps 1 to 26 provided in D8 are based on the data and indicators presented in this chapter and therefore compliment the figures presented at this place. The maps are in the same order as the equivalent figures: We start with inward BERD across countries (Maps 1, 3 and 4), compare with inward FDI stocks (Map 2) continue with cross-country variations in the distribution of home countries (Maps 5 to 12), outward BERD across countries (Maps 13 and 14) and a cross-sector comparison (Maps 15 to 26). Additionally, references to specific maps can be found in the notes below the corresponding figure.

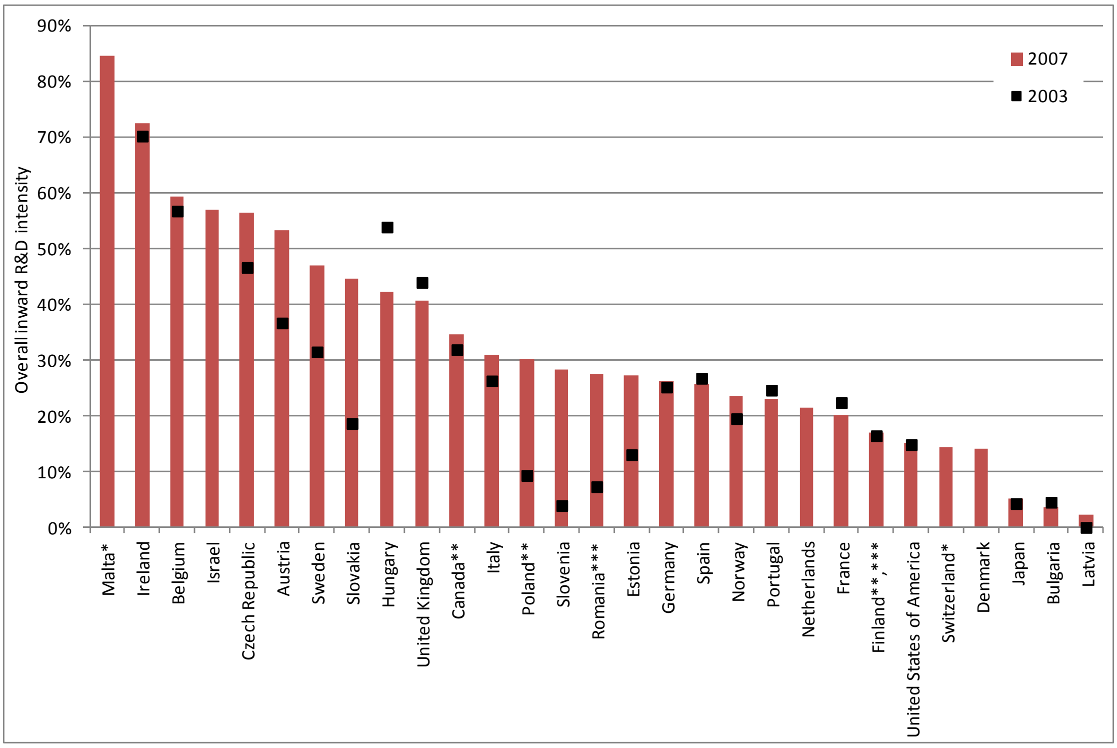
1.1. Inward BERD across countries and over time

This section compares the internationalisation of R&D across countries. We cover both inward and outward R&D as well as absolute BERD for the countries where data is available. Figure 1depicts the overall inward R&D intensity. This indicator measures the ratio of inward BERD to total BERD (including foreign-owned and domestically owned BERD). It thus shows the ability of a national innovation system to attract inward investments of foreign-owned firms.

We see in Figure 1 that the internationalisation of R&D is increasing in the majority of countries. Only Hungary and the United Kingdom experienced a decrease in the share of inward BERD between 2003 and 2007. The internationalisation of R&D, however, emerges only slowly, as we can see from the stagnant inward R&D intensities of a number of countries, including large countries such as France, the US, Japan or Germany. Huge changes between 2003 and 2007 can only be observed in small countries.

Small countries are leading the process of R&D internationalisation. Overall inward R&D intensity is highest in small countries. That is to say, inward BERD accounts for more than 50% of total BERD in Malta, Ireland, Belgium or Austria. Large countries such as Germany, Spain, France or the U.S., in contrast, show inward R&D intensities of only 15% to 26% of total BERD. But there are also important exceptions to this rule, for example Switzerland Denmark, Finland, or Latvia, which show only a low level of R&D internationalisation. It is difficult to find a common pattern in the figure, since overall inward R&D intensity seems to be unrelated to most science and technology policy or internationalisation indicators such as the share of aggregate R&D expenditure on GDP, share of persons with tertiary education on the workforce, positions of countries in the Innovation Union Scoreboard, or openness in terms of foreign trade, foreign direct investment or student's mobility.

Figure 1: Overall inward R&D intensity (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, see also Deliverable 8, Map 1

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

Figure 2 compares for the year 2007 the inward R&D intensity with the inward FDI intensity. The latter is defined as the ratio of inward FDI stocks to nominal GDP and used as a proxy to measure the presence of foreign-owned companies in an economy[1].A trend line is included to indicate the average values of combinations between the two variables.

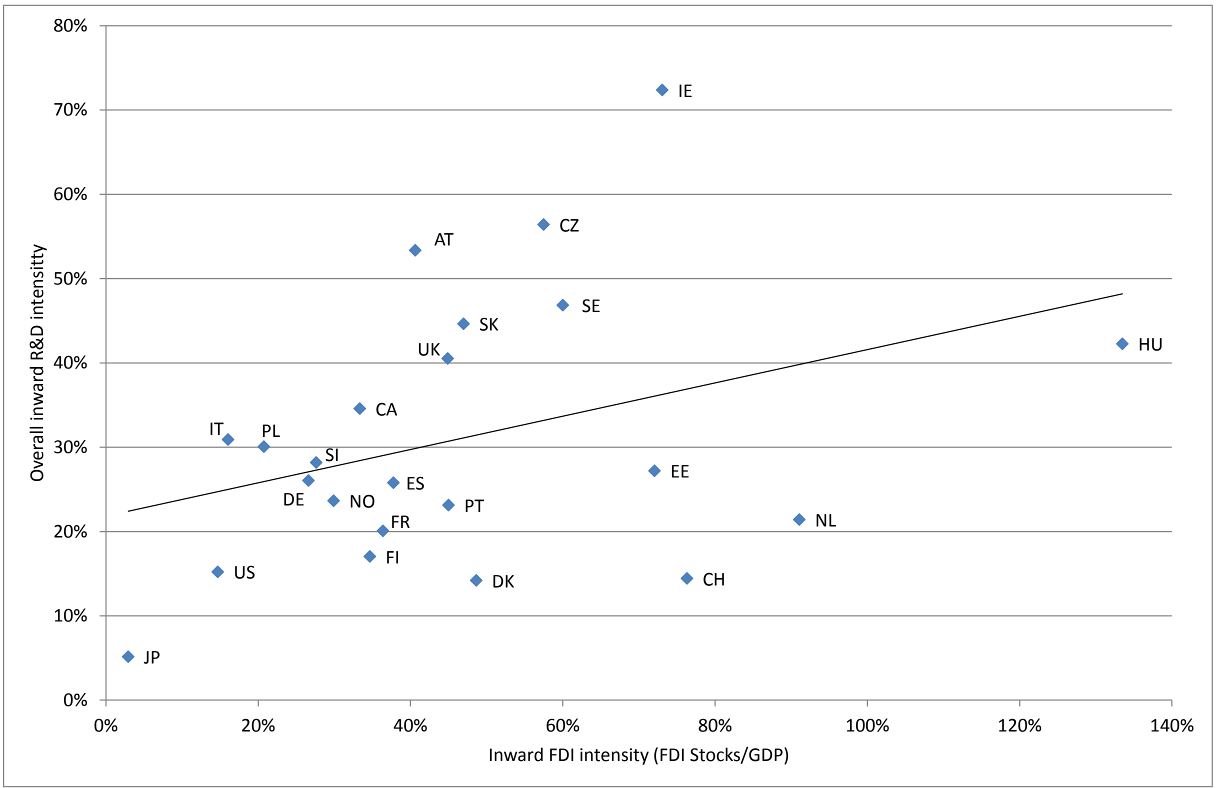
Not surprisingly, only countries with at least average levels of relative inward FDI stocks have a high inward R&D intensity. The best example for a country with both, high level of FDI stock and high inward intensity is Ireland, other countries with such a combination include the Czech Republic, Sweden, Slovakia, Austria and the United Kingdom.

However, high levels of inward FDI stocks do not always go along with above average inward BERD intensities. Hungary has by far the highest ratio of inward FDI stock to GDP but only an average inward BERD intensity, Switzerland, the Netherlands and Estonia are among the most internationalized countries in terms of inward FDI stocks but below average

[11] The use of the ratio of inward FDI stocks to GDP as a measure of the foreign presence in an economy is problematic because FDI stocks are not part of GDP. The more accurate measure, the share of foreign-owned firms on value added, is extensively analysed in chapter 3. However, given that FDI data is available for more countries than data on value added we make use of this ratio at this point to enable an inclusion of as many countries as possible to get a rough idea how the internationalisation of R&D is related to the overall presence of foreign firms in the countries considered.

internationalized in terms of business R&D. Similar to the R&D intensity, relative FDI stocks also tend to be lowest in large economies, most notable Japan and the United States.

Figure 2: Overall inward R&D intensity and inward FDI intensity (2007)



Notes: The inward FDI intensity is defined as the ratio of FDI stock to nominal GDP in 2007

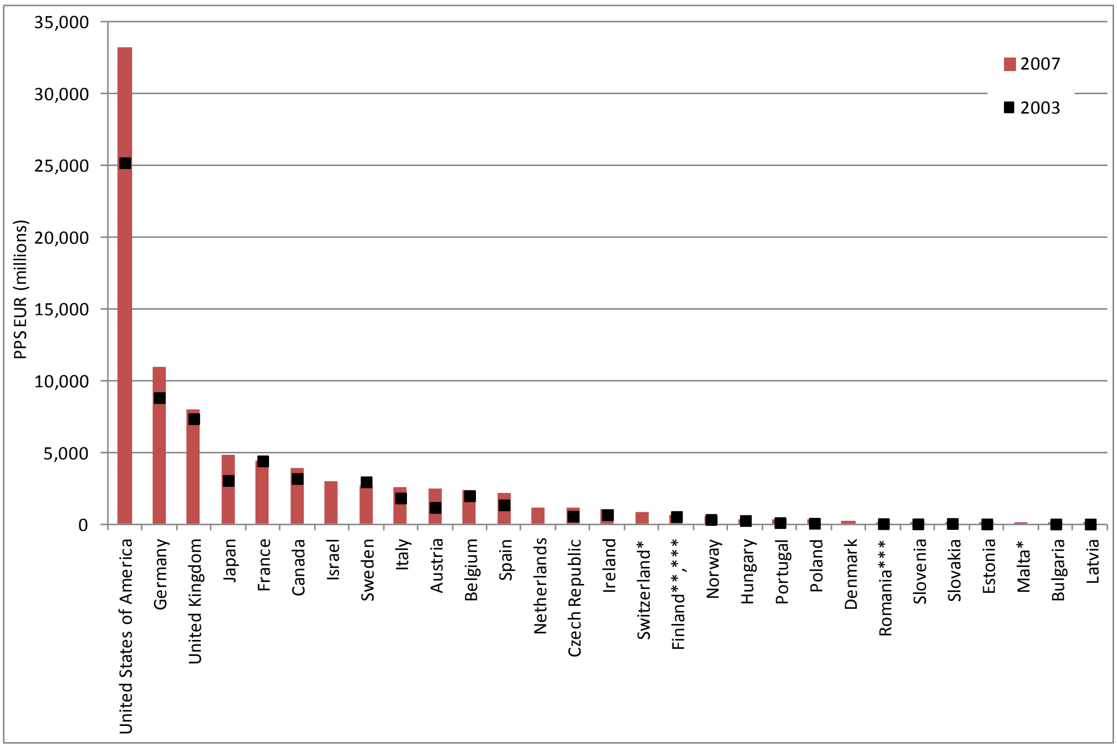
See also Deliverable 8, Map 1 and 2

In order to get an impression of the magnitude of the process of R&D internationalisation, it is important to have a look not only at relative, but also at absolute inward BERD. Total inward BERD (see Figure 3) is highest in the largest countries, even if these countries have low inward R&D intensities. In comparison to all other countries observed here, the U.S. accounts for a lion's share of total inward BERD.

Regarding absolute numbers, inward BERD increased in every single country, besides France and Sweden, although decreases in these countries are vanishingly small. Looking at Hungary and the United Kingdom, for which decreases were found in relative terms, in absolute terms total inward BERD grew. Again, the EU-12 countries show lowest total inward BERD among the EU-27 countries, whereas the EU-15 countries are ranked highest.

Total inward BERD as a % of GDP (Figure 4) is fairly stable over time for the majority of the countries. EU-15 countries tend to have higher and stable levels of inward BERD as % of GDP, EU-12 countries tend to have lower levels but higher growth rates. All countries with an inward BERD share of more than 0.5% of GDP are small and medium sized countries. With the Czech Republic also one EU-12 country is one of these top ranked countries. The few non-EU countries included, Canada, Switzerland, the United States and Norway, all have medium and stable levels of inward BERD as % of GDP.

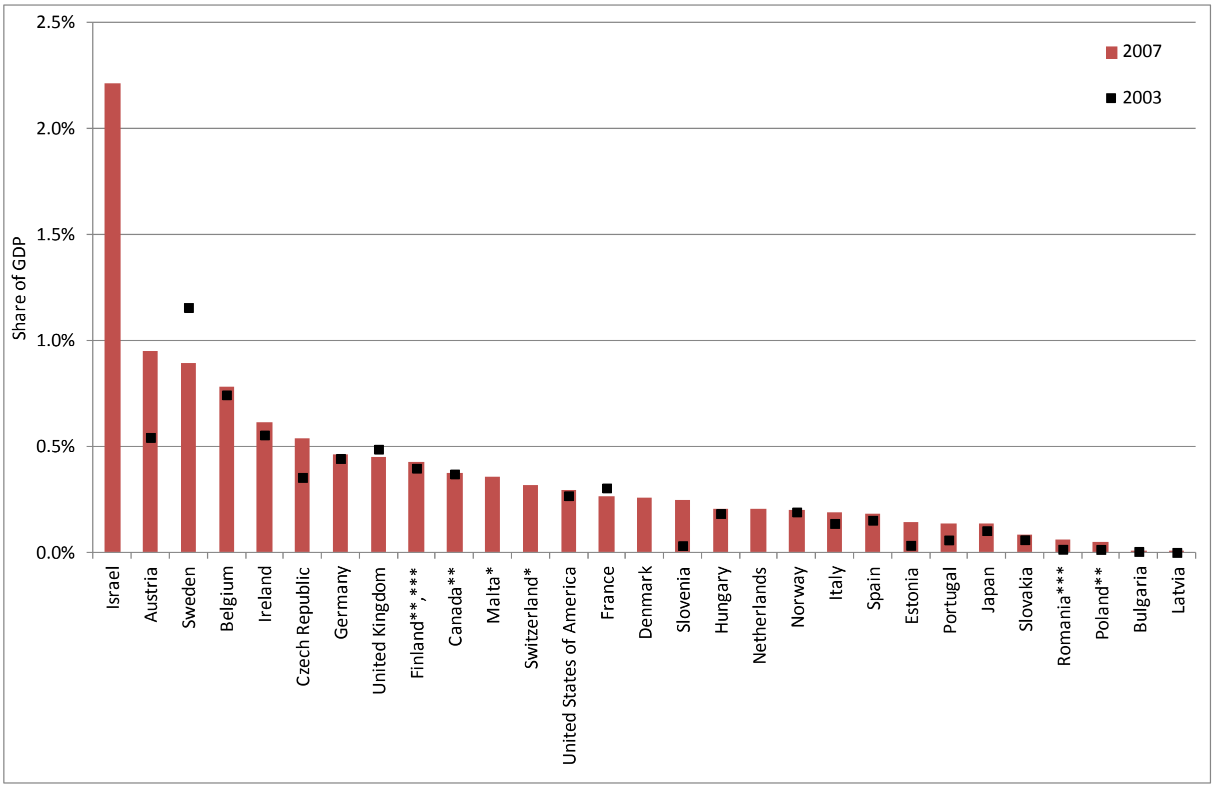
Figure 3: Total inward BERD (PPS EUR, 2003 and 2007)



Note: No 2003 data for Malta, Israel, Netherlands, Switzerland and Denmark; * 2008 instead of 2007; ** 2006 instead of 2007; *** 2004 instead of 2003, see also Deliverable 8, Map 3

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

Figure 4: Total inward BERD (as a % of GDP, 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, see also Deliverable 8, Map 3

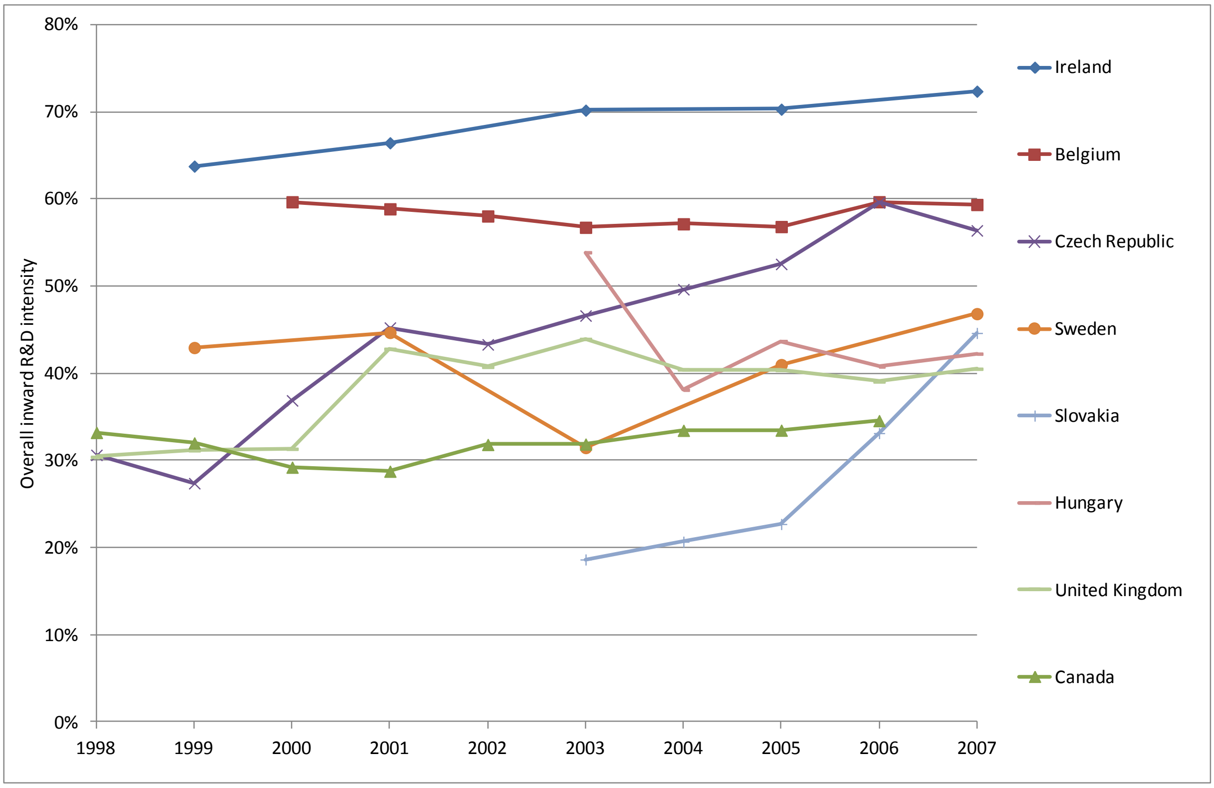
Source: OECD, Eurostat, national statistical offices, own calculations

Readers should be aware that summing up the inward BERD of the EU-27 member states to compare inward BERD in the US and the EU-27 is not appropriate, because the data for the EU-27 member states also include cross-border inward BERD between the member states. A comparison of the EU and the US follows below.

The internationalisation of R&D has increased or remained at least stable in almost all countries reported here over time, except Hungary and to a lesser extent the United Kingdom. The largest increases of overall inward R&D intensity can be found for the EU-12 countries such as Slovakia, Poland or Slovenia. This might be traced back to widely known R&D internationalisation patterns, stating that in most cases, the internationalisation of R&D follows the internationalisation of production.

The following three figures (Figure 5 to Figure 7) show the overall inward R&D intensity over time. It is evident that overall inward R&D intensity has been growing in almost all countries over the last decade (a decline of inward R&D intensity can be found only in Hungary, Spain and to a lesser extend in Italy). A constant and slightly increasing level of inward R&D intensity can be observed in most of the high intensity countries (Figure 5) and low intensity countries (Figure 7). A considerable level of volatility in contrast can be found in the medium intensity countries (Figure 6).

Figure 5: Overall inward R&D intensity (inward BERD / total BERD, 1998 to 2007, high intensity countries)

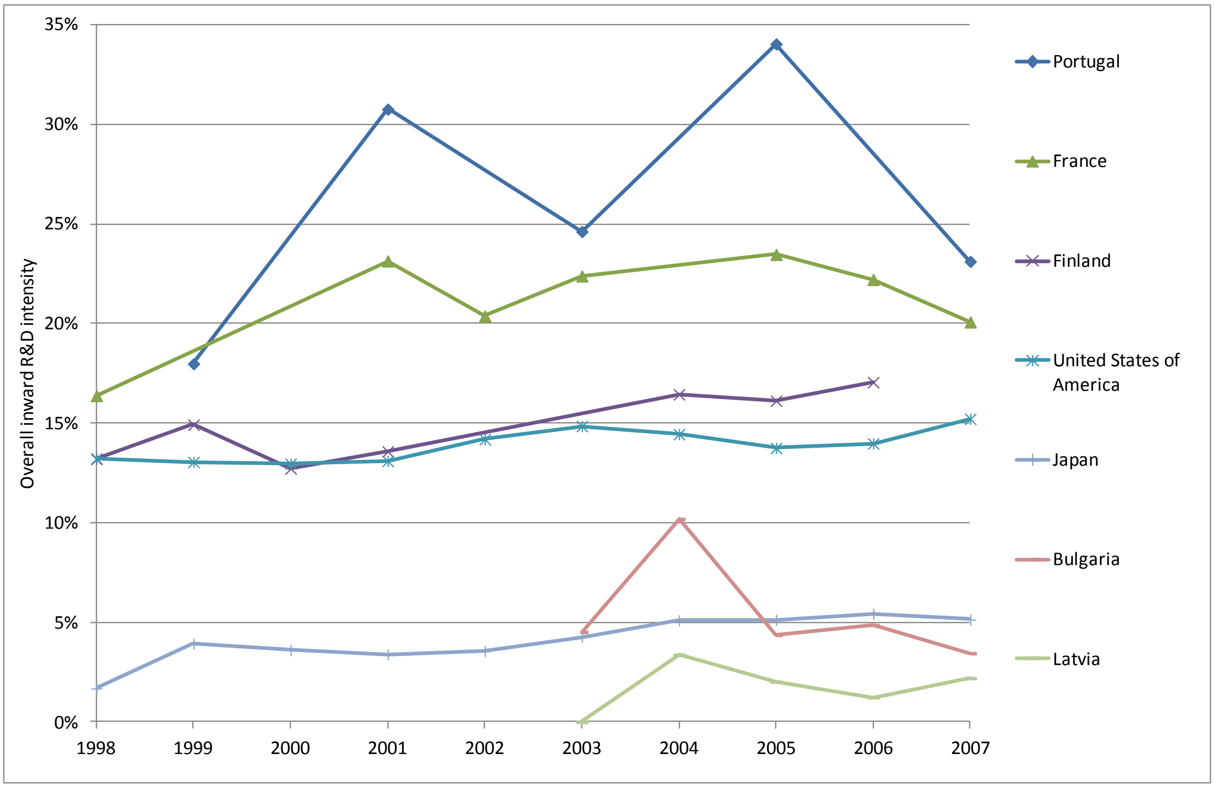


Source: OECD, Eurostat, national statistical offices, own calculations

Figure 6: Overall inward R&D intensity (inward BERD / total BERD, 1998 to 2007, medium intensity countries)

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

Figure 7: Overall inward R&D intensity (inward BERD / total BERD, 1998 to 2007, low intensity countries)



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

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 are only few foreign-owned affiliates 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 (Figure 5), Slovenia, Poland and Romania (Figure 6). Especially in the medium intensity countries (Figure 6), a convergence towards an inward R&D intensity level of about 20% to 30% can be observed. The case study in Chapter 4.5 on the Internationalisation of R&D in the automotive sector of the Czech Republic, Hungary, Slovakia and Romania analyses in detail some of the reasons for these observed changes.

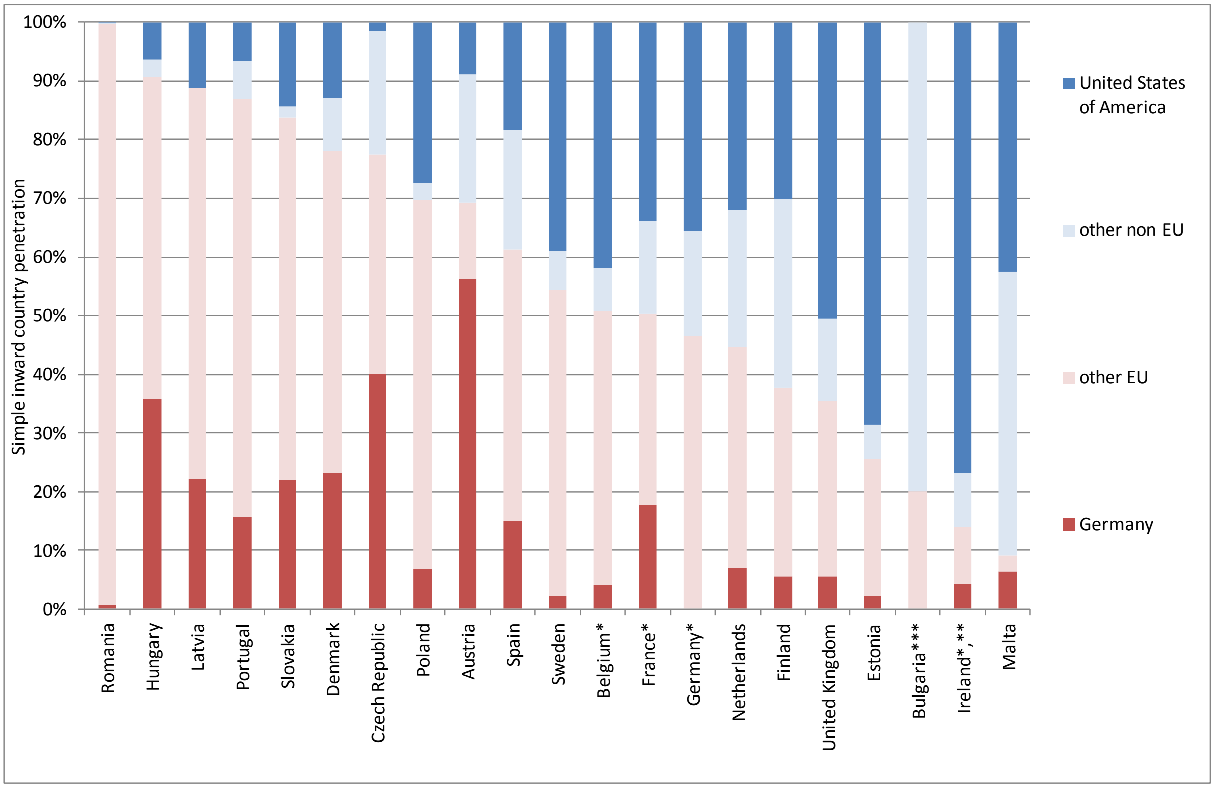
1.2. Cross-country variations in the distribution of home countries

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 home countries. In this chapter, we focus on the relative importance of various home countries and the question if the internationalisation of R&D in different countries is mainly due to the activities of European firms (intra-Europe internationalisation) or non-European firms, which are mainly US firms.

We measure the role of different home countries on overall inward BERD by the simple inward country penetration. The indicator shows the share of inward BERD from a particular country on total inward BERD. We distinguish between EU-27 and non EU-27 member countries. Further, Germany and the United States are listed separately, as they are the countries with the largest outward BERD.

Differences between countries in this indicator are huge (Figure 8). Countries such as Romania, Hungary, Latvia, or Portugal have virtually no inward BERD from non-European firms, while the opposite is true for Malta, Ireland and Bulgaria. Between these two extremes, virtually every distribution between European and non-European firms can be observed. Belgium, France and Sweden lie in the middle of this distribution.

Figure 8: 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, see also Deliverable 8, Maps 8, 9 , 10 and 11

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

Inward BERD in EU-12 countries mostly stems from European countries. The role of non-European 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 and other non-European countries. In contrast, major shares of inward BERD in Portugal and Denmark are from European countries. Large shares of inward BERD from the United States in Ireland, Malta or the United Kingdom might be explained by the same language. The reader should keep in mind that although Estonia shows a high share of inward BERD from the US, inward BERD in absolute terms is very small. The case study on internationalisation of R&D in knowledge-intensive business services (see chapter 4.2) reveals that a single US-owned company, Skype, is responsible for the observed high relative importance of the US as a home country for inward BERD R&D in Estonia. This might likewise be the case in Bulgaria, where data only allows us to differentiate between European and non-European countries of origin.

Distance - may it be socio-cultural or geographic distance - might have an impact on the simple inward country penetration as well. We conclude that this is the case for Austria, Hungary and the Czech Republic, where the largest shares of inward BERD come from Germany, referring to geographical distance. Additionally, the investment decisions of a small number of large MNCs play an important role. Especially German companies in the automotive sector (see case study in Chapter 4.5) and producers of electrical machinery and apparatus perform a significant amount of R&D in these countries.

Figure 9 shows the simple inward country penetration of the top investor country, which is the share of the top investor country on total inward BERD. There are eight countries with an inward country penetration of over 50%. This indicates that there are strong relationships between single countries which may have the following reasons.

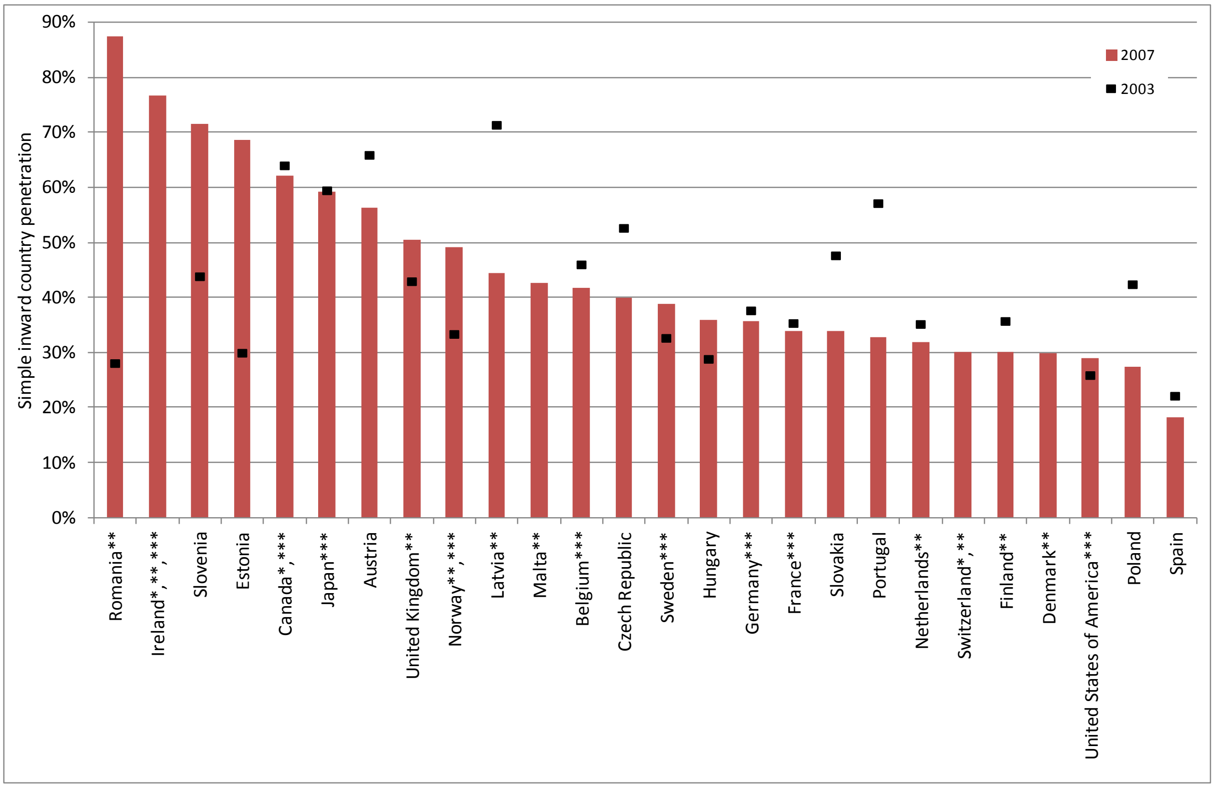
Single investment decisions of foreign-owned firms may have a big impact on the national level when the absolute size of inward and total BERD is small. Examples are Bulgaria, Slovenia or Estonia. We already know that in the case of Estonia the US-owned firm Skype accounts for main shares on total inward BERD. In the case of Slovenia the Swiss pharmaceutical company Novartis plays a similar role after the takeover of Slovenian pharmaceutical company Lek in 2002. As has been mentioned above, this is the very reason why these countries also show a high volatility of inward R&D intensities (see Figure 6).

The case of Ireland might be somewhat different, as total inward BERD in Ireland is higher than in the countries mentioned above. As described in the country report on Ireland, the country has focussed on attracting inward FDI from the US, and this policy has led to considerable increases in FDI inward stocks, above all from the United States (see also Figure 10). The level of inward FDI stock in Ireland can be compared to that of Canada.

Another reason might be the geographical distance. Canada’s geographical position may be one reason for the strong dependency of its neighbouring country. This is likewise the case for Austria, whose major part of inward BERD comes from German firms.

Furthermore, one determinant, albeit not observable from this figure, might be the technological proximity of two countries. We assume that this applies to for example Japan, accounting for a simple inward country penetration of almost 60%, which can be assigned to an alliance between France and Japan (see Deliverable 6, Part 3, Section 7.2).

Figure 9: Simple inward country penetration (inward BERD from country X / inward BERD) of top investor country 2003 and 2007

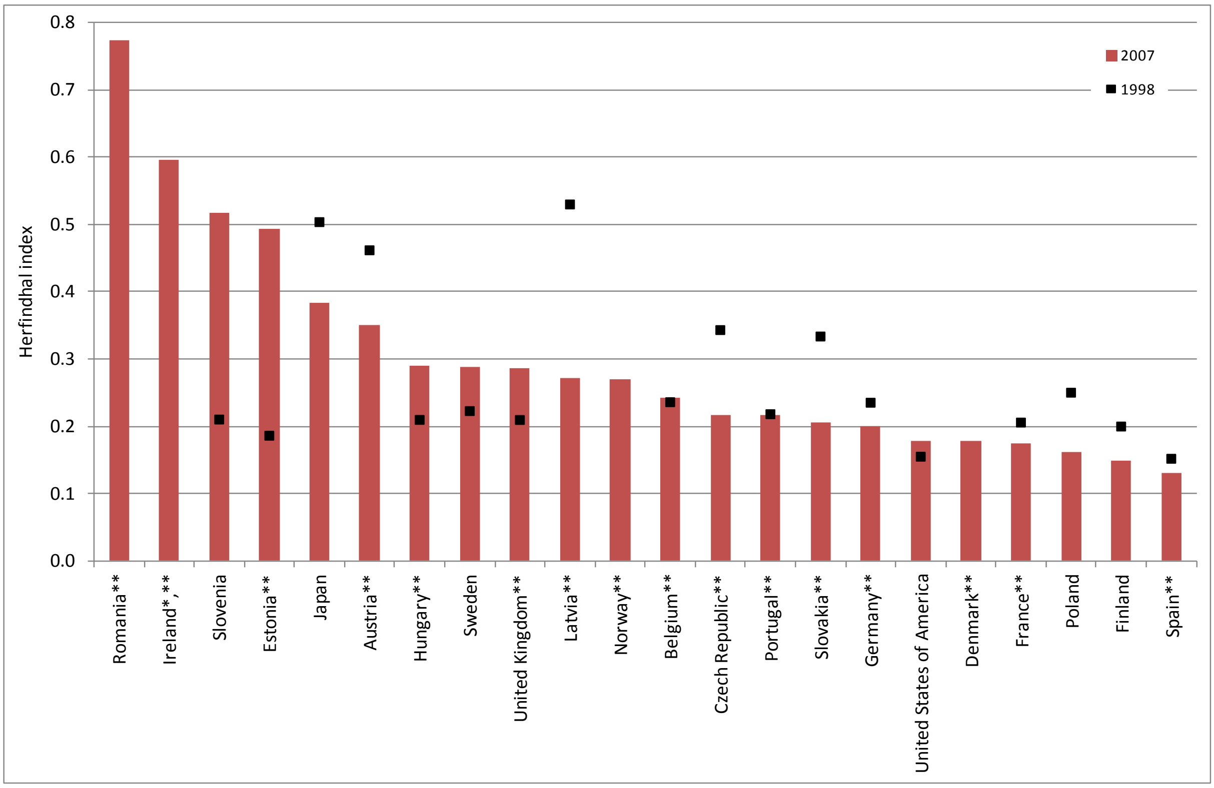


Note: * 2004 (Canada), 2005 (Ireland) and 2008 (Switzerland) instead of 2007; ** 1999 (United Kingdom), 2001 (Netherlands), 2004 (Latvia, Finland) and 2005 (Romania, Norway) instead of 2003; no data for 2003 (Ireland, Malta, Switzerland, Denmark); *** only manufacturing, see also Deliverable 8, Map 7

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

It is striking that simple inward country penetration declines in the majority countries between 2003 and 2007. Thus, we can assume that the internationalisation of R&D becomes more wide spread, it evolves from regional integration to true international integration where dependencies on a single country are declining and the concentration of controlling countries is decreasing. This is what we can also learn from Figure 10. It depicts the concentration of inward R&D by a Herfindahl-Index across countries. In comparison to Figure 9, this concentration index furthermore tells us about the skewness of the distribution of inward BERD by controlling countries. Obviously, the level of concentration basically complies with the ranking of countries observed in Figure 9 and thus, we can assume that the patterns are basically the same. It is however noteworthy that there are only three countries accounting for a concentration index larger than 0.5. These are identically to the countries where simple inward country penetration is largest. Furthermore, they belong to the minority of countries, whose concentration increased over the last decade. For the majority of countries, concentration decreased which indicates a tendency towards a diminishing skewness of the distribution of inward BERD, i.e. greater variety and a larger number of countries of origin and reduced dependencies on single countries.

Figure 10: Concentration of inward BERD by controlling country, 1998 and 2007



Note: * 2005 instead of 2007; ** 2004 (Hungary, Latvia), 2003 (Estonia, Austria, Czech Republic, Slovakia), 2001 (Germany), 2000 (Belgium) and 1999 (United Kingdom) instead of 1998; no data for 1998 (Romania, Ireland, Norway, Denmark), see also Deliverable 8, Map 12

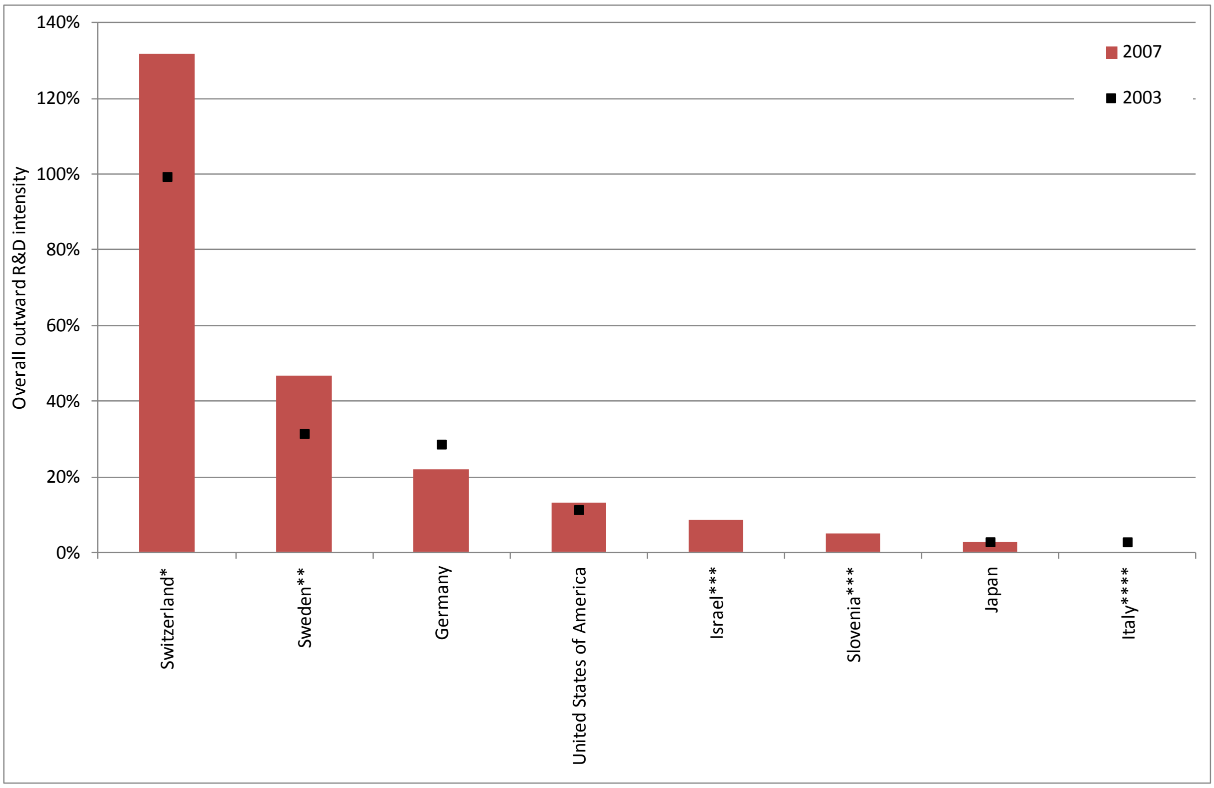
Source: OECD, Eurostat, national statistical offices, own calculations

1.3. Outward BERD across countries 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 data. Therefore, the cross-country comparison is only limited to a small number of countries. Data for France, the United Kingdom, the Netherlands, Spain, but also some Asian countries is missing in particular.

Corresponding to the overall inward R&D intensity, Figure 11 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).

Figure 11: 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, see also Deliverable 8, Map 13

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

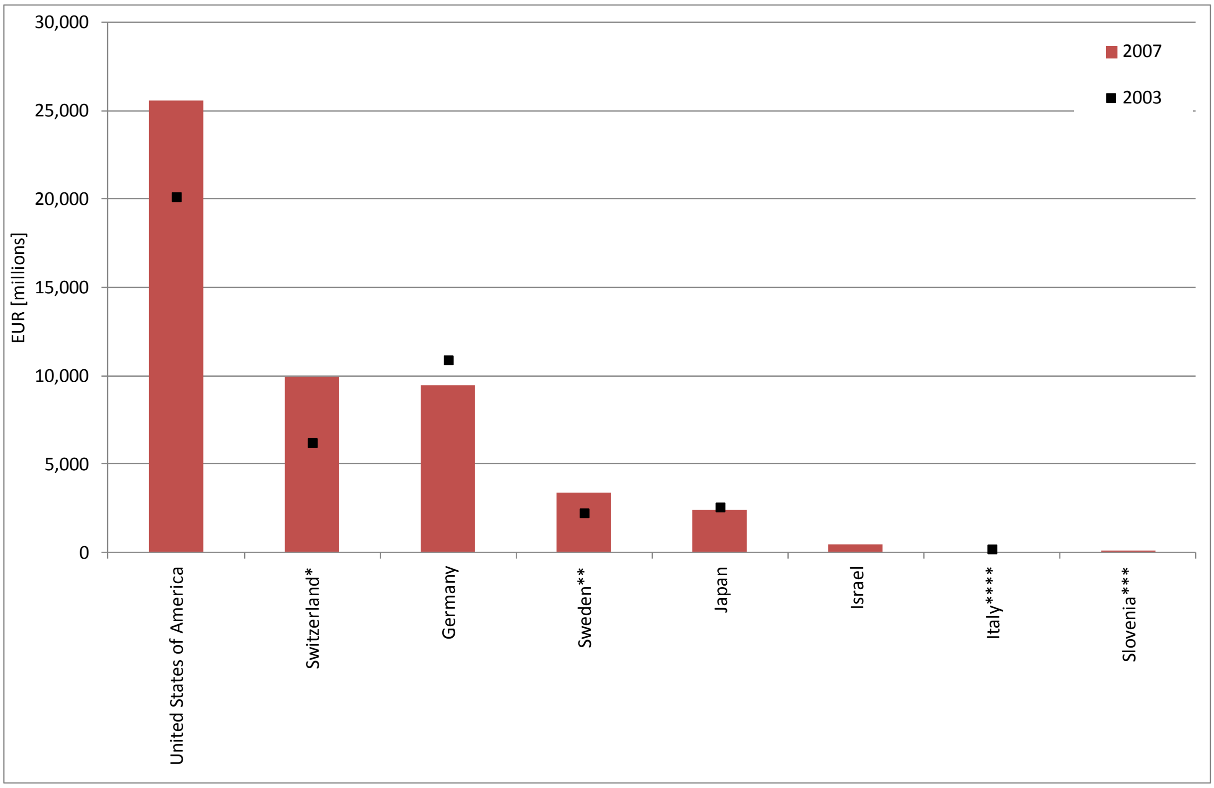
Outward R&D intensity has increased in nearly all countries. Particular attention should be given in the Figure to Switzerland, where outward R&D intensity yields results of more than 130%. In other words, R&D expenditure of Swiss firms abroad is higher abroad than in Switzerland. Another country with 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? One explanation is that 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.

Germany and the United States - ranked third and fourth - are large markets. For these countries, the second argument may be of greater importance; i.e. to use foreign R&D to augment and complement the domestic knowledge base. The level of outward R&D intensity of Germany and the 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.

Total outward BERD in absolute terms is depicted in Figure 12 below. It does not come as a surprise that total outward BERD is largest for the United States, as its stock of foreign direct investment abroad is largest of all countries observed here. Switzerland, whose outward R&D intensity is largest in relative terms (see Figure 11), 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. Largest increases can be found in the United States; Switzerland showed considerable increases as well. Germany lost shares in both absolute and relative terms. This is in contrast to FDI outflows, which increased significantly in both absolute and relative terms. We can therefore assume that German-owned firms abroad recently focussed on production rather than on research and development. The United States, Switzerland, Sweden or Japan increased both FDI outflows as well as outward BERD.

Figure 12: Total outward BERD (EUR, 2003 and 2007)



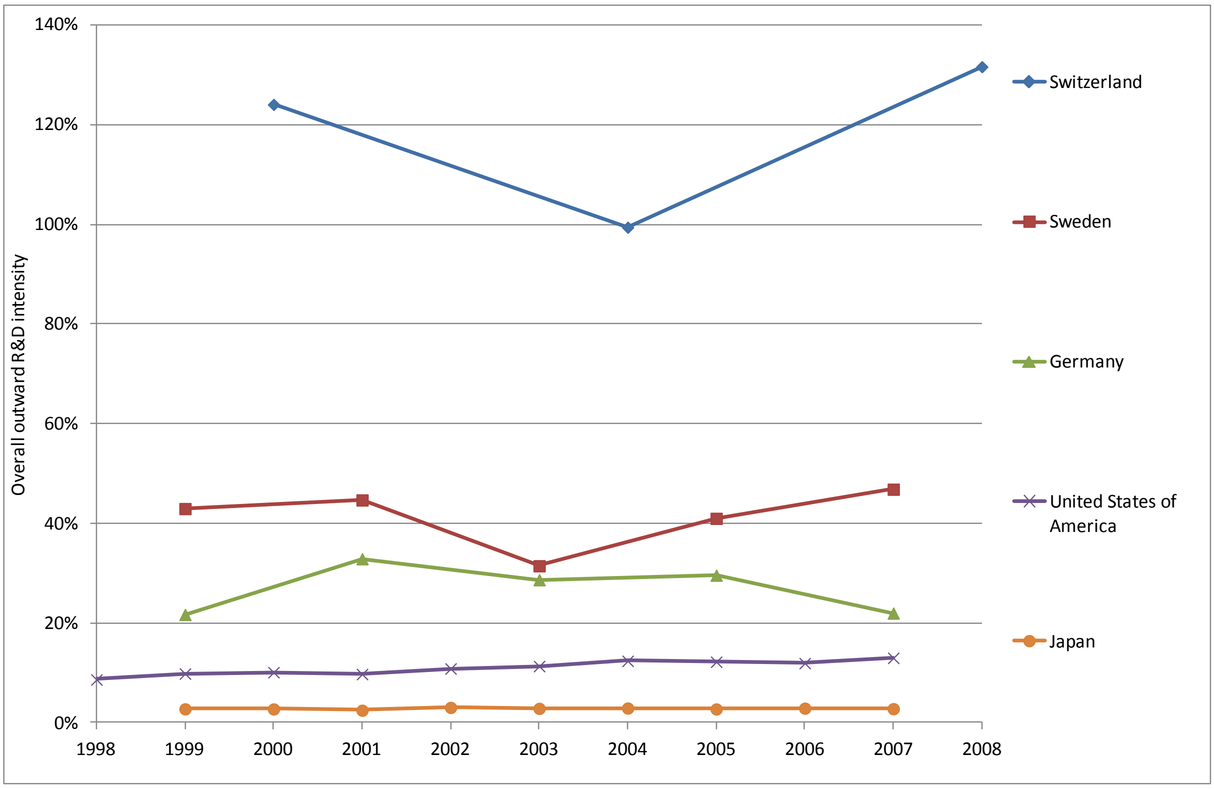
Note: * 2008 instead of 2007 and 2004 instead of 2003; ** only manufacturing included; *** no data for years before 2007; **** 2003 only year with data, see also Deliverable 8, Map 14

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

A more detailed picture of overall outward R&D intensity over time is given by Figure 13. Switzerland, as the country with the smallest market size, shows largest variations over time. This may be due to the small number of firms investing in R&D abroad and thus changes in the number of investing firms may cause these large variations. This is true, albeit to a lesser extent, for Sweden. Germany, for which decreases of total BERD were observed in Figure 12, had a peak in outward intensity already in 2001 and decreased since then. In contrast, overall outward R&D intensity increased in all other countries, except Japan, where outward intensity stayed constant over the last decade.

Since data on outward BERD is available for only a few countries, it is not possible to establish a sound relationship between outward R&D intensity and outward FDI stocks or flows. However, based on the literature, it is reasonable to assume that countries with considerable outward FDI flows or stocks may also have a considerable outward BERD. This can be confirmed for Sweden and Switzerland, two countries with outward FDI stocks considerable above OECD average and high outward R&D intensities.

Figure 13: Overall outward R&D intensity (outward BERD / total BERD, 1998 to 2008)



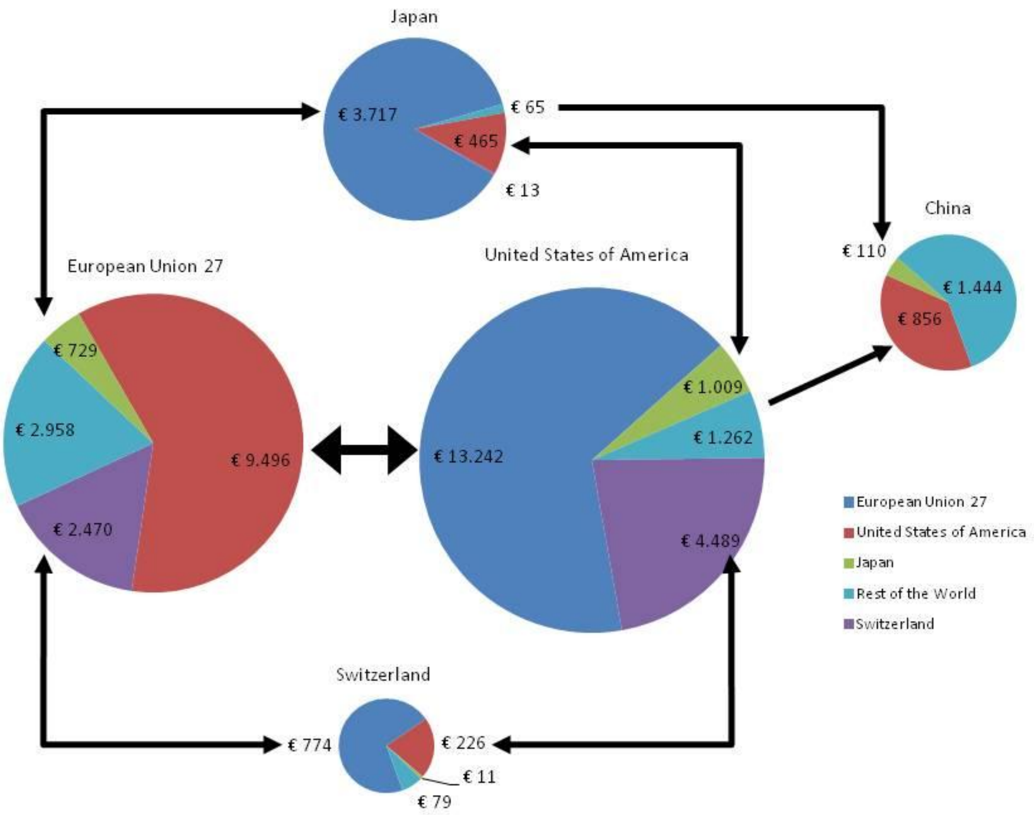
Source: OECD, Eurostat, national statistical offices, own calculations

1.4. 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 home countries for MNEs investing in R&D abroad and as locations for R&D activities of foreign MNEs. The relationship between the US and the EU is the single most important bilateral relationship in the internationalisation of business R&D. The following section 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 14 summarizes the relations in the internationalisation of business R&D between the EU, the United States, Japan and Switzerland measured by inward BERD. Additionally, we included R&D investments in China. These relations cover the lion's share of R&D expenditure of foreign-owned firms worldwide.

Figure 14: Overseas business R&D expenditure in manufacturing between the EU, the US, Japan, China and Switzerland (2007, EUR Mio, current prices)



Reading: Swiss firms spent 2.5 billion EUR on R&D in the European Union and 4.5 billion EUR in the US, while EU firms spent 774 million EUR and US firms spent 226 million EUR on R&D in Switzerland.

Note: 2006 (US) and 2008 (CH) instead of 2007. Circles represent the location of the R&D activity; values are based on the performing country's inward statistics. The value for EU-27 companies investing in the US includes all European except Swiss companies. EU inward data only includes countries with data available. Only manufacturing included except Switzerland and China (total business). US and JP investments in China are based on the countries' outward statistics. Rest of the World includes all other countries, in particular Canada, China, India, Korea and Australia but also all South American and African economies as well as investments from offshore financial centres.

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

For the US, EU, Japan and Switzerland, we have split inward BERD into the shares of US, EU, Japanese, Swiss firms and in the share of firms from the rest of the world. For China we were due to data constraints only able to distinguish between investments from the US, Japan and the rest of the world. EU and Swiss R&D investments are therefore in the case of China included in rest of the world. These shares are marked in different colours. Moreover, the figure illustrates the major relations with lines. The size of each circle represents total inward BERD.

In 2007, US firms spent around 13 billion EUR on R&D in the EU. R&D expenditure of EU firms in the US is about 9.5 billion EUR. Inward BERD from the US towards the EU-27 and vice versa, accounts for more than half of all inward BERD worldwide, if intra EU links are excluded.

R&D expenditure of EU-27 firms in Japan (3.7 billion EUR), R&D expenditure of Swiss firms in the EU-27 (2.5 billion EUR), and R&D expenditure of Swiss firms in the US (4.5 billion EUR) are the most important ones out the remaining cross border links. Inward BERD from countries summarized under Rest of the World appears, if at all, almost entirely in the US or the EU-27.

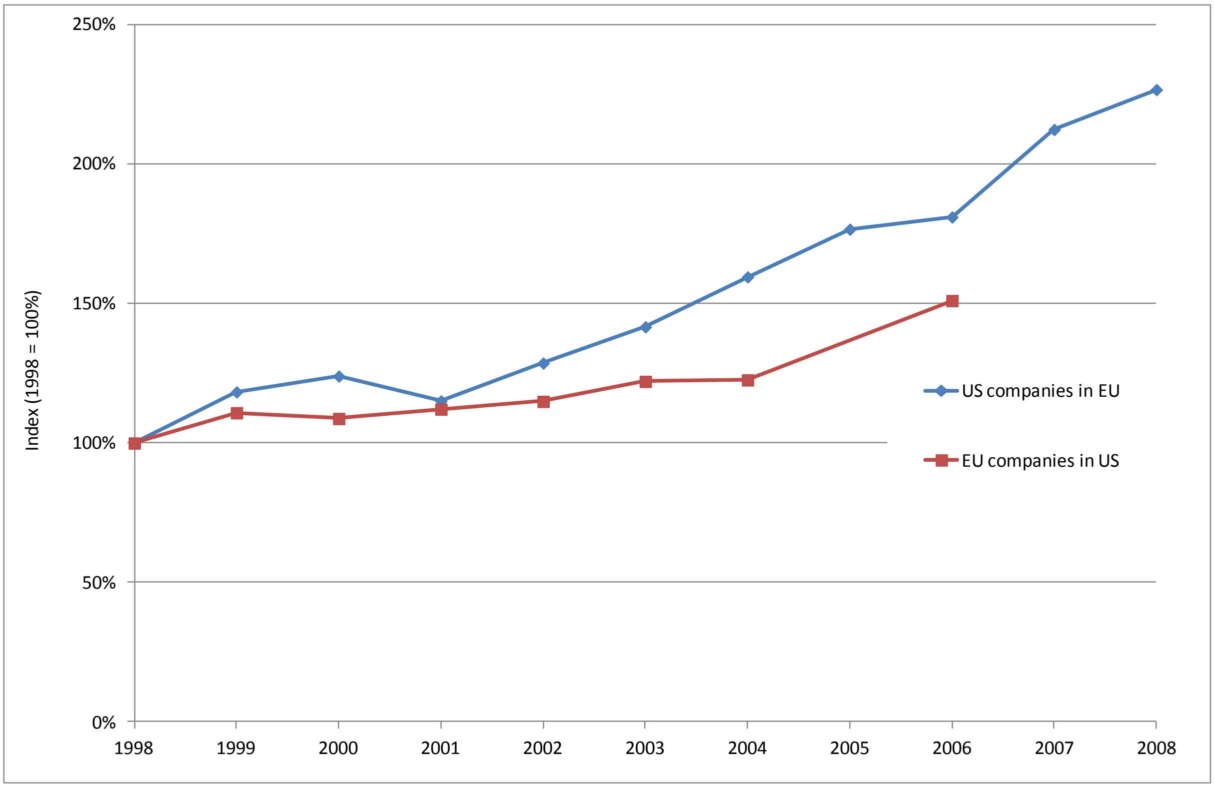
R&D investments in China are with about 2.3 billion EUR significantly smaller than investments in the US or EU. However, there are major gaps in the Chinese inward data set. US and Japanese firms account for about 40% of inward BERD in China, the remaining 1.4 billion EUR cannot be allocated to a specific home country and investments from EU countries are included in this value. With a maximum possible value of 1.4 billion EUR of R&D investments of EU firms in China, this value is about 10% of the corresponding investments of EU firms in the US. However, due to the growing importance of China also as a destination for inward BERD section 4.4 takes a detailed look on R&D investments in China.

Taking a closer look at R&D expenditure of EU-27 companies in the US reveals that these companies are by far the most important source of inward BERD in the US in 2006, accounting for about 70% of total inward BERD. Swiss companies account for almost another 20% of inward BERD in the US, pushing the European share to almost 90% of total US inward BERD. Asian R&D performing companies - with a share of considerably less than 10% - play a very limited role in the US.The figures are very similar if we look at R&D performed by US companies outside the US. In 2007, 62% of US overseas R&D expenditure is located in the EU member countries. Asia lags behind with a share of only 13%.

At the same time, US companies account for about 60% of inward BERD in the EU performed by non-EU companies, summing up to about 9.5 billion EUR in 2007. The four Asian economies considered, China, India, South Korea and Japan, together only account for about 1.3 billion EUR, less than 10% of the US value.

Figure 15 illustrates BERD performed by US companies in the EU and EU companies in the US from 1998 to 2007 in percent of the 1998 value based on US inward and outward R&D statistics measured in USD. Interestingly, while both investments grow significantly over time, the growth rate of US investments in the EU is above the corresponding value for EU investments in the US. At the same time, we know already that in most recent years the absolute value is higher for EU investments in the US. Therefore the higher growth rate of US R&D investments in the EU is rather a catching up of these investments compared to EU R&D investments in the US than a lagging behind of the EU R&D investments in the US. Taking the high absolute importance of these two investment streams (Figure 14) and the high growth in recent years (Figure 15) into account makes it very likely that this relationship will remain of outstanding importance in the future.

Figure 15: BERD of US companies in the EU and EU companies in the US (Index, 1998=100%, 1998-2007)



Note: EU companies in US include all European companies except Swiss companies only in the manufacturing sector. US companies in EU only include activities in the EU-15 (1998-2003) and EU-25 (2004-2006) in the total business sector

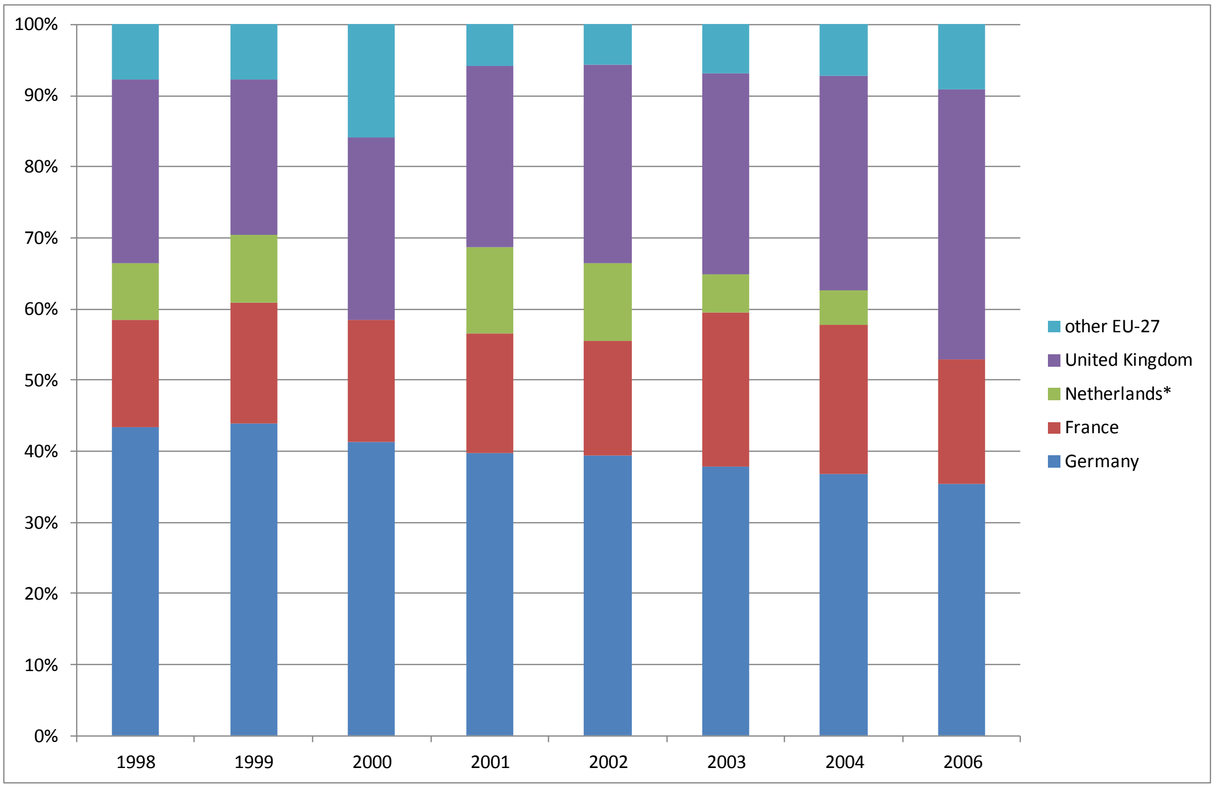
Source: OECD based on US data in USD, own calculations

In a next step, we take a closer look at the distribution of the R&D expenditure of EU firms in the US by home countries. Such an analysis has to be done 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 EU-27 as a whole. The only country aggregate available is total Europe and a few large economies in terms of business R&D expenditure. The EU total used for the analysis therefore includes total Europe, excluding Switzerland.

The simple inward country penetration, the ratio of inward BERD from a certain EU country to total inward BERD from the EU in the US (Figure 16), reveals that three countries are of outstanding importance, Germany, France and the United Kingdom. These three countries together account for at least 80% of total EU inward BERD in the US, in the last recent year with data[2] (2006) even more than 90%. In all but the last year Germany is the most important of these three countries and also worldwide. In 2006, the United Kingdom overtakes Germany as the most important foreign investor in business R&D in the US.

[2] While 2007 inward data including a country breakdown is available, there is no EU or Europe aggregate available for that year.

Figure 16: Simple inward country penetration (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.

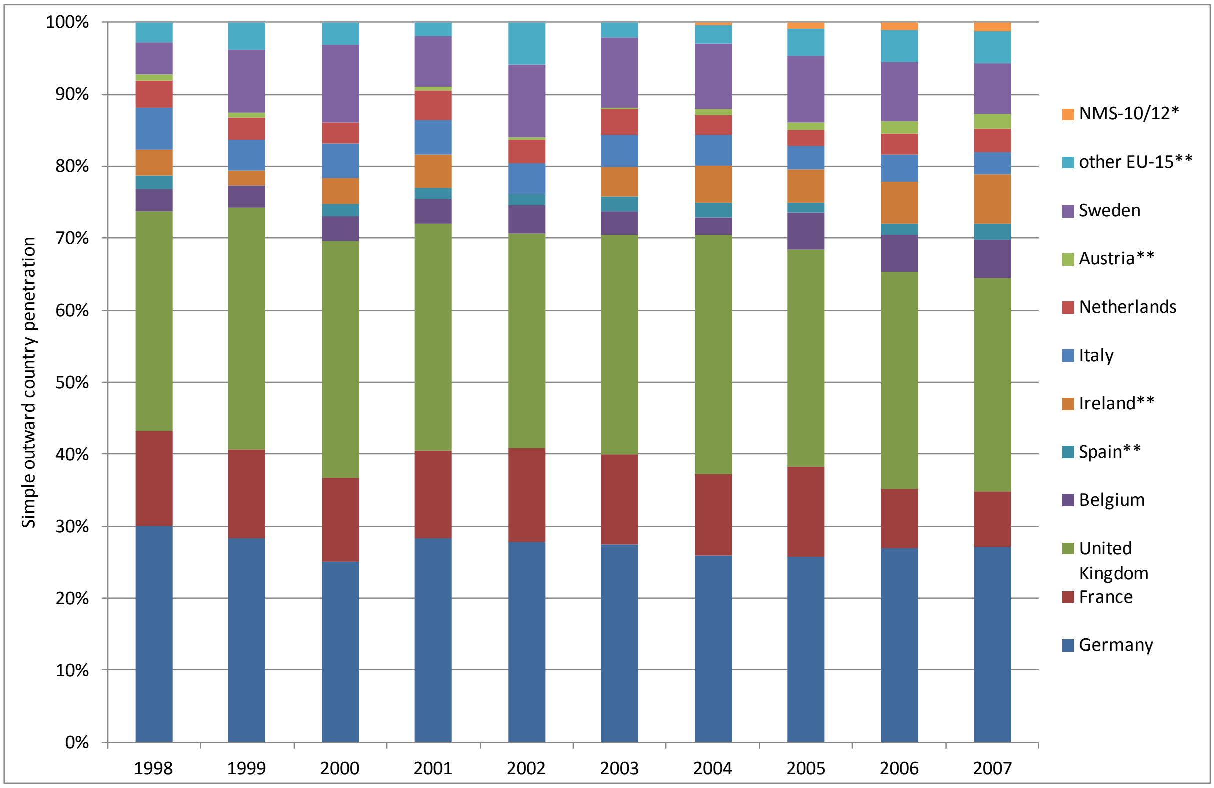
Source: OECD based on US data, own calculations

Figure 17 illustrates in the same way the distribution of R&D expenditure of US firms across EU member states. The more detailed country break-down in US outward data allows a more detailed analysis of the patterns of US investment in the EU. The three countries with outstanding importance are again the United Kingdom, Germany and, to a smaller extent, France. However, while the total amount of US inward BERD increased in all EU countries, the relative importance of the three top countries declines over time. As a result, in 2007 more than 1/3 of US-controlled BERD in the EU is located in other, mostly small and medium sized, EU countries. These 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.

While the outstanding importance of the European Union and the United States both as home countries of MNEs performing R&D abroad but also as a location of R&D performed by foreign MNEs was already visible from the previous chapters this section added some interesting insights into the relationship between the EU and the US.

The total amount of cross-border business R&D investments between the EU and the US grows considerable over the last decade. The two components of this relationship, EU investment in the US and US investment in the EU, grow at a similar pace and are by far the two largest cross-border business R&D investments in 2007. If the EU is considered as one entity, these two investment streams together account for more than half of worldwide cross border business R&D investments. Interestingly EU investments in the US still largely consist of investments by MNEs of the three largest EU economies, the United Kingdom, Germany and France. While these three countries are also most important as location for US MNEs performing R&D in Europe, small and medium sized EU countries, including Sweden, Austria, Netherlands, Italy, Ireland, Spain and Belgium are of growing importance.

Figure 17: Simple outward country penetration (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, own calculations

1.5. Cross-sector comparison

The following section compares the internationalisation of business R&D across different sectors. Due to data constraints, the analysis is limited in two respects: first, the data only allow an analysis of inward BERD data but not of outward BERD data. Second, the countries with data available differ across sectors and over time. As a result, only the analysis of the six largest sectors – five manufacturing sectors and knowledge-intensive services - is feasible and the interpretation of the results has to be done very carefully.

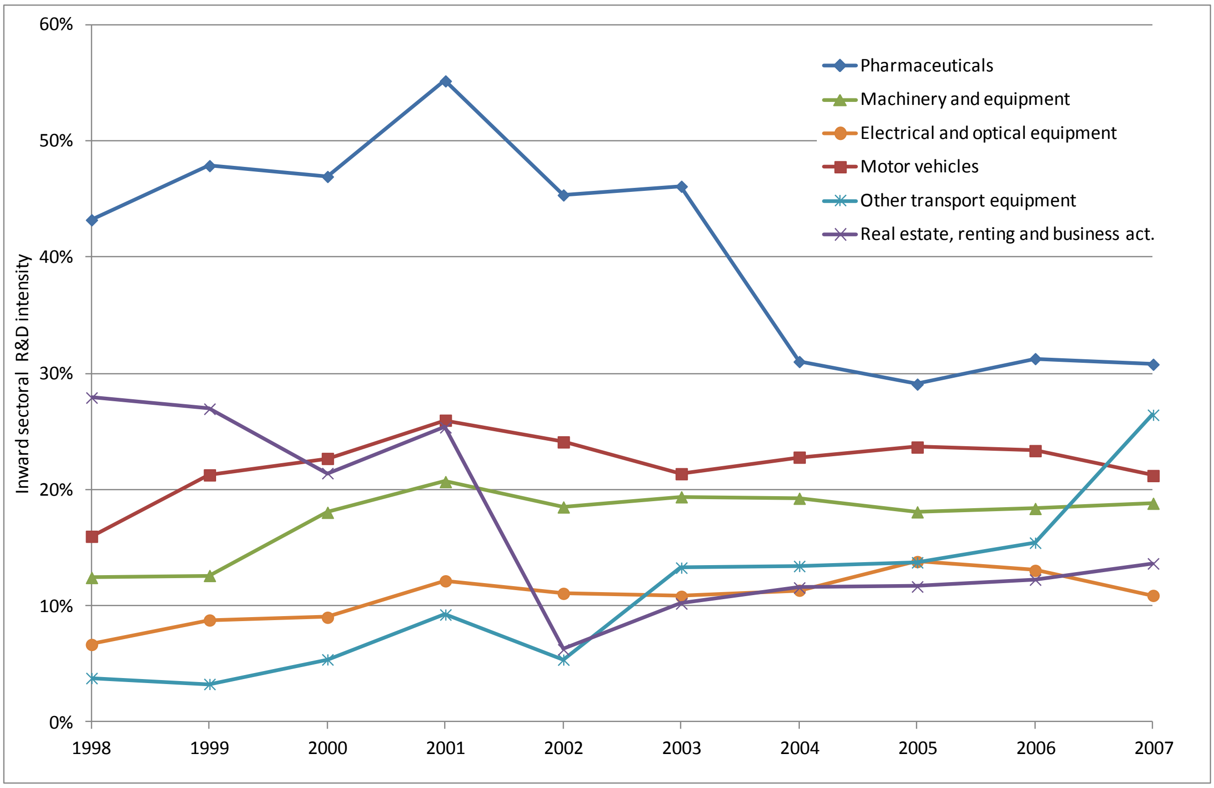
All five manufacturing sectors included are all high technology or medium-high technology sectors: pharmaceuticals, machinery and equipment, electrical and optical equipment (including office, accounting and computing machinery; electrical machinery and apparatus; radio, TV and communications and medical, 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), and in most countries even a huge proportion of total 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 18 compares the 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 for all countries with inward data available in a given year. Pharmaceuticals are the sector with the highest inward R&D intensity and thus the most internationalized sector over the whole period. However, there is a sharp decline of the inward intensity from 2003 (about 45%) to 2004 (about 30%). This decline is not caused by a reduction of inward BERD but by a massive increase of the reported 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. The result is an increase of the worldwide total sectoral BERD in pharmaceuticals of 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 of the sectoral R&D intensity.

The second massive drop in sectoral R&D intensities is in real estate, renting and business activities 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. Data for this sector for the US is not available before 2002, and the inclusion of US data boosts total sectoral BERD from 7.4 billion 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 of the intensity level of other transport equipment from 2006 to 2007, is again caused by a change in the largest economy, the US. However, in this case the movement is caused by a change in the inward BERD data, 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 for the most recent years.

Figure 18: Inward sectoral R&D intensity (inward BERD / total BERD, 1998 to 2007)



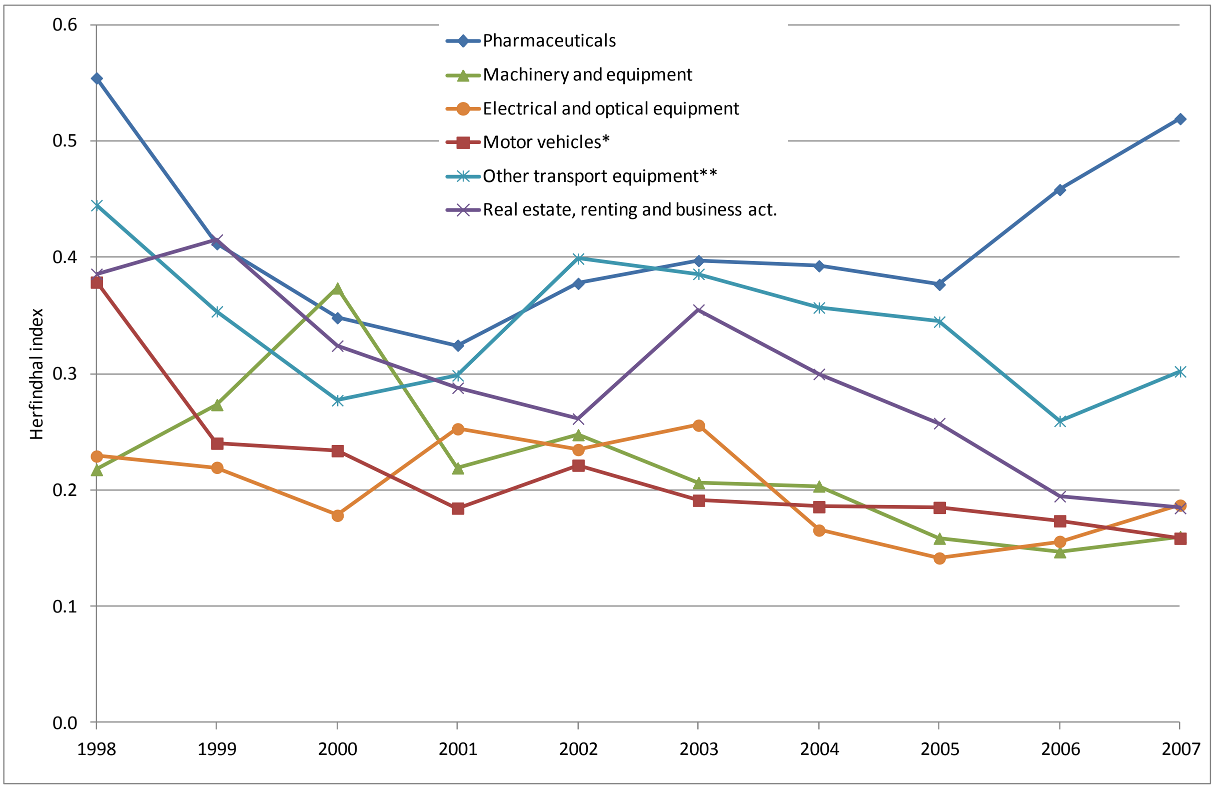
Note: Only includes **Belgium** (2000-2007), **Czech Republic** (1998-2007), **Germany** (2001-2007 except pharmaceuticals 2003-2007 and electrical and optical equipment 2005-2007; inward values in 2002, 2004 and 2006 own calculations), **Estonia** (only machinery and equipment 2006-2007, electrical 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

Figure 19 displays the concentration of inward BERD across destination countries for the six sectors considered measured by a Herfindahl-Index. This concentration index tells us the skewness of the distribution of inward BERD by destination countries. 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. Pharmaceuticals, and to a smaller extent other transport equipment, have sustained higher concentration levels.

The concentration in the pharmaceutical industry even increased considerably over the last observation 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 of the world 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. However, in four of the six sectors, concentration decreased, indicating a diminishing skewness of the distribution of inward BERD, i.e. greater variety and a larger number of countries of destination.

Figure 19: Concentration of inward BERD by destination country and sector (1998 to 2007)



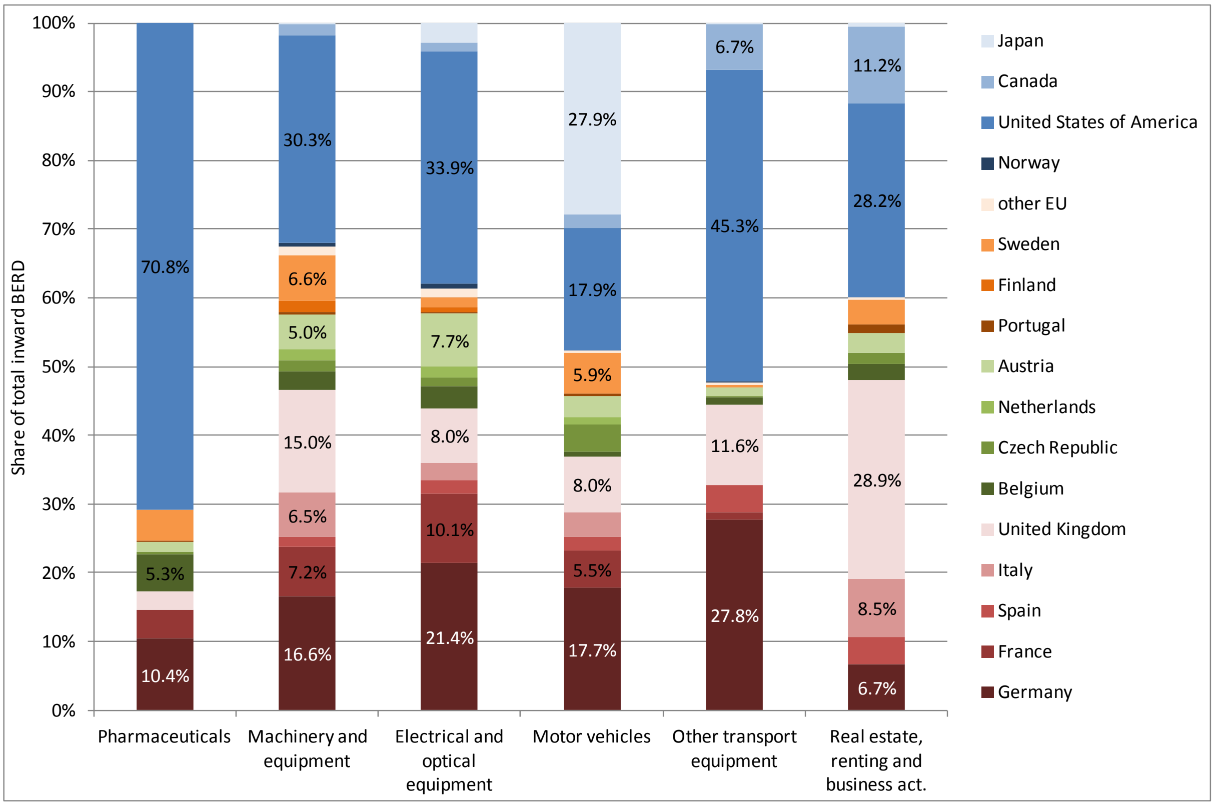
Note: Included countries see Figure 18

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

Figure 20 provides the simple inward country penetration values for each of the six sectors considered. These values equal to the share of inward BERD from a certain country on total inward BERD in the sector considered. All simple inward sector penetration values therefore add up to 100%.

Besides the US, which play 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. All other countries of the world together only account for about 15% of total sectoral inward BERD, explaining the before mentioned high concentration in that sector.

Figure 20: Share of total inward BERD by destination country and sector (inward BERD in country X in sector Y / total inward BERD in sector Y, 2007)



Note: Included countries see Figure 18**, s**ee also Deliverable 8, Map 15 to 20

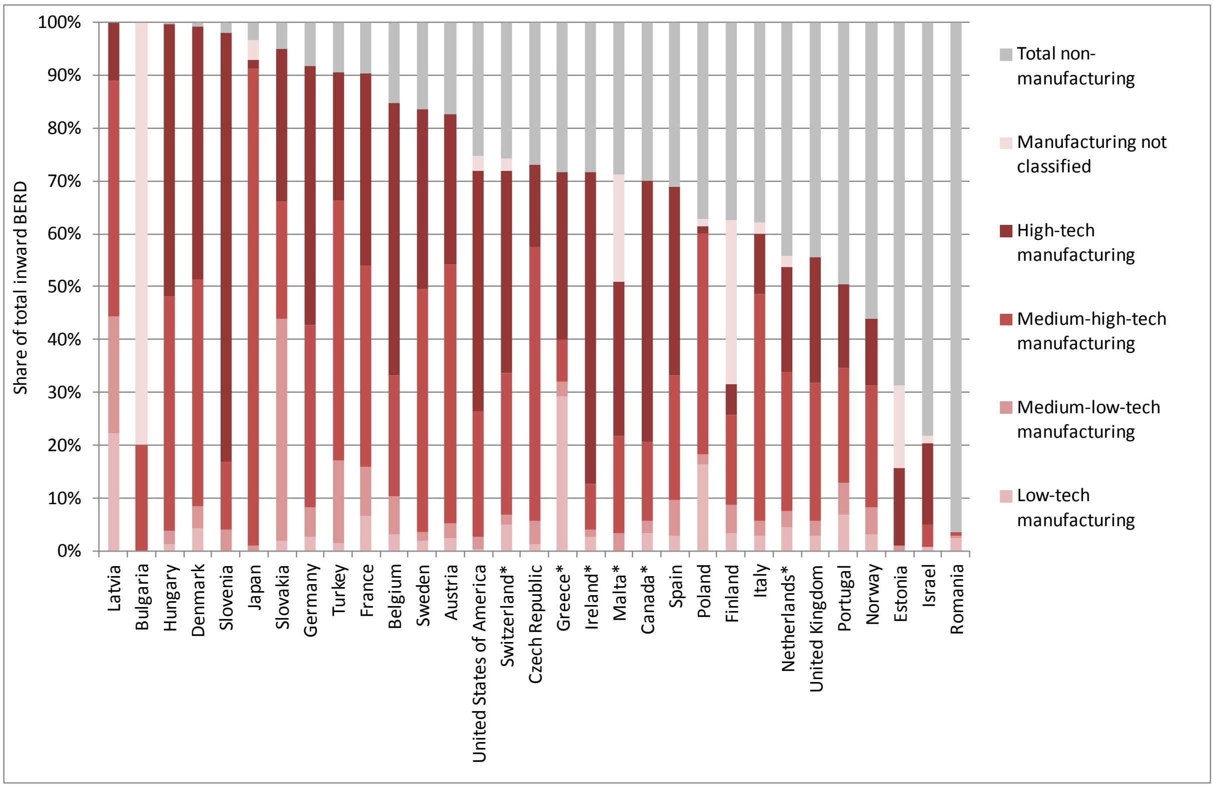
Source: OECD, Eurostat, national statistical offices, own calculations

Machinery and equipment, one of the sectors with the lowest concentration by controlling country, is the sector with the highest cumulated penetration value for all EU countries, all EU member countries together attract more than 2/3 thirds of total inward BERD in this sector. While the US plays a much smaller role, with more than 30% it still accounts for the lion share of the remaining inward BERD. Interestingly inward BERD in this sector is widely distributed across different EU countries. While two of the largest EU economies, Germany and the United Kingdom, are ranked two and three worldwide, also smaller economies, including 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 sectors has the highest number of 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 way from all other sectors. This 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 activity of a single French MNE in Japan. This is described in detail in the Japan country fiche.Inward BERD in other transport, 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 important country is Germany with another 28%. Two more countries, the United Kingdom (11.6%) and Canada (6.7%) are of importance, all other countries of the world play with together only 8.7% share a limited role.

The only service sector, real estate, renting and business activities, is also the only sector with an EU country, the United Kingdom attracting most inward BERD. Germany and France, major attractors or inward BERD in most manufacturing sectors, play a comparable small role while Canada, of no global importance in all manufacturing sectors but other transport, is with 11.2% of total inward BERD ranked three worldwide. With the US ranked two, 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.

Figure 21: 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), see also Deliverable 8, Map 21 to 26

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

Inward BERD by type of industry and country (Figure 21) reveals again that high and medium-high technology manufacturing industries play and outstanding role in almost all countries where data is available. Inward BERD from non-manufacturing sectors is only relevant in a few small and medium sized countries. Examples are Estonia and Israel, where foreign-owned firms in computer services have a considerable share on overall inward BERD. However, in most of these countries total inward BERD is comparable low and the results reflect the activities of a small number of actors. Also the countries with above average shares of low and medium-low technology industries have comparable small total inward BERD. It is important to note that the low importance of non-manufacturing in some countries may at least partly be caused by poor coverage of the services sector in some country's R&D surveys.

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

2. THE STRUCTURE OF CROSS-COUNTRY R&D EXPENDITURE: A SOCIAL NETWORK ANALYSIS PERSPECTIVE

We now move one step further and analyze the structure of R&D internationalisation from a network analytic perspective. In this perspective, we look at the whole set of countries and inward BERD relationships between these countries. This set of relations between countries as measured by inward BERD constitutes a network where nodes are represented by countries interconnected by edges representing inward BERD between these countries. From an economic perspective, inward BERD between two countries is a measure for international technology diffusion.

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 try to 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.

2.1. The social network analysis perspective

By network analytic perspective or social network analysis perspective, we refer to the notion of social network analysis (SNA) that has come into fairly wide use for the analysis of social systems in the recent past, offering a wide range of powerful analytical tools disclosing the structure of large social systems. The notion of a social network and the procedures of social network analysis have attracted considerable interest and curiosity from the social science community in recent years. Central to network analysis are identifying, measuring, and testing hypotheses about the structural forms and substantive contents of relations among actors (Knoke and Young 2008), in our case organizations 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 behaviours and resulting structures than are attributes of the actors.

The network analytic perspective is useful for identifying and describing the structure of cross-country R&D investment flows. By this, the section fits very well into the literature stream that investigates R&D networks from a network analytic perspective, using information on different forms of R&D interactions, such as joint research projects (see, for instance, Breschi and Cusmano 2004, Scherngell and Barber 2009 and 2011), joint publications (see, for instance, Hoekman et al. 2010, Scherngell and Hu 2011) joint assignment of patents (see, for instance, Maggioni et al. 2007) or – as in our case – R&D investment flows between organization, regions or countries.

The subsection that follows will present some exploratory network analytic indicators, including the visualization of the network of inward BERD flows. All countries where sufficient data is available are included. We will describe the cross-country network of inward BERD as a whole, and shed some 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.

2.2. Some descriptive analyses from a social network analysis perspective

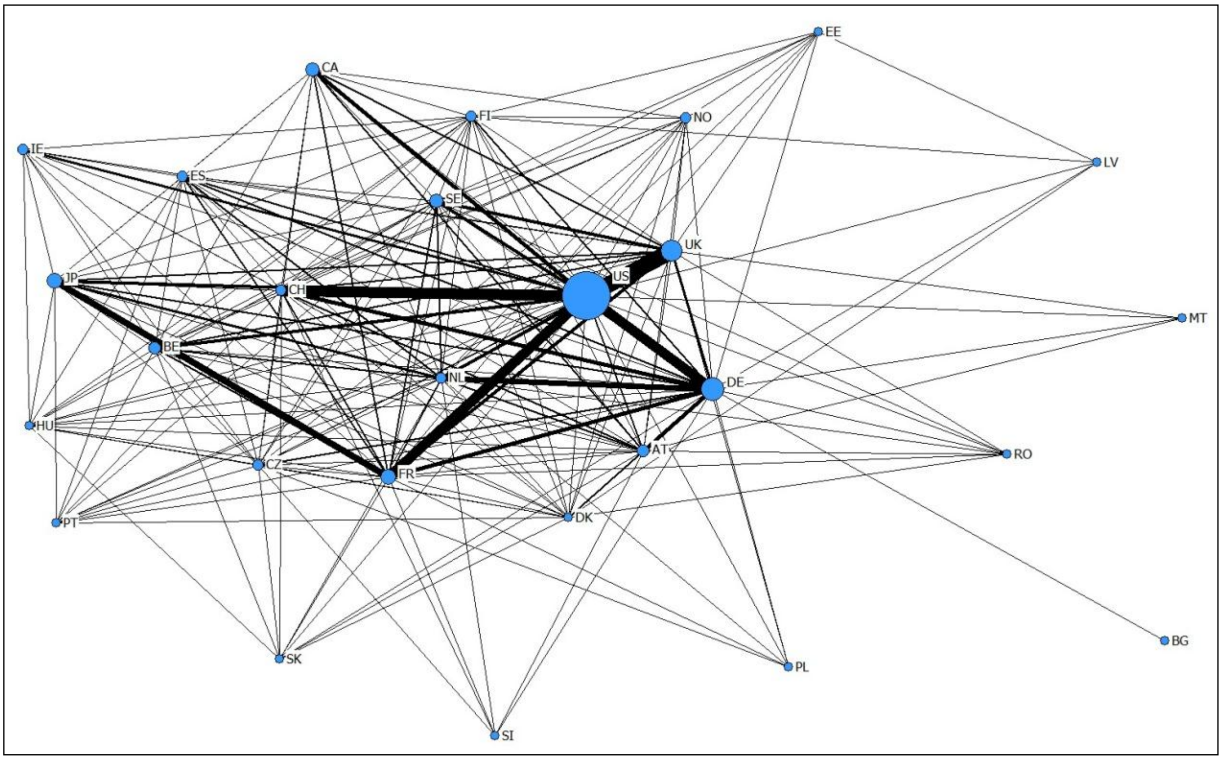
We take a network analytic perspective on the system of inward BERD flows between 27 countries to analyze its structure and patterns. A network of R&D investments can be viewed in several ways. In our context, the most useful view is as a graph consisting of nodes (vertices) and edges (links). A familiar 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 $\{v_i, v_j\} \in E$ are distinct and $\{v_i, v_i\} \notin E$ for $i \neq j = 1,...,n = 27$; 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 symmetriseG_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 22 visualizes the network of R&D investment flows using G_2 by means of information-theoretic techniques. We determine the position for the nodes (countries) using a standard approach from spectral graph analysis according to the normalized Laplacian, so that countries that show a relatively higher intensity of bilateral inward BERD flows are positioned nearer to each other (for details see the discussion of the normalized graph Laplacian, in e.g. Higham and Kibble 2004). 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.

It can be seen that in terms of absolute size the US represents the central hub in this network of R&D investments 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 may also be that Switzerland seems to be more embedded in extra-European countries, particularly the US and Japan, than in the European system of R&D investments.

Concerning the overall network structure, we cannot observe a high level of modularity in this network of cross-country R&D investments, i.e. there are no distinct clusters or groups that are highly integrated, but only loosely connected with other parts of the network (Figure 22). This finding is confirmed using so-called community identification algorithms by the type employed by Barber, Fischer and Scherngell (2011) leading to all countries to be assigned to one single cluster. Anyway, we can visually identify from Figure 22 some patterns pointing to some geographical logic in the network of R&D investments, i.e. in some areas countries are positioned nearby to each other in the network visualization that are also relatively close to each other in geographical space. For instance, in the bottom of Figure 22 we can identify the group of eastern European countries including Bulgaria, Romania, Poland, Slovenia and Slovakia. In the top we find a cluster of northern European countries, including Sweden, Norway and Finland as well as the Baltic countries Estonia and Latvia.

Figure 22: Network of R&D investment flows between 27 countries, 2007



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

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

In what follows, we will further investigate the structure of the inward BERD network between 27 countries using indicators that shed some light on the connectedness and cohesion of this network. Table 1 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 1 are given in Wasserman and Faust (1994). For comparison purposes we relate the SNA indicators calculated for the network of R&D investments with those calculated for a random graph. The random graph is produced by means of the well-known Erdös-Renyi conceptualization of random graphs (see Erdős and Rényi 1959) using the same number of nodes (n = 27) as in the network of R&D investments. The properties of such a random graph are in general similar to properties of different scale-free real-world social networks, as for instance with respect to their so-called small world character (see Newman 2010, Watts and Strogatz 1998).

The results from Table 1 indicate that in a social network analysis context the connectedness and cohesion of the network of R&D investments is comparably high, pointing to the general importance of the internationalisation of R&D and the strategic orientation of firms to distribute their R&D in different countries and/or the ability of countries to provide framework conditions to attract foreign R&D investments. By this, the analysis provides further empirical evidence on the global trends in the offshoring of R&D. While internationalisation is not a new phenomenon at all, it is now spreading more widely in a geographical sense across countries, including particularly emerging economies. This shift, mainly driven by large multinational enterprises, is related to changing motivations for foreign R&D investments, where such firms seek not only to exploit knowledge generated at home in other countries, but also to get access to knowledge produced elsewhere and to tap into global centres of knowledge. Further, the growing mobility of researchers is to be mentioned as crucial element of these internationalisation processes (see, for instance, OECD 2008b).

The main results underlining these trends from a social network analysis perspective may be summarized as follows: *First*, the density of the network of R&D investments 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. This 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. In combination with the clustering coefficient, measuring the likelihood that two associates of a country are associates themselves, i.e. the likelihood that – given a hypothetic 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). This is also reflected by the diameter – referring to the highest path length observed in a network – showing a value of 2 for the network of R&D investments 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.

Table 1: Indicators for cohesion in the network of R&D investments

Indicator	Network of R&D investments	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: we use the unweighted graph G1 for these indicators; *Erdös-Renyi conceptualization of random graphs

Source: own calculations

Table 2 complements these results focusing on the centralization within the network of R&D investments in order to get insight into the heterogeneity of the network and the variance of the degrees of the nodes, i.e. countries. A high centralization indicates a strong concentration of a graph on a few nodes given by a high difference between the highest and the lowest degree observed in the network under consideration. In this analysis we draw on the weighted graph G_2 distinguishing between three types of centralization. Degree-based centralization shows a much higher value for the network of R&D investments than for the random graph due to the high difference in the magnitude of R&D investments between the country pairs, i.e. the concentration in terms of absolute size is in the network of R&D investments very high. However, concerning betweenness-based centralization – related to the number of nodes that show a very high betweenness centrality and therefore act as so-called ‘gatekeeper’ in the network (see Wasserman and Faust 1994 for details) – we find a quite similar value as for the random graph, i.e. the number of nodes that take a role as ‘gatekeeper’ in the network is quite similar to other real-world networks. Closeness based centralization is significantly higher than for the random graph, indicating that the network of R&D investments features a comparably high number of nodes showing a low distance to other nodes. This underlines results and conclusions obtained for the average path length in Table 1.

Table 2: Centralisation of the network of R&D investments

Centralisation index	Network of R&D investments	Random graph*
Degree-based	44,08	12.40
Betweenness-based	13,97	15,24
Closeness-based	28,53	18,96

Note: *Erdös-Renyi conceptualization of random graphs

Source: own calculations

A central point in the context of the structural analysis of the network of R&D investments is the role that different countries take in this network. The concept of centrality is a useful graph-theoretic 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 (see, for instance, Heller-Schuh et al. 2011) 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* of a vertex can be defined as the fraction of geodesic paths between any pair of vertices on which this vertex lies. It 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 3 presents the results on the centrality rankings of our 27 countries participating in the international network of R&D investment flows. The first column contains the calculated values for degree-based centrality. It can be seen that Germany shows the highest degree centrality among the countries under consideration, followed by the US, i.e. Germany has the highest number of partner countries it shares R&D interactions with. 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 R&D investments in total, pointing to a comparably spatially dispersed partner structure of the Czech Republic. In the system of R&D investments under consideration, 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.

Table 3: Centrality of countries in the network of R&D investments

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

Note: AT … Austria; BE … Belgium; BG … Bulgaria; CA … Canada; CH … Switzerland; CZ … Czech Republic; DE … Germany; DK … Denmark; EE … Estonia; ES … Spain; FI … Finland; FR … France; IE … Ireland; JP … Japan; LV … Latvia; HU … Hungary; MT … Malta; NL … Netherlands; NO … Norway; PL … Poland; PT … Portugal; RO … Romania; SI … Slovenia; SK … Slovakia; SE … Sweden; UK … United Kingdom; US … United States of America

Source: own calculations

Concerning 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.

The results for the closeness based and the betweenness-based centrality are similar to those for the degree-based centrality ranking. Only minor changes in the rankings between these three centrality measures are observable which is related to the overall network structure (see Figure 22 and Table 1) that points to a low modularity of network, i.e. there are no community groups observable where specific nodes could take a role as 'gatekeeper' between such community groups.

Figure 23 intends to complement the network analytic visualization given in Figure 22 by focusing on the spatial structure of the network of R&D investments, in this case limited to European countries. Here, we do not position the nodes according to methods from spectral graph theory, but according to their spatial location, i.e. nodes representing participating countries are positioned at the location of the capital city of the respective country. Again edge size corresponds to the weighted degree centrality of a country that is defined as the sum of R&D expenditure of firms from country A in country B and vice versa. The node size of each country corresponds to the sum of R&D expenditure of foreign-owned firms in the country.The spatial network map presented in Figure 23 clearly reveals a clustering of R&D investment in the centre of Europe while the periphery is participating to a lower extent. 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 highest magnitudes of R&D investments 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. In terms of the policy goal of an integrated European Research Area (ERA) (see, for instance, European Commission 2008) we find mixed results. It can be seen that Eastern European countries are in general connected to the system of R&D investments in Europe, but with comparably low magnitudes, with the Czech Republic showing the highest embededdness. This may be mainly related to the fact that the number of multinational companies originating from these countries is still rather low. Further, the results show that integration in business R&D investments is far less developed than in public research, including universities and research institutions, as shown by a similar representation of a spatial network map when using information on international collaboration patterns in the European Framework Programmes (FPs) (see Scherngell and Barber 2011). In the FPs Eastern European countries seem to be rather well integrated in pan-European research collaborations, while this is not the case for the industry sector. By this, the results obtained in this analysis correspond very well to those of Scherngell and Barber (2011).

Figure 23: R&D investment flows between European countries

Note: the strength of the lines between countries A and B corresponds to the sum of R&D expenditure of firms from country A in country B and vice versa. The node size of each country corresponds to the sum of R&D expenditure of foreign-owned firms in the country.

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

2.3. The relative importance of cross-country R&D flows

The exploratory analyses from above sheds some light on the structure of cross-country R&D investment flows from a social network analysis perspective, in particular in terms of the existence of links and in terms of link size. However, from social network analysis we know that we should consider the relative strength of the links between nodes, i.e. 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).

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.

In our study the index is defined as

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

where

$$y_{i\bullet} = \sum_{\substack{j=1 \\ j \neq i}}^{n} y_{ij}\,, \quad y_{\bullet j} = \sum_{\substack{i=1 \\ i \neq j}}^{n} y_{ij} \qquad i, j = 1, \ldots, n \qquad (2)$$

where y_{ij} is the number of observed R&D investment flows between countries i and j.

The calculation of the J_{ij} coefficient for our (i, j)-country pairs leads to interesting results concerning the spatial structure of R&D investment flows. Table 4 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 4. 50% of the Top 20 country pairs in terms of their relative link size are direct spatial neighbours (10 country pairs).

The strongest bilateral links exist between neighbouring countries, such as DE-NL, AT-DE et cetera. The only exception in Table 4 are a number of country pairs that involve JP and the US. If we remove country pairs with participation of the US and JP, only ES-NL and AT-CA as country pairs which are not direct neighbours remain. This is a particularly interesting result and will be further evaluated in the section that follows by means of a basic gravity modelling approach. In theoretical terms, the results underline the importance of the internationalisation of R&D, and the increasing diversity of partner countries. However, the relative intensity of R&D investments of a country seems to be still focused on countries located nearby in geographical space.

Table 4: Top-20 country pairs in terms of their relative link size

Country pair		Jaccard index
UK	US	0.266
DE	US	0.163
FR	JP	0.150
FR	US	0.118
CH	US	0.114
DE	NL	0.094
DE	AT	0.084
DE	CH	0.069
DE	FR	0.068
NL	JP	0.058
SE	UK	0.054
US	CA	0.049
SE	NO	0.045
ES	NL	0.044
FR	UK	0.042
NL	UK	0.040
ES	PT	0.038
JP	US	0.037
AT	CA	0.033
AT	CH	0.032

Source: own calculations

2.4. Closing comments

This section sheds light on the system of inward BERD flows between countries from a social network perspective. Networks are defined to constitute a system of nodes and edges that interconnect these nodes. In this analysis nodes are represented by countries interconnected by edges representing R&D investment flows between these countries. Such a graph-theoretic representation of the network is useful for the analysis of patterns, structural features and the spatial distribution of the web of international R&D investment flows between 27 countries.

The exploratory analysis based on social network indicators is focused on the structure of the network of inward BERD. Concerning the overall network structure, we cannot observe a high level of modularity in this network of cross-country R&D investments, i.e. there are no clusters or separated groups explicitly observable. Further, results from indicators measuring connectedness of the network show that its connectedness is quite high, pointing to the general importance of the internationalisation of R&D and the strategic orientation of firms to distribute their R&D in different countries and/or the ability of countries to provide framework conditions to attract foreign R&D investments. The analysis provides further empirical evidence on the global trends in the internationalisation of R&D that is obviously now spreading more widely in a geographical sense across countries, including particularly emerging economies. It seems that firms seek not only to exploit knowledge generated at home in other countries, but also to get access to global centres of knowledge. Further, in a European policy context the results point to integration processes; Eastern European countries are in general connected to the system of R&D investments in Europe, but with comparably low magnitudes. However, the results correspond well to empirical evidence obtained by Scherngell and Barber (2011) for collaborations in the European Framework Programmes (FPs) showing a rather lower integration intensity for industry than for public research collaborations. Important insights into the roles of single countries in the system are provided by the analysis of different types of centralities of each country. Germany shows the highest degree centrality among the countries under consideration, i.e. it has the highest number of partner countries, followed by the US and the Netherlands. Concerning eigenvector-based centrality, the ranking changes significantly taking into account the centrality of the partners of a country. The US shows the highest eigenvector centrality indicating that its partner structure is focused on countries that show a high centrality by themselves. Countries like Switzerland, Japan and Canada show comparably low degree-based centralities (i.e. they show a comparably low number of partner countries) but comparably high eigenvector-based centralities (i.e. they have a high number of partner countries with a high centrality). The opposite is the case for the Netherlands, Austria, the Czech Republic and Denmark.

Further, the analysis of the relative importance of cross-country R&D investments by means of the Jaccard index produces interesting results. The by far highest relative interaction intensity is identified for the country pair UK and US. However, one striking result is that high relative interaction intensities are in most cases subject to geographically nearby partner countries, even to direct spatial neighbours. This result points to some geographical logic in the system of R&D investments indicating that the relative intensity of R&D investments of a country seems to be still focused on countries located nearby in geographical space.

Finally, some ideas for a future research agenda come to mind. *First*, one weakness of the analysis presented in this section is that it is based on a sample of countries for which data on R&D investments are available. Using a larger set of countries may change the results in some respect, in particular with respect to the inclusion of rapidly developing countries such as China. *Second*, a longitudinal analysis would provide a deeper understanding on the evolution and changing patterns of the international network of R&D investments.

3. DRIVERS OF R&D INTERNATIONALISATION – A QUANTITATIVE APPROACH

While it is far from a new phenomenon, during the last two decades, the internationalisation of business R&D activities has accelerated strikingly. Specifically, as highlighted by OECD (2008a), between 1995 and 2003, R&D expenditure of foreign affiliates has increased twice as rapidly as their turnover or their host countries' aggregate imports which renders R&D activities of foreign affiliates one of the most dynamic elements of the process of globalisation. However, until recently, the main actors and recipients of cross-border R&D expenditure were developed countries.

Lately, some new players emerged, giving rise to new patterns of R&D internationalisation. Specifically, almost all countries increased their outward R&D activities. Especially in Asia, emerging economies gained importance as host countries of R&D internationalisation activities but developing countries also increasingly engaged in outward R&D. Furthermore, in addition to asset exploiting motives of R&D internationalisation, asset seeking motives started to play an ever growing role. Despite these developments, the largest part of international R&D still takes place between the triad area, comprising the US, the EU and Japan (OECD 2008b). Among OECD countries, the US is still the most preferred destination for R&D, despite declining relative importance. As such, in 2005, the US received around 38% of total R&D expenditure under foreign control in selected OECD countries. In contrast, Germany received around 16%, the UK and France around 11% and Japan around 6% (OECD 2008b).

However, by comparison, there is still relatively little work on patterns of R&D internationalisation at the sectoral level. What little is known suggests that host countries play a decisive role in emerging differences across sectors.

3.1. Comparison across sectors and countries: a graphical analysis

3.1.1. Sectoral R&D and value added shares

Whether production or R&D is more internationalised is subject of the ensuing analysis. Methodologically, a graphical analysis is pursued which compares the share of inward R&D of foreign affiliates (defined as the share of business R&D of foreign affiliates in total R&D of all firms in a sector) with the share of value added of foreign affiliates (defined as the share of value added generated by foreign affiliates to total value added generated by all firms in a sector) at the sectoral level.

The analysis uses value added (instead of e.g. turnover) as a proxy for production as 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, the concept of 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.

The shares of R&D and value added are specified as follows:

$$\frac{R\,\&\,D_{inward}}{R\,\&\,D_{total}} \overset{45°}{=} \frac{VA_{inward}}{VA_{total}}. \qquad (3)$$

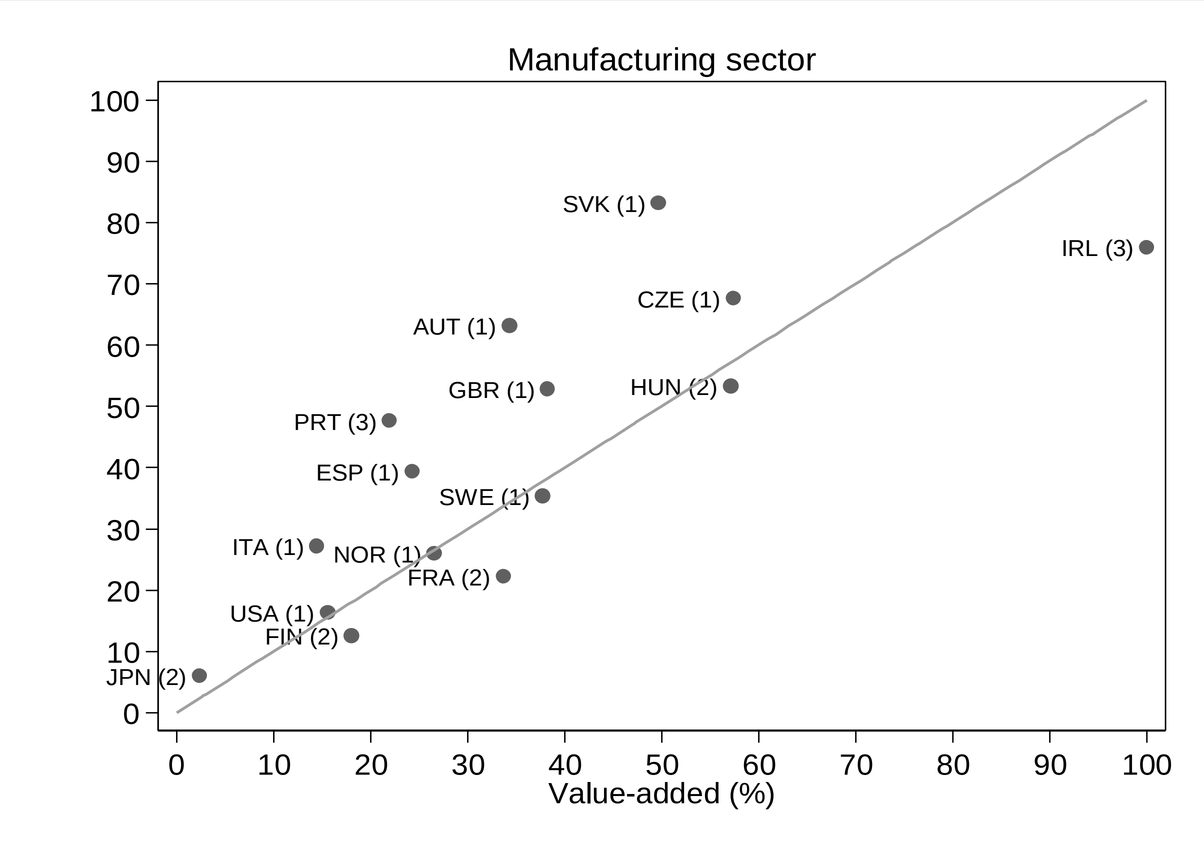
Equation (3) emphasises that if the share of R&D expenditure of foreign affiliates is equal or close to equal to the share of value added of foreign affiliates, host countries will align along or close to a 45 degree line. However, if the share of R&D expenditure of foreign affiliates is larger than the share of value added of foreign affiliates, host countries are located to the north-west of the 45 degree line while a larger share of value added of foreign affiliates (relative to the share of R&D expenditure of foreign affiliates) will push host countries to the south-east. The ensuing 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/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/sectors whose production activities are strongly internationalised.

Data for the descriptive analysis stem from different sources: both, information on business R&D expenditure of foreign affiliates ($R\&D_{inward}$) as well as total R&D expenditure ($R\&D_{total}$) represent data collected by both the Austrian Institute for Technology (AIT) and the Vienna Institute for International Economic Studies (wiiw) from national contact points (national statistical offices, science policy offices etc.) in the course of this project. In contrast, the official OECD *Activities of Foreign Affiliates* statistic (OECD AFA) exclusively provides information on value added of foreign affiliates in a host country (VA_{inward}), available for the period from 1995 to 2007. Finally, data on total value added (VA_{total}) exclusively originate from the *OECD Structural Analysis Database* (OECD STAN), available from 1970 up to 2009.

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.

Moreover, due to insufficient or altogether lacking data on foreign affiliates' R&D expenditure or value added, total R&D or total value added, the set of countries covered by the graphical analysis is rather limited. Specifically, Belgium (BEL), Bulgaria (BUL), Canada (CAN), Denmark (DNK), Estonia (EST), Germany (GER), Israel (ISR), Latvia (LVA), Malta (MTA), the Netherlands (NLD), Poland (POL), Romania (ROM), Slovenia (SVN) had to be excluded due to insufficient data on value added of foreign affiliates Moreover, lacking data on both value added and business R&D expenditure of foreign affiliates led to the exclusion of Australia (AUS), Greece (GRC), Iceland (ISL), Korea (KOR), Malta (MTA), Luxembourg (LUX), Switzerland (CHE) and Turkey (TUR). Hence, as a result, the following 15 countries are subject of the analysis: Austria (AUT), the Czech Republic (CZE), France (FRA), Finland (FIN), Hungary (HUN), Ireland (IRL), Italy (ITA), Japan (JPN), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Slovakia (SVK), the UK (GBR) and the US (USA).

Figure 24: Share of business R&D and value added of foreign affiliates in manufacturing (2004-2007)



Notes: the share of value added for IRL 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

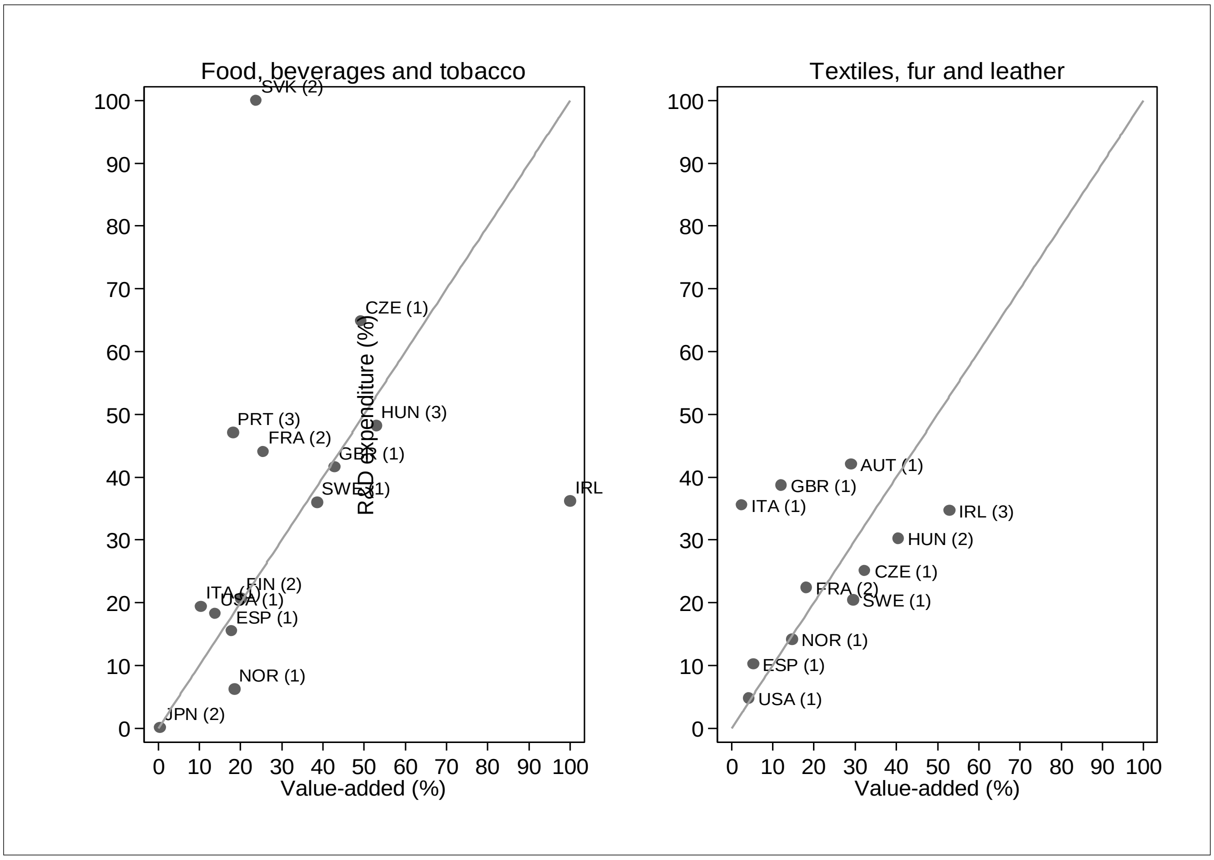
In what follows, all sectors are presented and discussed separately while a full table of R&D and value added shares for the period from 2004 to 2007 can be found in Appendix 3 for completeness sake (see Table 41)[3].Figure 24 depicts the shares of business R&D and value added of foreign affiliates in 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. Moreover, with a few exceptions only, the share of R&D of foreign affiliates is consistently higher than the share of value added which suggests that, *for the set of countries considered*, research and development is more internationalised than production, which is consistent with findings of the OECD (2009) for a comparable set of countries. Moreover, the degree of internationalisation of research differs across countries and 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.

In order to reveal prevailing sector specific patterns and degrees of internationalisation of both research and production, Figures 24 to 32 dig deeper and look at a more disaggregated sectoral level. In that respect, Figure 25 shows the food, beverages and tobacco sector and the textiles, fur and leather sector and again highlights that the degree of internationalisation of

[3] Table 41also captures some dynamic effects as the evolution of both R&D and value added shares are traced over time (for the period 2004 to 2007).

both research and production varies broadly across countries. Specifically, research in the food, beverages and tobacco sector is considerably more internationalised than production in the Slovak Republic and Portugal, while the opposite holds true for Ireland, whose food, beverages and tobacco sector is an attractive production hub for foreign affiliates.

Figure 25: Share of business R&D and value added of foreign affiliates in the food and textiles sectors (2004-2007)



Notes: (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

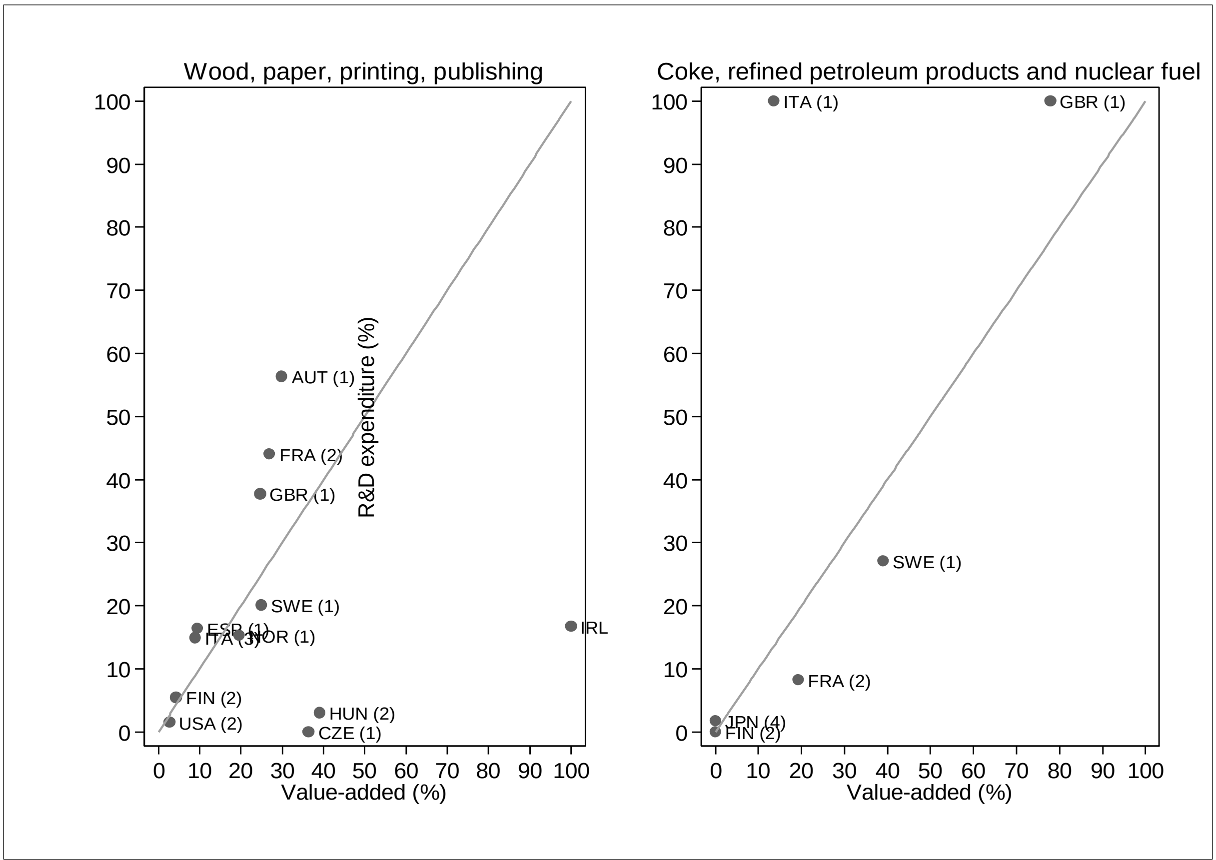
Source: Data collected from national contact points, OECD AFA, OECD STAN

In contrast, in the textiles, fur and leather sector, the variation in the share of business R&D of foreign affiliates across countries is quite moderate, ranging between 5% in the USA and around 45% in Austria. Additionally, all countries covered by the analysis align pretty closely along the 45 degree line, indicating that both production and research have similar degrees of internationalisation. The only exceptions are Italy and the UK whose textiles, fur and leather sectors are more internationalised in terms of research activities while the opposite holds true for Ireland, whose production activities show a higher degree of internationalisation.

The wood, paper, printing and publishing sector and coke, refined petroleum products and nuclear fuel sector are depicted in Figure 26. It emphasises that only in the case of Austria are research activities more internationalised than production. Specifically, the share of value added of foreign affiliates is close to 30% while the share of R&D expenditure of foreign affiliates is almost 60%. In contrast, production is significantly more internationalised in the wood, paper, printing and publishing sectors in Ireland, Hungary and the Czech Republic. Specifically, in the Irish case, the share of R&D expenditure of foreign affiliates only reaches 15% while the share of value added is 100% (a result of data inconsistencies, however).

Hungary also stands out as the share of value added of foreign affiliates reaches 40% while the share of R&D expenditure of foreign affiliates only amounts to approximately 5%. The focus on production is even more extreme in the Czech case: foreign affiliates do not spend any resources on R&D activities but solely focus on production and generate value added that accounts for around 35% of total value added.

Figure 26: Share of business R&D and value added of foreign affiliates in the wood, paper, printing and publishing and coke, refined petroleum products sectors (2004-2007)



Notes: for the wood, paper, printing, publishing sector: the share of value added for IRL was rescaled to 100; for the coke, refined petroleum products and nuclear fuel sector: the share of R&D for GBR and ITA was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

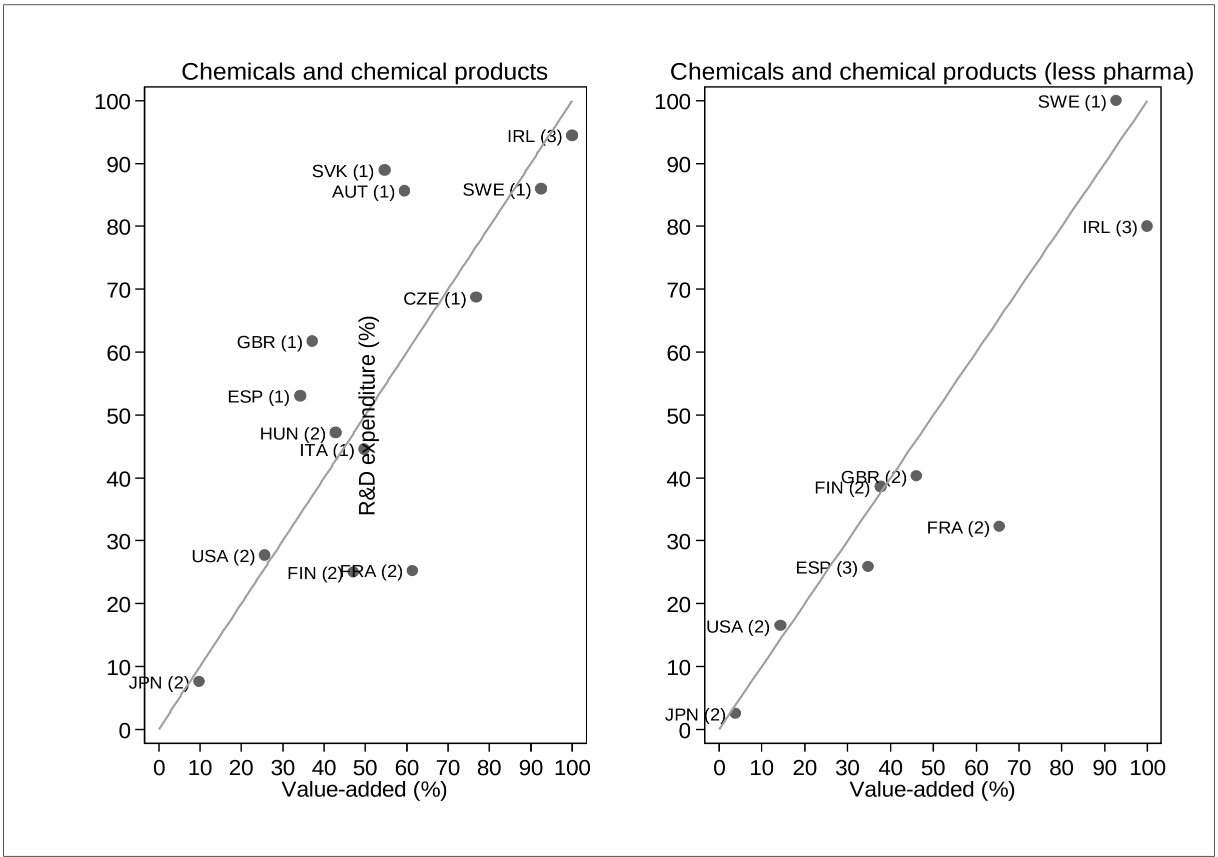
Source: Data collected from national contact points, OECD AFA, OECD STAN

The emerging picture is different for the coke, refined petroleum products and nuclear fuel sector and has to be interpreted with caution. Firstly, due to confidentiality issues, only a limited number of observations are available. Secondly, probably due to data inconsistencies, R&D shares in Italy and the UK exceed 100% (and had to be rescaled to 100%). Aside from that, production appears more internationalised in the Swedish and French coke, refined petroleum products and nuclear fuel sectors.

Figure 27 shows the chemicals and chemical products sectors (with and without pharmaceuticals). Specifically, research is more internationalised in the chemicals and chemical products sector of the Slovak Republic, the UK, Austria and Spain while production is relatively more internationalised in France and Finland. In contrast, research and production are of similar degrees of internationalisation in Japan, the USA, Italy, Hungary, the Czech Republic, Sweden and Ireland.

However, once the pharmaceuticals sector is excluded from the chemicals and chemical products sector a different pattern emerges. In particular, only with a few exceptions (Sweden, Finland and the USA), production activities are more internationalised than R&D activities. In particular, production is most internationalised in Ireland and France.

Figure 27: Share of business R&D and value added of foreign affiliates in the chemicals and chemical products sectors (with and without pharmaceuticals) (2004-2007)



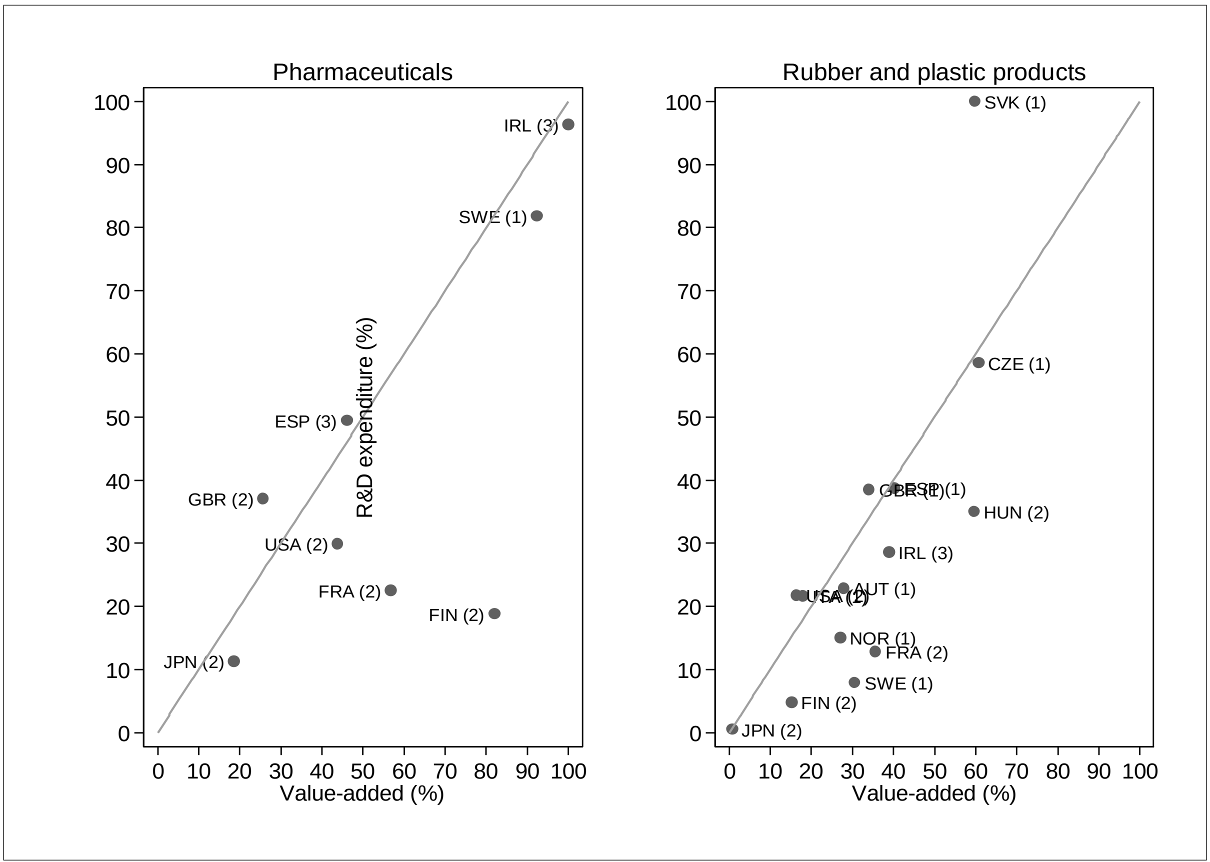
Notes: for the chemicals and chemical products sector: the share of value added for IRL was rescaled to 100; for the chemicals and chemical products sector (less pharma): the share of value added for IRL was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The pharmaceuticals sector and the rubber and the plastic products sector are depicted in Figure 28. Unfortunately, due to issues of data confidentiality, only a few cases are available (no information is available for Austria, the Czech Republic, Hungary, Italy and the Slovak Republic). The remaining set of countries point at a sector whose production and R&D activities have similar degrees of internationalisation across countries. The only exceptions are the French and Finnish pharmaceuticals sectors whose production activities appear significantly more internationalised than their R&D activities. Specifically, the share of R&D of foreign affiliates in the French pharmaceuticals sector only reaches around 20% while their value added share is more than twice as high, amounting to 55%. More extremely, the share of R&D of foreign affiliates which operate in the Finnish pharmaceuticals sector barely reaches 20% while the share of value added is four times as high (about 80%).

Likewise, production in the rubber and plastic products sector is more internationalised in the majority of countries covered. Specifically, production is most internationalised in the Hungarian, French and Swedish rubber and plastic products sectors. In contrast, probably due to data inconsistencies, R&D activities are more internationalised in the case of the Slovak Republic.

Figure 28: Share of business R&D and value added of foreign affiliates in the pharmaceuticals and rubber and plastic products sectors (2004-2007)



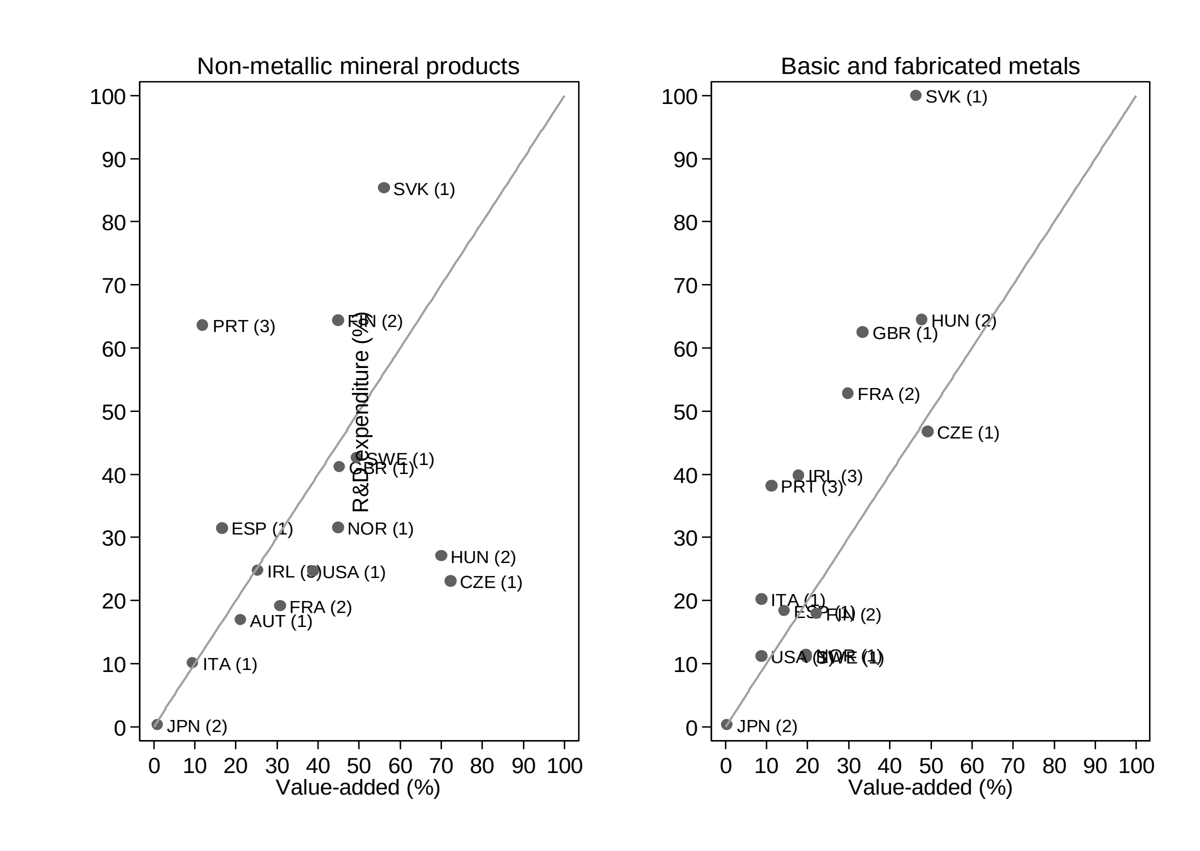
Notes: for the pharmaceuticals sector: the share of value added for IRL was rescaled to 100; for the rubber and plastic products sector: the share of R&D for SKV was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

Figure 29 looks at the non-metallic mineral products and basic and fabricated metals sectors. It emphasises that production tends to be more internationalised than research in the majority of non-metallic mineral products sectors. In particular, production is particularly internationalised in the Czech and Hungarian non-metallic mineral products sectors. The share of R&D of foreign affiliates is around 25% in both cases while the share of value added of foreign affiliates is almost three times as high and amounts to approximately 70% in both cases. On the contrary, research is significantly more internationalised in the Portuguese, Slovak and Finnish non-metallic mineral products sectors. In that respect, the Portuguese non-metallic mineral products sector represents the most extreme case: the share of value added of foreign affiliates only amounts to around 10% while foreign affiliates' R&D share reaches 65%.

In contrast, a cross-country comparison shows that research is more internationalised in the basic and fabricated metals sector. Specifically, the R&D share of foreign affiliates is almost four times as high as the share of value added of foreign affiliates in Portugal and more than or almost twice as high in the UK, France and Ireland.

Figure 29: Share of business R&D and value added of foreign affiliates in the non-metallic mineral products and basic and fabricated metals sectors (2004-2007)

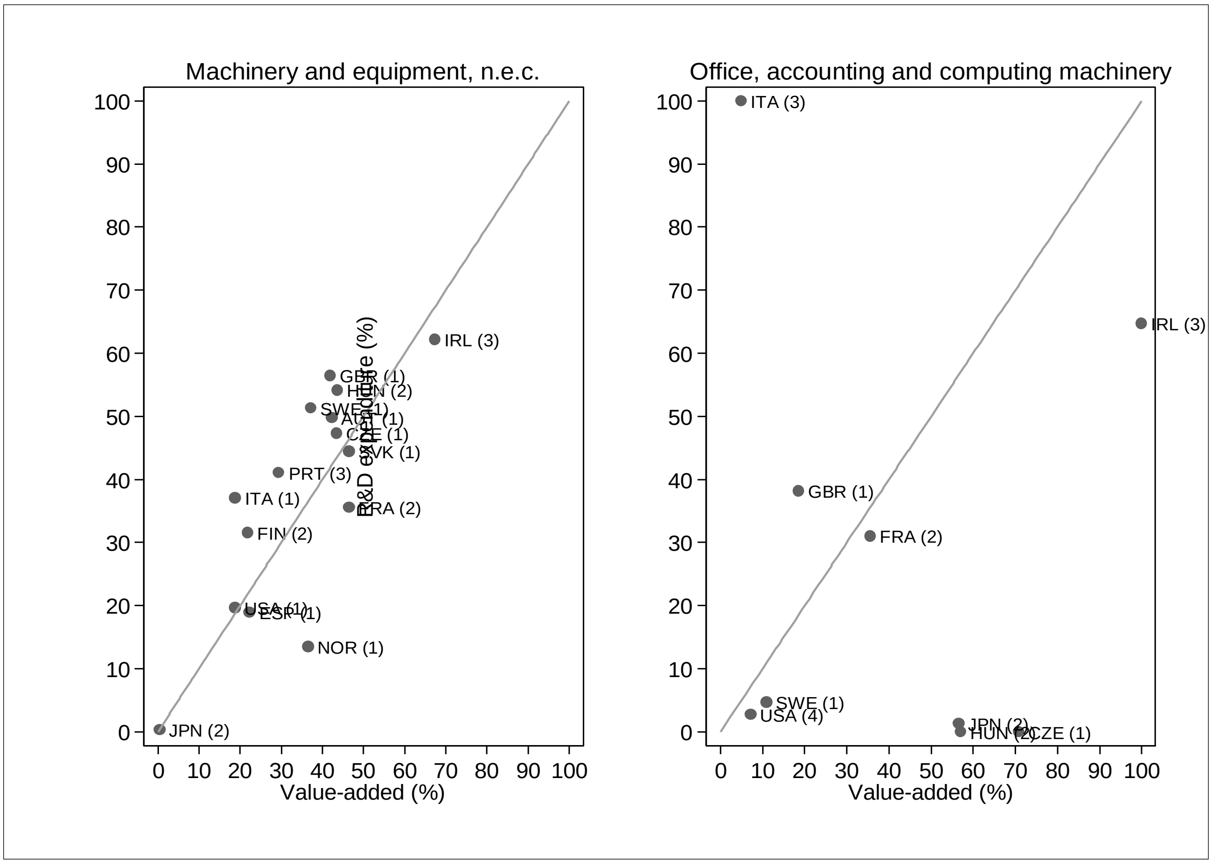


Notes: for the basic and fabricated metals sector: the share of R&D for SVK was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The machinery and equipment and office, accounting and computing machinery sectors are shown in Figure 30. Obviously, almost all countries are closely clustered around the 45 degree line. Moreover, the majority of countries are concentrated within a short range only: in the range from 40% to 60%, both in terms of R&D shares and value added shares. Hence, both research and production are of similar degree of internationalisation in all countries considered. The only exception is Norway, whose machinery and equipment sector is more strongly internationalised with respect to production.

Figure 30: Share of business R&D and value added of foreign affiliates in the machinery and equipment and office, accounting and computing machinery sectors (2004-2007)



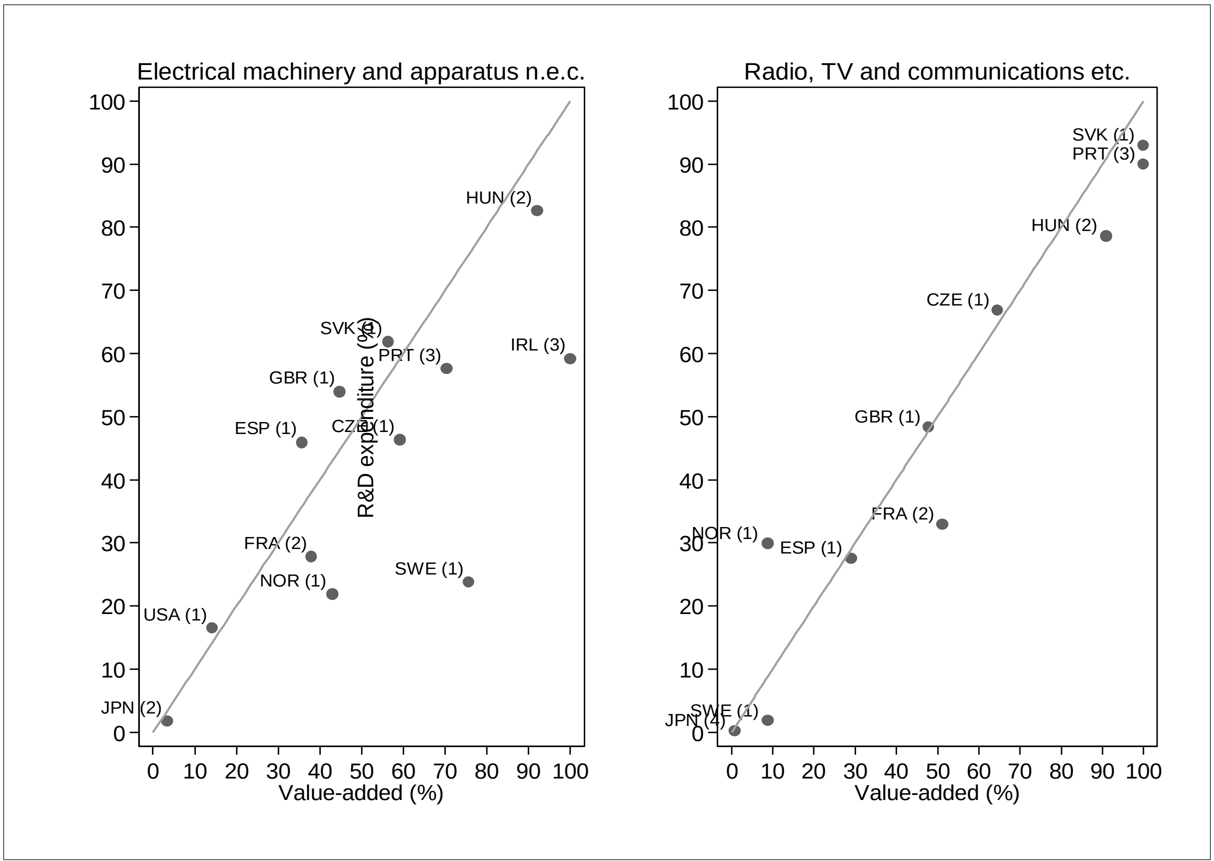
Notes: for the office, accounting and computing sector: the share of value added for IRL was rescaled to 100 and the share of R&D for ITA was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The emerging pattern is more extreme in the office, accounting and computing machinery sector. Specifically, research in the Italian office, accounting and computing machinery sector appears to be entirely monopolised by foreign affiliates, while foreign affiliates appear to dominate production in the Irish office, accounting and computing machinery sector. However, these patterns should be interpreted with caution since they very likely result from poor data quality and data inconsistencies. Moreover, Hungary and the Czech Republic represent interesting cases: foreign affiliates which operate in the Hungarian and Czech office, accounting and computing machinery sectors do not spend any resources on R&D activities but instead exclusively concentrate on production. But with respect to production, the share of value added foreign firms generate through production is higher in the case of the Czech Republic (with around 70%) than in the case of Hungary (with around 57%), which renders production in the Czech other transport equipment sector more internationalised than production in the Hungarian other transport equipment sector. In contrast, the Japanese case is less extreme as foreign affiliates which operate in the office; accounting and computing machinery sector also predominantly pursue production activities but still spend some (relatively) negligible resources on R&D activities.

Figure 31 focuses on the electrical machinery and apparatus and the radio, TV and communications sectors. It highlights that there are no outliers in the upper region which indicates that in none of the countries considered is research more internationalised than production. Moreover, only the Irish and Swedish electrical machinery and apparatus sectors are characterised by production that is significantly more internationalised than research. Specifically, the share of value added of foreign affiliates (75%) is three times higher than the share of R&D of foreign affiliates (22%), while the Irish case is the result of data inconsistencies.

Figure 31: Share of business R&D and value added of foreign affiliates in the electrical machinery and apparatus and radio, TV and communications sectors (2004-2007)



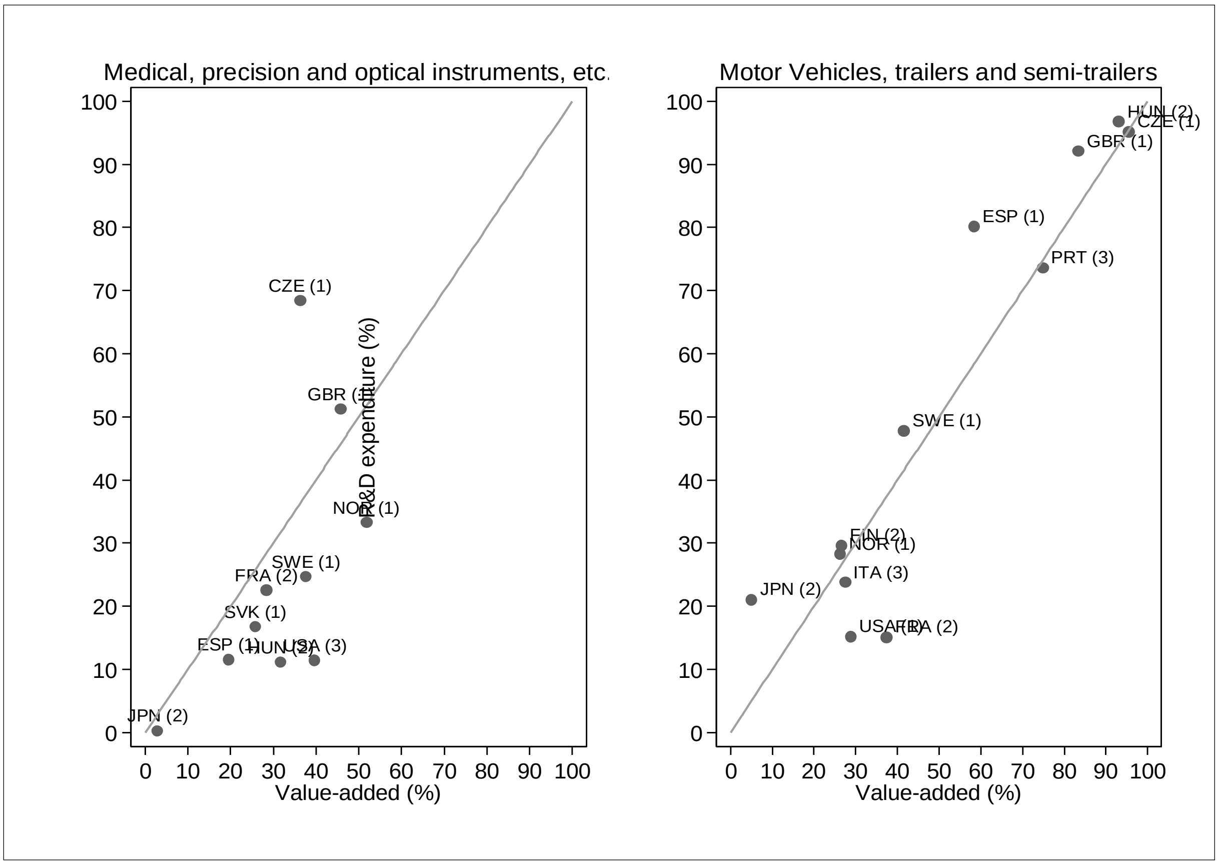
Notes: for the electrical machinery and apparatus n.e.c sector: the share of value added for IRL was rescaled to 100; for the radio, TV and communications sector: the shares of value added for SVK and PRT were rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

In contrast, the radio, TV and communications sector is characterised by a high dispersion of both R&D and value added share of foreign affiliates. Specifically, both shares range between 0% in the case of Japan and around 90% in the case of the Slovak Republic and Portugal. Moreover, countries also very closely align along the 45 degree. Hence, both production and research are characterised by similar degrees of internationalisation. The only exception is Norway, whose radio, TV and communications sector is unambiguously more internationalised with respect to research. Specifically, while the share of value added of foreign affiliates only amounts to around 10%, the share of R&D of foreign affiliates is three times higher and reaches 30%.

The medical, precision and optical instruments and the motor vehicles, trailers and semi-trailers sectors are shown in Figure 32. Strikingly, in the medical, precision and optical instruments sector, with the exception of the Czech Republic and the UK, all countries are positioned below the 45 degree line which is indicative of a sector whose production activities tend to be more internationalised. However, with the exception of the USA, these countries all closely align along the 45 degree line. In the case of the USA, production is significantly more internationalised since the share of R&D of foreign affiliates is only 10% while the share of value added is four times as high, amounting to 40%. In contrast to all this, the Czech Republic is a clear outlier whose research activities in the medical, precision and optical instruments sector is significantly more internationalised than its production activities: while the share of value added of foreign affiliates is only 30%, the share of business R&D of foreign affiliates is more than twice as high (almost 70%).

Figure 32: Share of business R&D and value added of foreign affiliates in the medical, precision and optical instruments and motor vehicles, trailers and semi-trailers sectors (2004-2007)



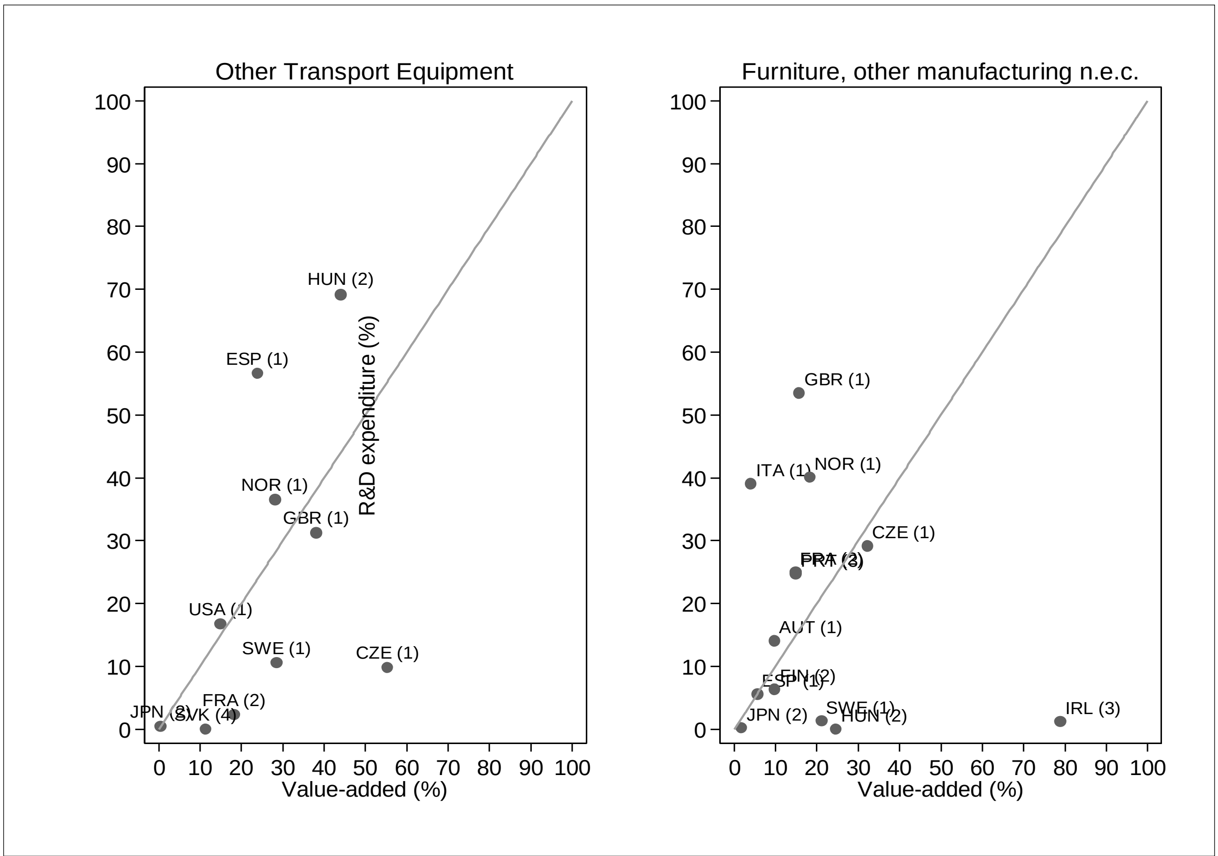
Note: (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

In contrast, in the motor vehicles, trailers and semi-trailers sector, both research and production are characterised by similar degrees of internationalisation as countries closely align along the 45 degree line. However, in contrast to other sectors, both business R&D and value added shares of foreign affiliates show a more pronounced dispersion, ranging from 15% to almost 100%.

Finally, Figure 33 depicts the other transport equipment sector and the furniture and other manufacturing sector. It highlights that research is considerably more internationalised in the Spanish other transport equipment sector only. In contrast, the majority of countries depicted are characterised by production activities that are more internationalised. As an extreme case, foreign affiliates do not invest at all in any innovative R&D activities in the Slovak other transport equipment sectors but exclusively focus on production only. Moreover, production is also considerably more internationalised (than research) in the case of the Czech Republic, France and Sweden.

Figure 33: Share of business R&D and value added of foreign affiliates in the other transport equipment and furniture and other manufacturing sectors (2004-2007)



Note: (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

A more diverse picture emerges for the furniture and other manufacturing sector. Specifically, while the majority of countries again align along the 45 degree line, some outliers can be identified. On the one hand, research is significantly more internationalised than production in the British and Italian furniture and other manufacturing sectors. In the UK, with around 55%, the share of business R&D is almost four times as high as their share of value added (15%). In the Italian case, the share of business R&D of foreign affiliates amounts to almost 40% while their share of value added is only 4%. On the other hand, production is significantly more internationalised than research in the Irish, Hungarian and Swedish furniture and other manufacturing sectors. Moreover, in all three cases, the R&D share of foreign affiliates lies between 0% and 2% only while the share of value added ranges between 20% (in the case of Sweden) and 80% (in the case of Ireland). As such, foreign affiliates do not spend any (as in the Hungarian case) or hardly any resources (as in the Swedish and Irish cases) on research but instead (almost) exclusively focus on production.

3.1.2. *Relative R&D intensities of domestic and foreign firms*

However, while a comparison of R&D and value added shares of foreign affiliates is insightful by itself and helps identify some aspects to study more thoroughly and some avenues to explore, it does not allow for a direct comparison of foreign and domestic firms and their respective R&D expenditure or levels of value added they generate through production. Hence, in what follows, a direct comparison of R&D intensities (as the share of business R&D expenditure in value added) of foreign and of domestic firms is drawn to identify the relative size of research efforts undertaken by both types of firms.[4] As such, the ensuing analysis helps identify sectors that are characterized by a disparity between R&D intensities of both foreign affiliates and domestic firms.

Methodologically, the following comparison is drawn:

$$\frac{R\,\&\,D_{foreign}}{VA_{foreign}} \overset{45^\circ}{=} \frac{R\,\&\,D_{domestic}}{VA_{domestic}} \qquad (4)$$

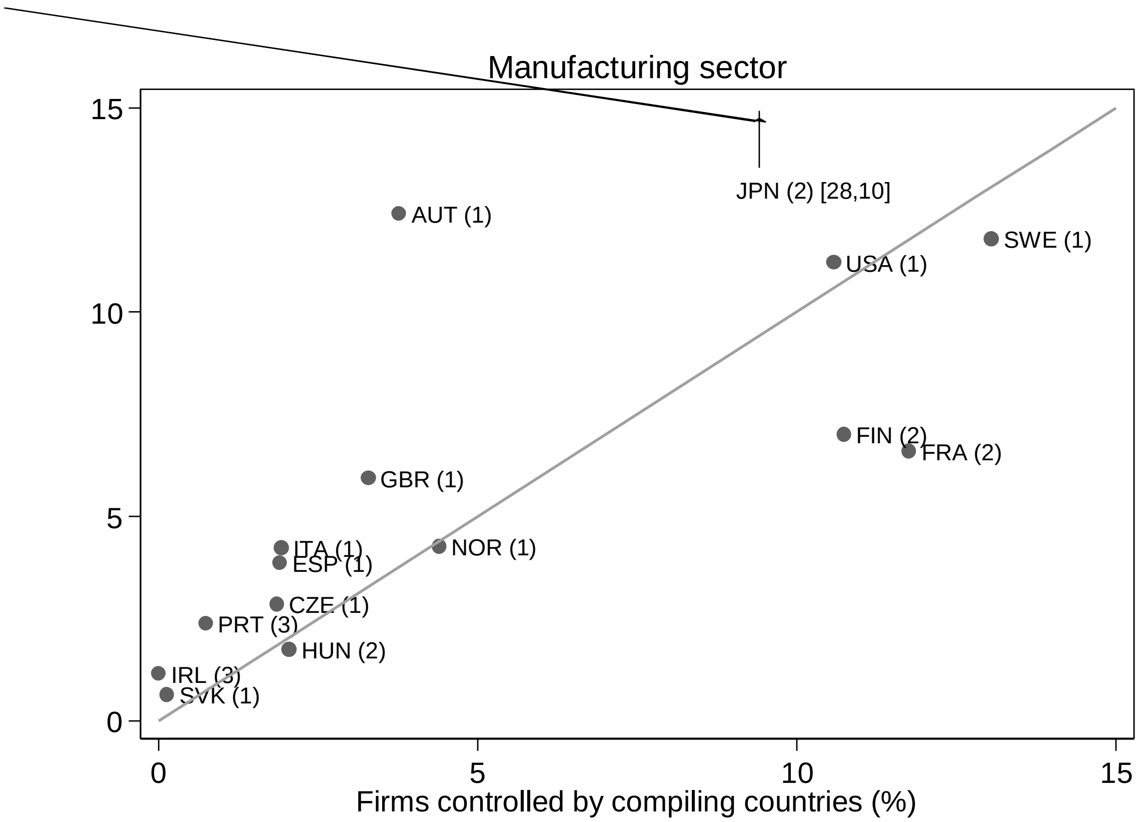
Similarly, equation (4) emphasises that if R&D intensities of foreign affiliates correspond to or are close to R&D intensities of domestic firms, countries will align along or close to a 45 degree line. However, if R&D intensities of foreign firms are larger than R&D intensities of domestic firms, countries are located to the north-west of the 45 degree line while larger R&D intensities of domestic firms (relative to R&D intensities of foreign firms) push host countries to the south-east. The ensuing analysis again predominantly focuses on the latter two cases.

As a starting point, Figure 34 shows the total manufacturing sector separately.[5] It highlights that R&D intensities are pretty moderate and range between 0% and 15% only. Moreover, R&D intensities of both foreign-owned and domestic firms are pretty similar across countries considered. However, the Japanese and the Austrian manufacturing sector are the only exceptions as the R&D intensities of foreign affiliates is close to 30% in Japan and as such, almost three times as high as R&D intensities of domestic firms (10%). This strong disparity in R&D intensities of foreign and Japanese firms can be attributed to the strong concentration of foreign affiliates in the motor vehicles, trailers and semi-trailers sector and their extensive investments in research and development (Figure 42).

4 See section 3.1.1 above for the rationale of using value added instead of e.g. turnover.

5 For completeness sake, a full table of both domestic and foreign R&D intensities for the period from 2004 to 2007 can be found in Table 42, Appendix 3 Drivers of R&D Internationalisation (Quantitative)

Figure 34: R&D intensities in the manufacturing sector (2004-2007)



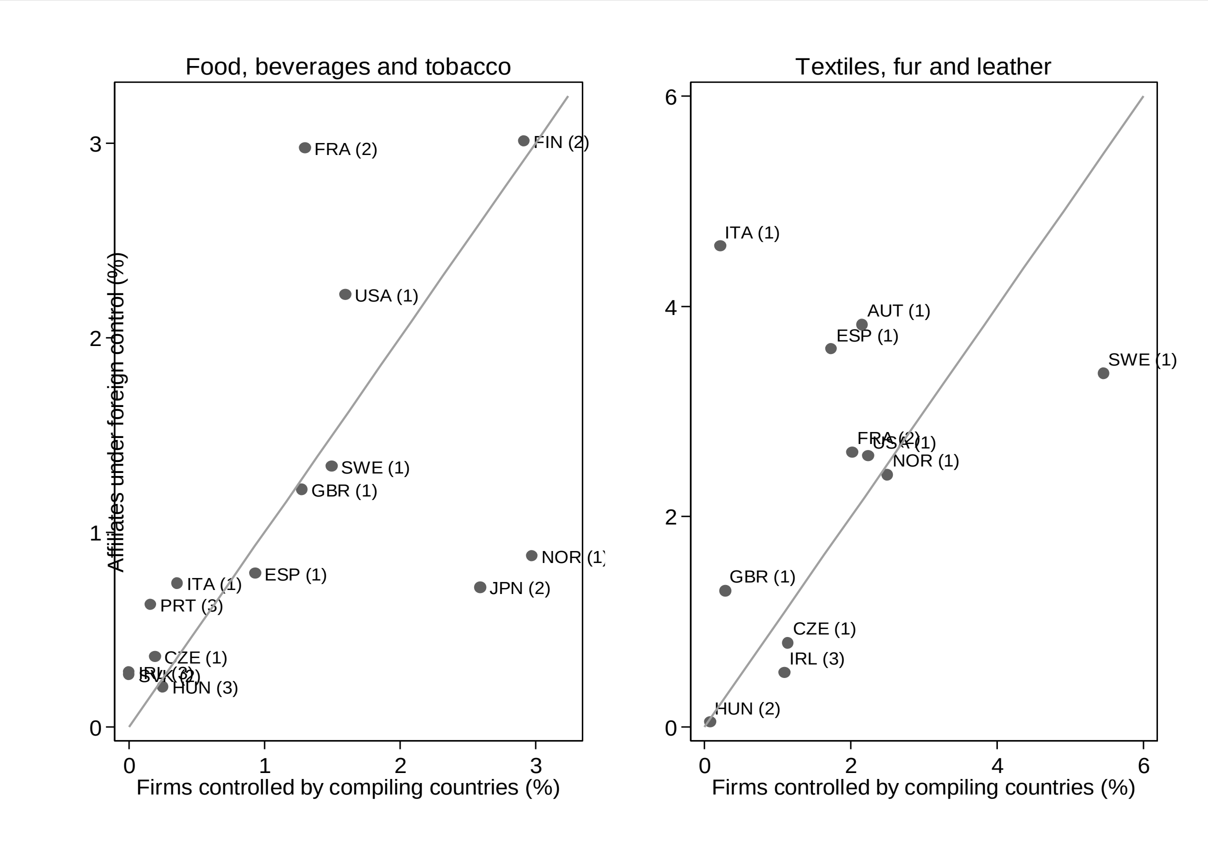
Notes: R&D intensity of domestic firms in IRL was rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

Figure 35 depicts the food, beverages and tobacco sector and the textiles, fur and leather sector. It highlights that generally, R&D intensities (of both foreign and domestic firms) are very low, reaching 3% at the maximum only. Furthermore, it shows that in the French food, beverages and leather sector, R&D intensities of foreign affiliates are three times higher than R&D intensities of domestic firms. In contrast, R&D intensities of domestic firms are significantly higher in the Norwegian and Japanese food, beverages and tobacco sectors: three times higher in both cases.

In contrast, R&D intensities are somewhat higher in the textiles, fur and leather sectors, amounting to almost 6% at most. Particularly outstanding are the Italian textiles, fur and leather sector where R&D intensities of foreign affiliates are 20 times higher than R&D intensities of domestic firms and the Austrian and Spanish textiles, fur and leather sectors where R&D intensities of foreign affiliates are twice as high as R&D intensities of domestic firms. On the contrary, the opposite holds true for the Swedish textiles, fur and leather sector: while R&D intensities of foreign affiliates only reaches around 3%, R&D intensities of their domestic counterparts is almost twice as high (5.5%).

Figure 35: R&D intensities in the food, beverages and tobacco and the textiles, fur and leather sectors (2004-2007)



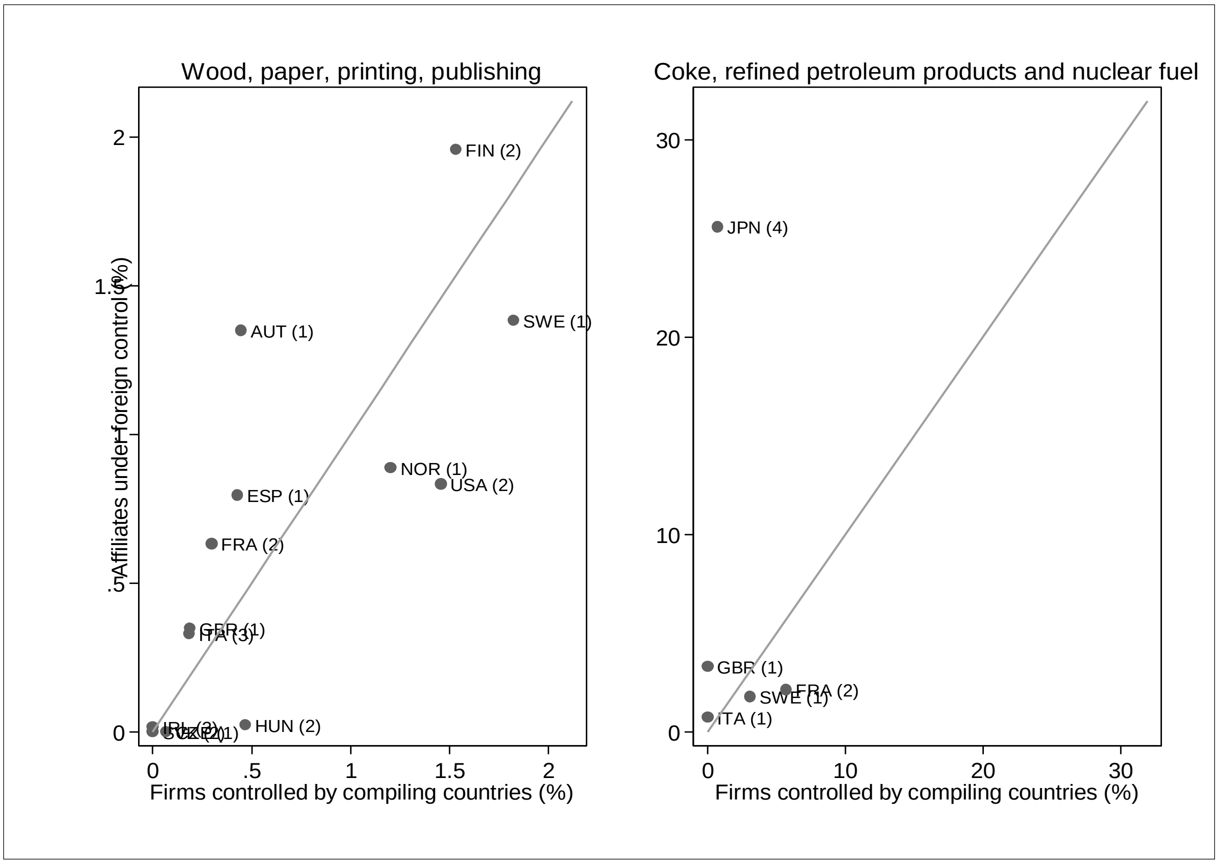
Notes: for the food, beverages and tobacco sector: the R&D intensity of domestic firms in IRL was rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The wood, paper and printing sector and the coke, refined petroleum products and nuclear fuel sector are shown in Figure 36. Apparently, with 2% at most, R&D intensities of both foreign and domestic firms which operate in the wood, paper and printing sector are even lower than those in the food, beverages and tobacco sector (Figure 35). Moreover, by comparison, with only 2% at most, R&D intensities are lowest across all manufacturing sectors considered here. Generally, the Austrian wood, paper and printing sector stands out since, despite the generally low R&D intensities, with 1.5%, R&D intensities of foreign affiliates are three times higher than those of domestic firms (only around 0.5%).

The emerging pattern is different in the coke, refined petroleum products and nuclear fuel sector. While the majority of countries considered cluster around 3% to 5% at most, the Japanese coke, refined petroleum products and nuclear fuel sector is a clear outlier. Specifically, while R&D intensities of domestic firms amount to only 0.7%, foreign affiliates' R&D intensities reach more than 25%.

Figure 36: R&D intensities in the wood, paper, printing and the coke, refined petroleum products and nuclear fuel sectors (2004-2007)



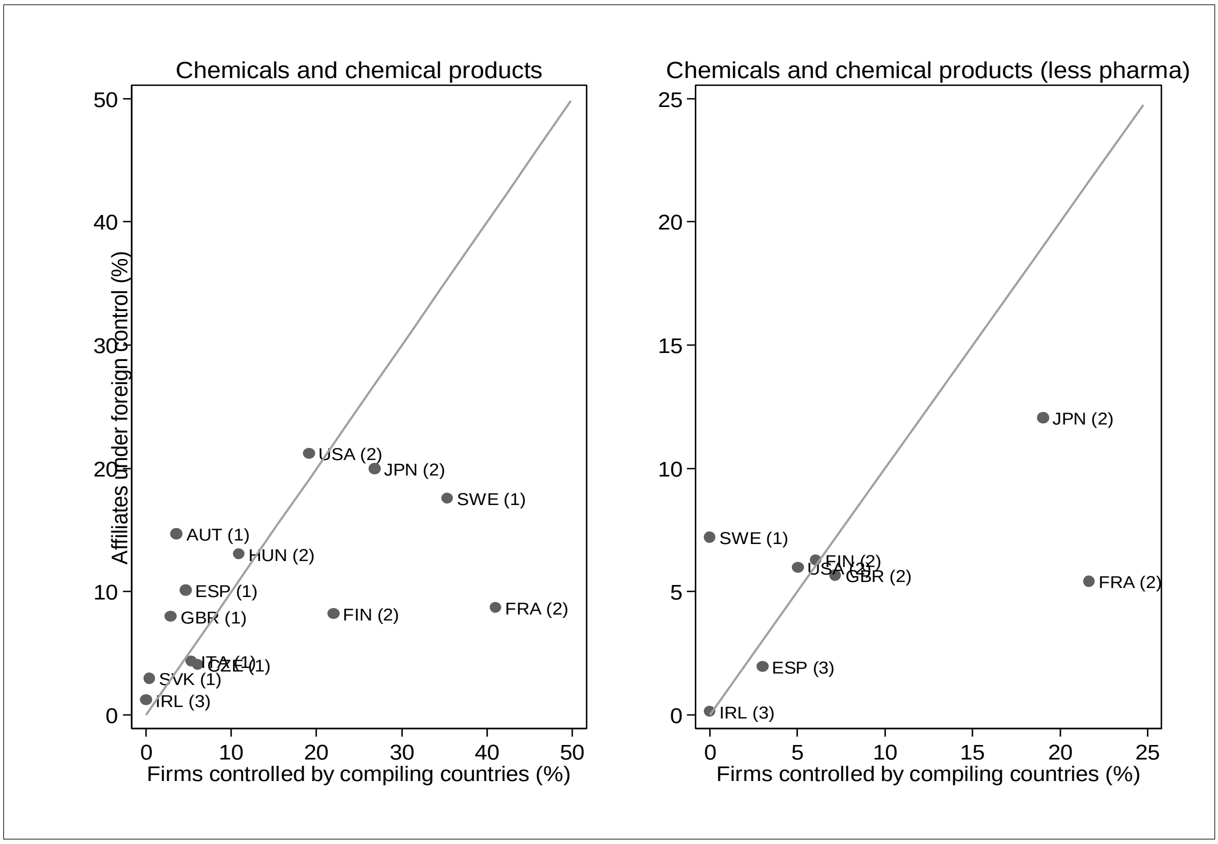
Notes: for the wood, paper, printing, publishing sector: the R&D intensity of domestic firms in IRL was rescaled to 0; for the coke, refined petroleum products and nuclear fuel sector: the R&D intensity of domestic firms in GBR was rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

Figure 37 depicts the chemicals and chemical products sector as well as the chemicals and chemical products sector (excluding pharmaceuticals). A closer look at the whole chemicals and chemical products sector reveals that R&D intensities of domestic firms tend to be higher than R&D intensities of foreign affiliates. This is particularly true for the French, Swedish and Finnish chemicals and chemical products sectors: here, R&D intensities of domestic firms are four times higher than R&D intensities of foreign firms in the French case and two times higher in the Finnish and Swedish cases.

Excluding pharmaceuticals, the picture remains pretty much the same. The only exception is Sweden: in particular, R&D intensities of foreign firms are higher than those of domestic firms in the Swedish chemicals and chemical products sector. However, this is the result of data inconsistencies.

Figure 37: R&D intensities in the chemicals and chemical products and the chemicals and chemical products (less pharmaceuticals) sector (2004-2007)



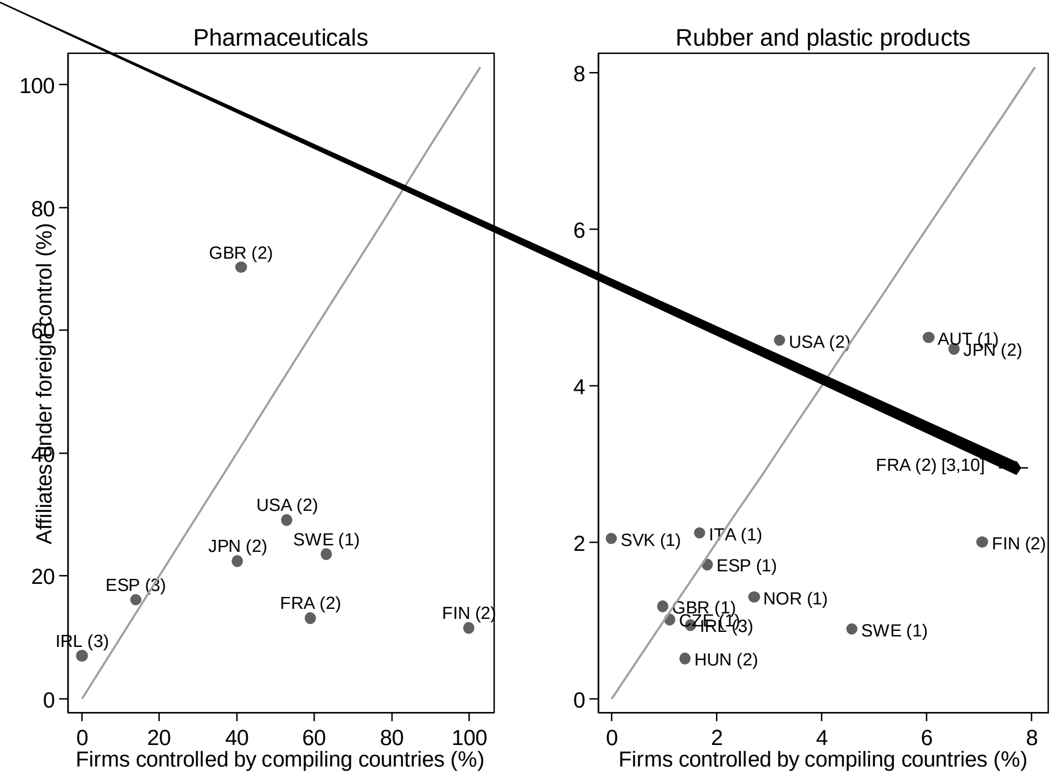
Notes: for the chemicals and chemical products (less pharma) sector: the R&D intensity of domestic firms in SWE was rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The pharmaceuticals sector and the rubber and plastic products sector are shown in Figure 38. Generally, R&D intensities of foreign affiliates and of domestic firms show a broad variation, ranging from 10% to almost 80%. And while the majority of cases cluster more or less closely around the 45 degree line, some outliers emerge. Specifically, R&D intensities of foreign affiliates which operate in the British pharmaceuticals sector are significantly higher than R&D intensities of domestic, British firms: specifically, with 80%, R&D intensities of foreign affiliates are twice as high as R&D intensities of British firms (40%). However, the opposite is observable in the pharmaceuticals sectors of Finland, France and Sweden. In all three cases, R&D intensities of domestic firms far exceed those of foreign affiliates. In particular, R&D intensities of domestic Swedish and French amount to around 60% while R&D intensities of foreign firms which operate in either the Swedish or the French pharmaceuticals sectors only reach 25% and 12%, respectively. Finally, the Finnish case is due to data inconsistencies and should therefore be interpreted with caution.

R&D intensities are generally lower in the rubber and plastic products sector and only amount to up to 10% for domestic firms and to only 5% at most for foreign affiliates. And while for the majority of countries, R&D intensities of both foreign and domestic firms (almost) coincide, three outliers can be identified: in the French and Swedish rubber and plastic products sectors, R&D intensities of domestic firms are almost four times higher than R&D intensities of foreign affiliates. Moreover, in the Finnish rubber and plastic products sector R&D intensities of domestic firms are three times higher than R&D intensities of foreign firms.

Figure 38: R&D intensities in the pharmaceuticals and the rubber and plastic products sectors (2004-2007)



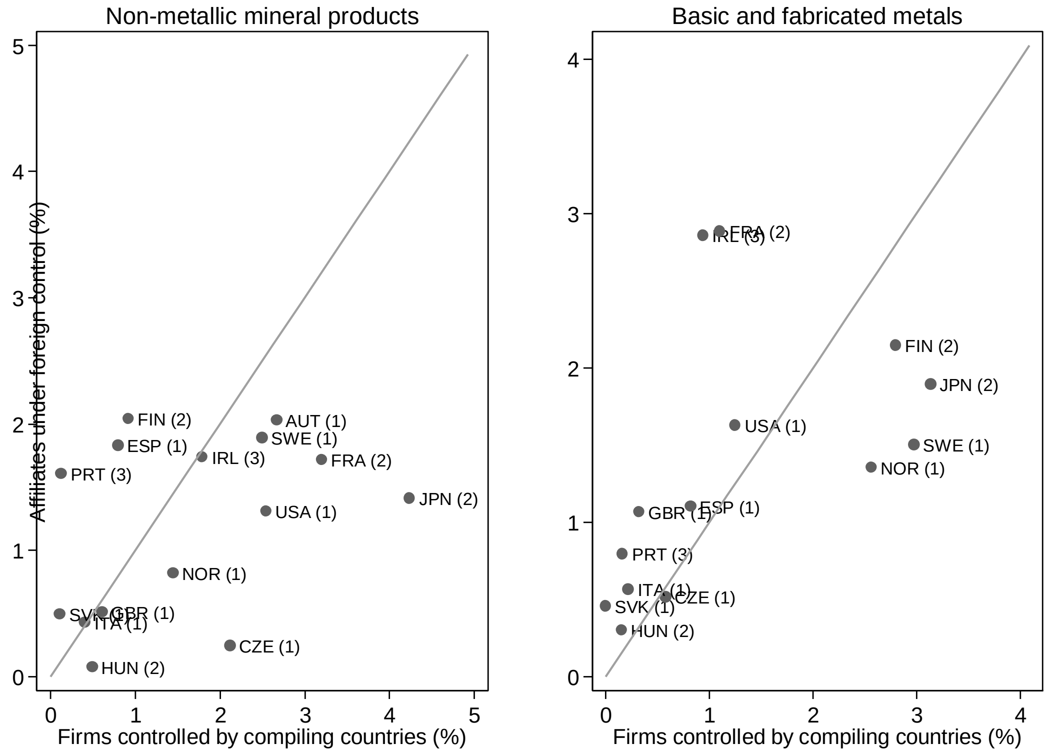
Notes: for the pharmaceuticals sector: the R&D intensity of domestic firms in IRL was rescaled to 0 and of domestic firms in FIN was rescaled to 100; for the rubber and plastic products sector: the R&D intensity of domestic firms in SVK was rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The non-metallic mineral products sector and the basic and fabricated metals sector are presented in Figure 39. It demonstrates that in the non-metallic mineral products sector, R&D intensities are pretty low, only reaching around 2% for foreign affiliates and only around 4% for domestic firms. Again, some outliers can be identified: in the Finnish and Spanish non-metallic mineral products sectors, R&D intensities of foreign firms are twice as high as R&D intensities of domestic firms; the Slovak and Portuguese positions are again the result of data inconsistencies and should therefore be interpreted with caution. In contrast, R&D intensities of domestic firms far exceed R&D intensities of foreign firms in the Japanese and Czech non-metallic mineral products sector: specifically, R&D intensities of Japanese firms are around 4%, while R&D intensities of foreign affiliates only amount to around 1.5%. Likewise, R&D intensities of Czech firms reach around 2% while those of their foreign counterparts only amount to around 1.4%.

In the basic and fabricated metals sector, R&D activities of both domestic and foreign firms are also pretty low and only reach 3% at most. A comparison across countries shows that R&D intensities of foreign firms are significantly higher (than R&D intensities of domestic firms) in the French and Irish basic and fabricated metals sectors: specifically, in both cases, with only 1%, R&D intensities of domestic firms fall short of R&D intensities of foreign affiliates which amount to 3%. On the contrary, R&D intensities are comparatively higher for domestic firms in the Swedish basic and fabricated metals sector: R&D intensities of Swedish firms reach 3% while R&D intensities of foreign firms amount to only 1.5%.

Figure 39: R&D intensities in the non-metallic mineral products and the basic and fabricated metals sectors (2004-2007)



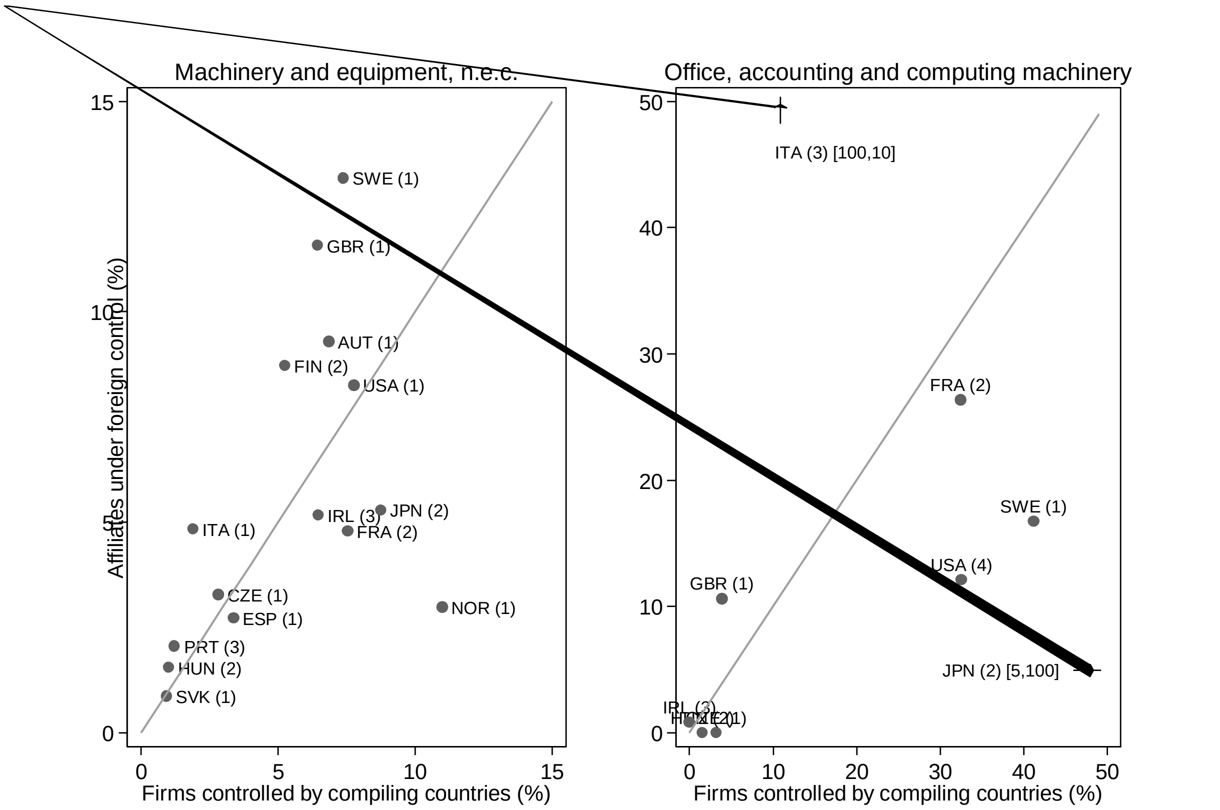
Notes: for the basic and fabricated metals sector: the R&D intensity of domestic firms in SVK was rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

Figure 40 shows the machinery and equipment sector and the office, accounting and computing machinery sector. R&D intensities in the machinery and equipment sector reach almost 15% for both domestic and foreign firms. Moreover, the Norwegian machinery and equipment sector stands out as R&D intensities of domestic firms far exceed R&D intensities of foreign firms. In particular, with only 3%, R&D intensities of foreign affiliates falls far short of R&D intensities of Norwegian firms whose R&D intensities are around 11%.

Unfortunately, the office, accounting and computing machinery sector is plagued by data issues – both, in terms of data confidentiality which only leaves a small amount of countries to consider and compare as well as in terms of data inconsistencies which render both the Italian and the Japanese results artificial and incomparable. The remaining countries considered cluster pretty closely along the 45 degree line so no noteworthy differences in R&D intensities of both domestic and foreign firms can be identified.

Figure 40: R&D intensities in the machinery and equipment and the office, accounting and computing machinery sectors (2004-2007)



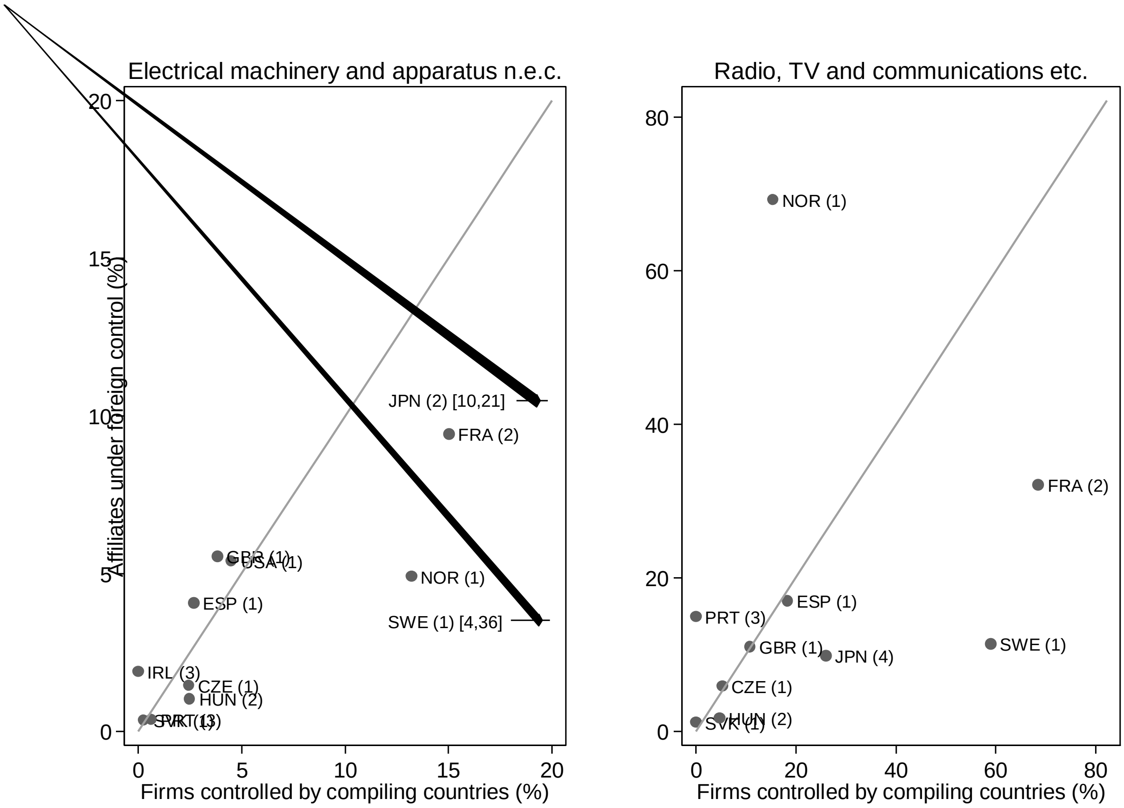
Notes: for the office, accounting and computing machinery sector: the R&D intensity of domestic firms in JPN was rescaled to 100 and of domestic firms in IRL to 0; the R&D intensity of foreign firms in ITA was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The electrical machinery and apparatus sector and the radio, TV and communications sector are depicted in Figure 41. It highlights that in the electrical machinery and apparatus sector R&D intensities diverge partly strongly and tend to be higher for domestic firms than for foreign affiliates. The most striking case is the Swedish electrical machinery and apparatus sector where R&D intensities of foreign affiliates only amounts to around 3% while R&D intensities of their Swedish counterparts reach around 36%.

Likewise, the radio, TV and communications sector also hosts interesting outliers. On the one hand, R&D intensities of foreign firms are significantly higher than R&D intensities of domestic firms in the Norwegian radio, TV and communications sector: with 70%, R&D intensities of foreign affiliates are almost five times higher than R&D intensities of their domestic counterparts, whose R&D intensities only amount to 15%. On the other hand, R&D intensities of domestic firms are significantly higher than R&D intensities of foreign firms in the French and Swedish radio, TV and communications sectors: R&D intensities of foreign affiliates (70%) are more than twice as high as R&D intensities of domestic firms (32%). Similarly, with 60%, R&D intensities of Swedish firms are more than five times higher than those of foreign firms whose R&D intensities amount to around 11% only.

Figure 41: R&D intensities in the electrical machinery and apparatus and the radio, TV and communications sectors (2004-2007)

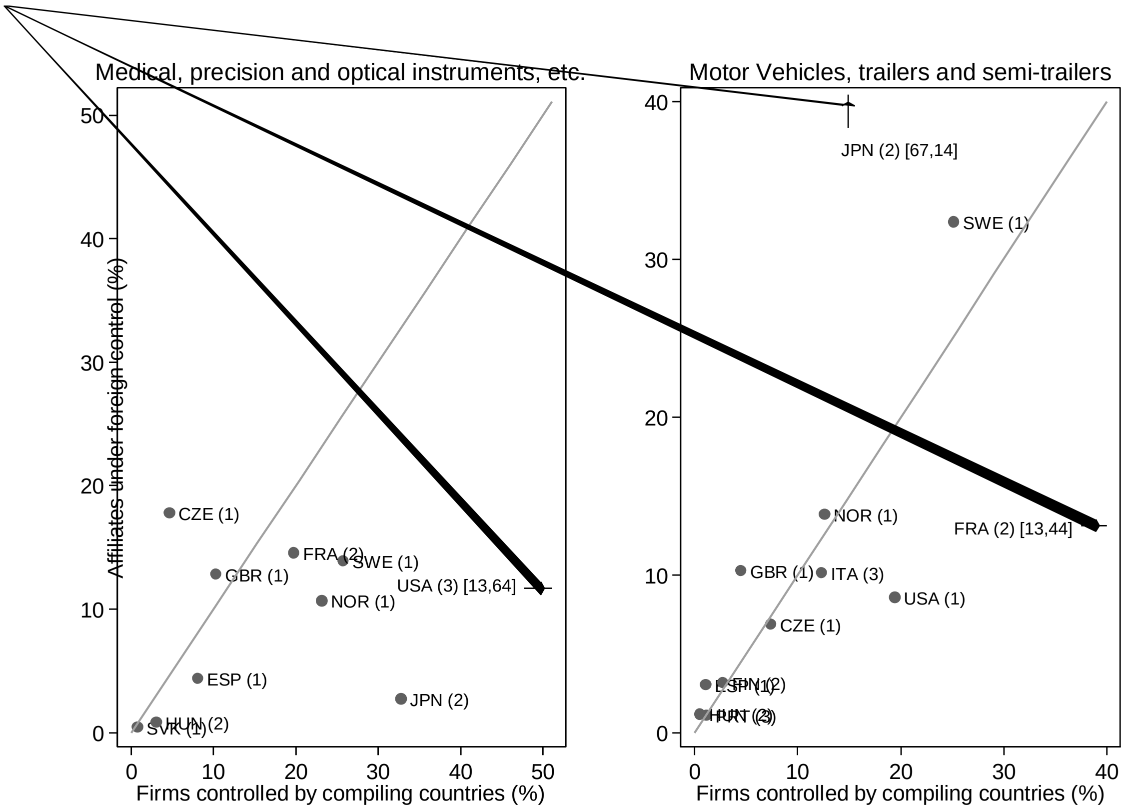


Notes: for the electrical machinery and apparatus n.e.c. sector: the R&D intensity of domestic firms in IRL was rescaled to 0; for the radio, TV and communications sector: the R&D intensities of domestic firms in SVK and PRT were rescaled to 0; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

The medical, precision and optical instruments sector and the motor vehicles, trailers and semi-trailers sector are shown in Figure 42. It highlights that except for the USA, R&D intensities of both foreign and domestic firms reach 20% to 30% only. Moreover, some outliers emerge. In particular, with 18%, R&D intensities of foreign firms far exceed R&D intensities of domestic firms (5%) in the Czech medical, precision and optical instruments sector. On the contrary, R&D intensities of domestic firms far exceed those of foreign firms in the US and Japanese medical, precision and optical instruments sectors. Specifically, in the case of the US, R&D intensities of foreign firms amount to only 13% while R&D intensities of US firms are five times higher and amount to 64%. Likewise, in the case of Japan, R&D intensities of foreign affiliates are only around 3% while R&D intensities of Japanese firms are eleven times higher and reach 33%.

Figure 42: R&D intensities in the medical, precision and optical instruments and the motor vehicles, trailers and semi-trailers sectors (2004-2007)



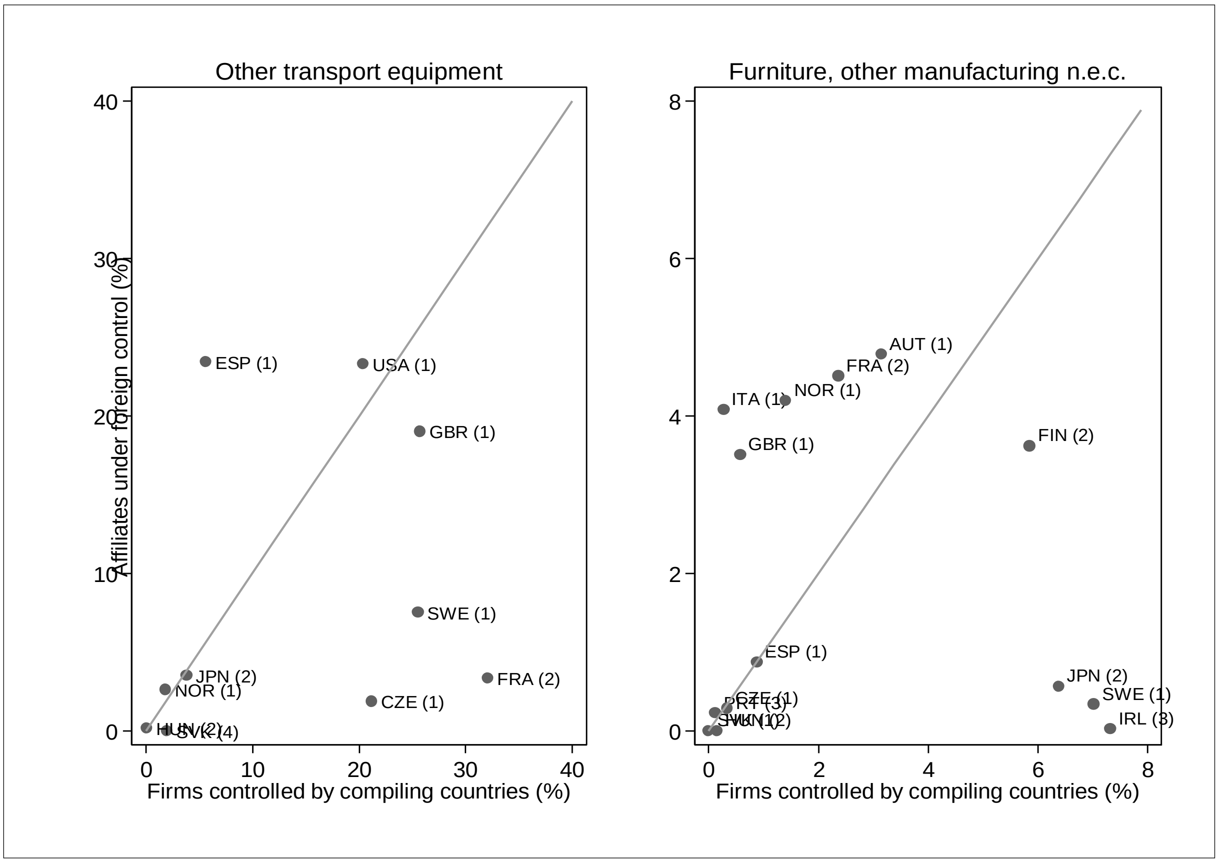
Notes: (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

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

R&D intensities of both domestic and foreign firms in the motor vehicles, trailers and semi-trailers sector are quite substantial and reach up to 40% and around 70%, respectively. Across countries, due to a strong disparity between domestic and foreign R&D intensities, the Japanese motor vehicles, trailers and semi-trailers sector sticks out. In particular, with 70%, R&D intensities of foreign affiliates are five times higher than R&D intensities of Japanese firms (14%). On the contrary, R&D intensities of domestic firms far exceed R&D intensities of foreign affiliates in the French and US motor vehicles, trailers and semi-trailers sectors. Specifically, R&D intensities of French firms (44%) are almost four times higher than R&D intensities of foreign affiliates (13%) in the medical, precision and optical instruments sector. Similar disparities emerge in the US motor vehicles, trailers and semi-trailers sector as R&D intensities of US firms amount to 20% while R&D intensities of their foreign counterparts amount to 10% only.

Finally, the other transport equipment sector and the furniture and other manufacturing sector are shown in Figure 43. It emphasises that in the other transport equipment sector, R&D intensities of both foreign and domestic firms reach up to 25% and 30%, respectively. Moreover, among countries considered, R&D intensities of foreign firms far exceed R&D intensities of domestic firms in the Spanish other transport equipment sector only. In particular, with 24%, R&D intensities of foreign affiliates are four times higher than R&D intensities of Spanish firms (6%). On the contrary, R&D intensities of foreign affiliates fall far short of R&D intensities of domestic firms in the French, Swedish and Czech other transport equipment sectors. In particular, as the most extreme case, with 32% (compared to only 3%), R&D intensities of French firms in the other transport equipment sector are almost 11 times higher than R&D intensities of foreign affiliates. Similarly, R&D intensities of Czech firms are 10 times higher than R&D intensities of foreign affiliates: 21% compared to only 2%. Finally, in the Swedish other transport equipment sector R&D intensities of Swedish firms reach 26%, which is more than three times higher than R&D intensities of foreign affiliates (8%).

Figure 43: R&D intensities in the other transport equipment and the furniture and other manufacturing sectors (2004-2007)



Notes: (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

Finally, the furniture and other manufacturing sector is not very R&D intensive: R&D intensities of both foreign and domestic firms only amount to 5% and 7% at most, respectively. Remarkable disparities between R&D intensities of domestic and foreign firms emerge in a number of countries. On the one hand, R&D intensities of foreign firms exceed R&D intensities of domestic firms in the Italian and British furniture and other manufacturing sectors. Specifically, with 4%, R&D intensities of foreign firms are 13 times higher than R&D intensities of Italian firms (0.3% only). And with 4%, R&D intensities of foreign firms are almost seven times higher than R&D intensities of British firms. On the other hand, a small cluster of countries emerges that is characterised by significantly higher R&D intensities of domestic firms relative to R&D intensities of foreign affiliates. In particular, in the Japanese furniture and other manufacturing sector, with 6%, R&D intensities of Japanese firms are ten times higher than those of foreign affiliates (0.6%). Moreover, in the Swedish furniture and other manufacturing sector, R&D intensities of Swedish firms (7%) are more than 20 times higher than R&D intensities of their foreign counterparts (0.3%). Finally, R&D intensities of

Irish firms in the furniture and other manufacturing sector amount to around 7% while those of their foreign counterparts reaches 0.02% only.

A similar analysis can also be conducted from a different perspective. Instead of analysing each sector separately and discussing the emerging dispersion of individual countries for each sector, each country can be analysed separately, providing the dispersion of sectors for each country. As such, the country perspective allows a comparison across sectors per country which helps identify sectoral outliers for each country. The respective graphs for countries for which data are available are provided in Appendix 3 Drivers of R&D Internationalisation (Quantitative)(Figure 71 to Figure 80). However, to conserve space and to avoid a repetition of results, the graphical representation is not accompanied by a thorough discussion; instead the graphs are left to speak for themselves.

3.1.3. Summary

An overview and condensed picture of the general findings of above graphical analyses are provided in Table 5 and Table 6 below. In particular, Table 5 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, research 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 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. This missing-data problem is particularly true for medium-high-tech and high-tech sectors, which, by definition, are highly R&D intensive and whose research is expected to be more internationalised than production. In particular, with more than 50% of all country points missing, the missing-data problem is most severe in the coke, refined petroleum and nuclear fuel sector (Figure 26), followed by the chemicals and chemical products sector (less pharma) (Figure 27), the pharmaceuticals sector (Figure 28). In addition, the office, accounting and computing machinery sector (Figure 30) and the radio, TV and communications sector (Figure 31), the medical precision and optical instruments sector (Figure 32) as well as the other transport equipment sector (Figure 33) suffer from similar data problems as around 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 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 if all data were available.

Table 5: Summary of emerging patterns - shares of inward business R&D and value added of foreign affiliates (2004-2007)

Sectors	Tech-intensity	No. of observations	General pattern: **Higher internationalisation in:**	Outliers above 45° line	Outliers below 45° line	Missing observations for:
Total manufacturing		15	R&D	SVK, AUT, PRT	IRL	
Food, beverages and tobacco	LT	14	R&D	SVK, PRT	IRL	AUT
Textiles, fur and leather	LT	11	similar	ITA, GBR	IRL	PRT, JPN, SVK, FIN
Wood, paper etc.	LT	12	production	AUT	IRL, HUN, CZE	PRT, JPN, SVK
Coke, refined petroleum etc.	MLT	6	data issues	ITA, GBR	SWE, FRA	PRT, SVK, IRL, CZE, AUT, HUN, ESP, NOR, USA
Chemicals & chemical products		13	R&D	SVK, GBR, AUT, ESP	FRA, FIN	NOR, PRT
Chemicals and chemical products (less pharma)	MHT	8	similar		FRA, IRL	NOR, ITA, PRT, HUN, AUT, CZE, SVK
Pharmaceuticals	HT	8	production		FRA, FIN	NOR, ITA, PRT, HUN, AUT, CZE, SVK
Rubber and plastic products	MLT	14	production	SVK	HUN, FRA, SWE	PRT
Non-metallic mineral products	MLT	15	production	PRT, SVK, FIN	CZE, HUN	
Basic and fabricated metals	MLT	14	R&D	PRT, GBR, FRA, IRL		AUT
Machinery and equipment	MHT	15	similar		NOR	
Office, accounting and computing machinery	HT	9	production	ITA	HUN, IRL, JPN	AUT, FIN, PRT, ESP, NOR, SVK
Electrical machinery and apparatus	MHT	12	production		IRL, SWE	AUT, FIN, ITA
Radio, TV and communications	HT	10	similar	NOR		IRL, AUT, ITA, FIN, USA
Medical, precision and optical instruments	HT	10	production	CZE	USA	IRL, AUT, ITA, FIN, PRT
Motor vehicles, trailers and semi-trailers	MHT	12	similar	None		IRL, AUT, SVK
Other transport equipment	MHT	10	production	ESP	SVK, CZE, FRA, SWE	IRL, AUT, PRT, ITA, FIN
Furniture, other manufacturing	LT	13	similar	ITA, GBR	IRL, HUN, SWE	SVK, USA

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.

Moreover, Table 6 stresses that, **for the sample of countries considered, the majority of manufacturing sectors is characterised by similar R&D intensities of both foreign and domestic firms.** However, in some sectors R&D intensities are higher for foreign firms like the textiles, fur and leather sector, the wood, paper, printing and publishing sector, the basic fabricated metals sector and the machinery and equipment sector. In contrast, domestic firms' R&D intensities are higher in the pharmaceuticals sector, the rubber and plastic products sector, the non-metallic mineral products sector, the electrical machinery and apparatus sector, the medical, precision and optical instruments sector and the other transport equipment sector.

Again, in the face of prevailing missing-data issues, emerging patterns must be interpreted with some care. In particular, in some of the medium-high tech and high-tech sectors considered (the coke, refined petroleum and nuclear fuel sector (Figure 36), the chemicals and chemical products sector (Figure 37), the pharmaceutical sector (Figure 38), the office, accounting and computing machinery sector (Figure 40), the radio, TV and communications sector (Figure 41), the medical precision and optical instruments sector (Figure 42) and the other transport equipment sector (Figure 43), between 30% to 50% of all country points are missing, potentially providing a biased picture of the relative scale of R&D intensities of both domestic and foreign firms.

Moreover, above graphical analyses also offer two important and relevant lessons for the econometric analyses of drivers of R&D internationalisation (see section 3.2). Both the graphical analyses of the shares of R&D and value added of foreign affiliates pursued in section 3.1.1 (Figure 24 to Figure 33) and of R&D intensities of both foreign affiliates and domestic firms pursued in section 3.1.2 (Figure 34 to Figure 43) reveal two basic commonalities: 1) except for a few outliers per industry, countries locate close to or along the 45 degree line, and 2), in none of the sectors considered are all countries located either above or below the 45 degree line.

The former finding highlights that R&D shares and value added shares of foreign affiliates on the one hand and R&D intensities of both domestic and foreign firms on the other are positively related. Hence, across sectors, R&D and production exhibit similar degrees of internationalisation. Furthermore, high R&D intensities of domestic firms are (closely) matched by high R&D intensities of foreign firms. Or, put differently: *The scale of R&D intensities of domestic firms is an important driver of R&D expenditure of foreign firms.* This latter observation is substantiated by results of econometric analyses (which control for additional crucial characteristics) conducted in section 6.2 which point at robust complementarities between R&D intensities of domestic and foreign firms.[6]

Moreover, the latter finding emphasises that, for the sample of countries considered, none of the sectors is un-ambiguously more internationalised either in terms of R&D or in terms of production and in none of the sectors are R&D intensities of foreign affiliates consistently higher or lower than R&D intensities of domestic firms. Hence, there is evidence of non-negligible within-sector cross-country heterogeneity.

Apart from these two apparent lessons, no additional lessons can be learned from the extensive descriptive analysis as the nature of R&D attraction is very complex and multi-facetted, driven and determined by numerous different factors. Hence, to identify the various effects or determinants of inward R&D expenditure as well as their relative importance, a

[6] But the underlying causality remains an open issue since the analysis' short time horizon did not allow for a test on causality.

more systematic econometric approach is necessary which will be pursued in sections 3.2 and 6 below.

Table 6: 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	JPN		
Food, beverages and tobacco	LT	14	similar	FRA	NOR, JPN	AUT
Textiles, fur and leather	LT	11	foreign firms	ITA, AUT, ESP	SWE	PRT, JPN, SVK, FIN
Wood, paper etc.	LT	13	foreign firms	AUT		PRT, JPN
Coke, refined petroleum etc.	MLT	5	similar	JPN		PRT, SVK, FIN, IRL, CZE, AUT, HUN, ESP, NOR, USA
Chemicals & chemical products		13	similar		FRA, SWE, FIN	NOR, PRT
Chemicals and chemical products (less pharma)	MHT	8	similar	SWE	JPN, FRA	NOR, ITA, PRT, HUN, AUT, CZE, SVK
Pharmaceuticals	HT	8	domestic firms	GBR	FIN, FRA, SWE	NOR, ITA, PRT, HUN, AUT, CZE, SVK
Rubber and plastic products	MLT	14	domestic firms		FIN, FRA, SWE	PRT
Non-metallic mineral products	MLT	15	domestic firms	FIN, ESP	CZE, JPN	
Basic and fabricated metals	MLT	14	foreign firms	FRA, IRL	SWE	AUT
Machinery and equipment	MHT	15	foreign firms		NOR	
Office, accounting and computing machinery	HT	9	similar	DATA ISSUES		AUT, FIN, PRT, ESP, NOR, SVK
Electrical machinery and apparatus	MHT	12	domestic firms		SWE	AUT, FIN, ITA
Radio, TV and communications	HT	10	similar	NOR	FRA, SWE	IRL, AUT, ITA, FIN, USA
Medical, precision and optical instruments	HT	10	domestic firms	CZE	JPN, USA	IRL, AUT, ITA, FIN, PRT
Motor vehicles, trailers and semi-trailers	MHT	12	similar	JPN	FRA	IRL, AUT, SVK
Other transport equipment	MHT	10	domestic firms	ESP	CZE, FRA, SWE	IRL, AUT, PRT, ITA, FIN
Furniture, other manufacturing	LT	14	similar	ITA, GBR	IRL, JPN, SWE	USA

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.

3.1.4. *Inward and outward BERD in Japan and the US*

Above graphical analysis exclusively relied on *inward* business R&D expenditure as proxy for the internationalisation or globalisation of R&D activities. However, this unilateral perspective totally neglects the opposite flow of resources intended to fund R&D activities of foreign affiliates. In particular, countries not only host foreign affiliates but are also home to domestic firms with foreign affiliates abroad intended to exploit foreign market potentials, to harness foreign talent and human capital and to capitalise on foreign research and technological capabilities.

However, data availability on *outward* business R&D expenditure is rather limited. Only Japan and the USA provide a detailed 2-digit sectoral breakdown of both *inward* and *outward* business R&D expenditure. Hence, in what follows, a comparison of inward and outward R&D shares (defined as the share of inward (outward) business R&D expenditure in total business R&D expenditure) is drawn for both Japan and the US which is specified as follows:

$$\frac{R\&D_{inward}}{R\&D_{total}} \overset{45°}{=} \frac{R\&D_{outward}}{R\&D_{total}}. \qquad (5)$$

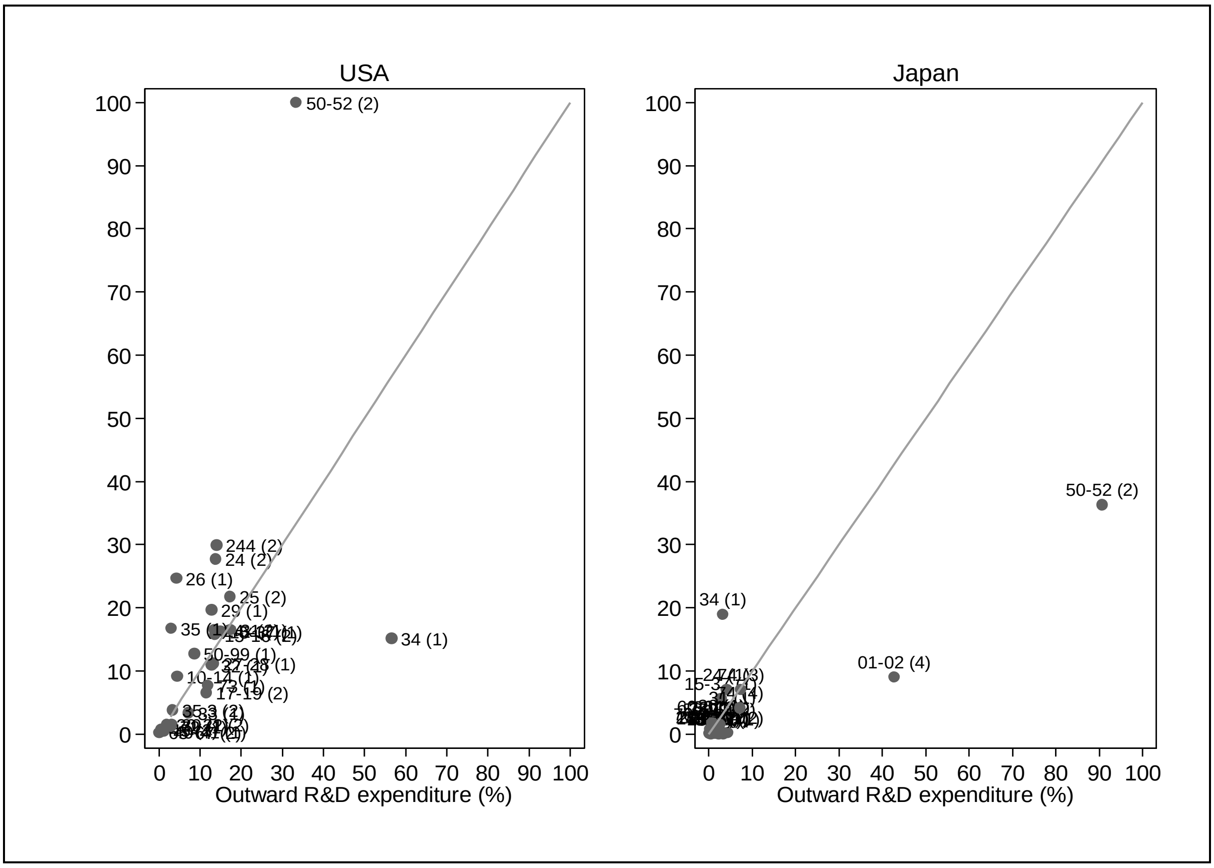
This approach is intended to identify sectors that are either predominantly *inward oriented (=net recipients of R&D expenditure)*, such that sectors are characterised by comparatively higher R&D inflows than outflows, or *outward oriented (=net senders of R&D expenditure)*, such that sectors are characterised by comparatively higher R&D outflows than inflows. Graphically, if inward and outward R&D shares coincide, sectors align along a 45 degree line. However, if inward R&D shares exceed outward R&D shares, sectors locate to the north-west of the 45 degree line. And if outward R&D shares exceed inward R&D shares, sectors locate to the south-east of the 45 degree line.

Again, a backward-looking approach is taken (ranging from 2007 to 2004) to provide the most complete and comprehensive picture on the sectoral orientation or classification in terms of net recipient or net sender of business R&D expenditure or flows.

Figure 44 provides a comparison of inward and outward R&D shares for both the USA and Japan at the sectoral level.[7] It demonstrates for the USA that the majority of sectors cluster around the 45 degree line in the range of 0% to 30%, both in terms of inward and outward R&D shares. However, two outliers emerge: on the one hand, the wholesale, retail trade and motor vehicle repair sector (50-52) is an obvious net recipient of business R&D expenditure. In particular, in 2006, foreign affiliates which operated in the US wholesale, retail trade and motor vehicle repair sector spent more on R&D than foreign affiliates of US firms spent on R&D activities undertaken abroad: foreign affiliates in the USA spent 4.8 billion euro on R&D, US foreign affiliates located abroad only spent 917 million euro on R&D abroad. On the other hand, the US motor vehicles, trailers and semi-trailers sector (34) is a net sender of business R&D expenditure. Specifically, in 2007, US foreign affiliates spent 6.6 billion euro on R&D abroad while foreign affiliates located in the US only allotted around 1.8 billion euro to R&D activities in the US.

[7] A list of sectors can be found in Table 40 in the Appendix 3 Drivers of R&D Internationalisation (Quantitative).

Figure 44: A comparison of inward and outward business R&D expenditure for the USA and Japan (2004-2007)



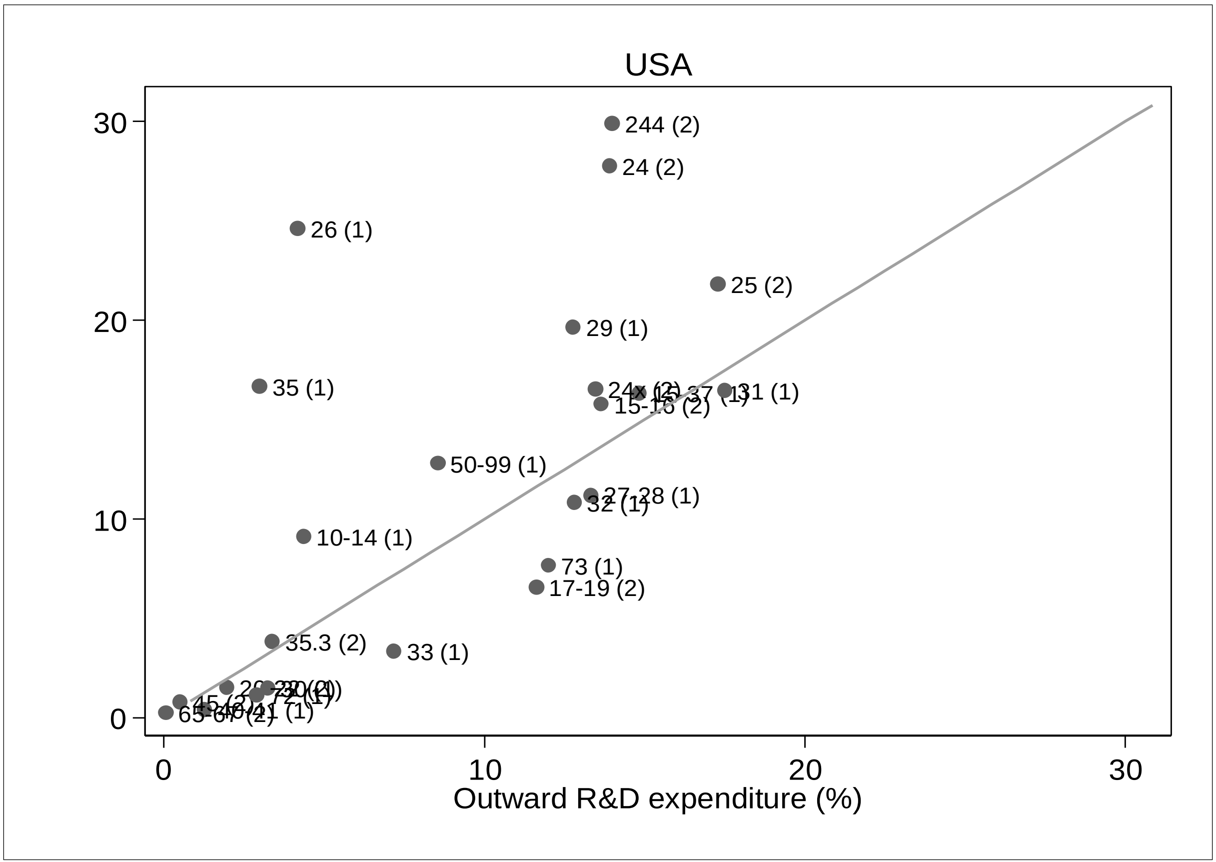
Notes: for the USA: the share of inward R&D for 50-52 was rescaled to 100; (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

Source: OECD AFA, own calculations

In Japan, the cluster of sectors is even more concentrated, in the range of 0% to 10%, both in terms of inward and outward R&D shares. However, three outliers appear. On the one hand, the Japanese motor vehicles, trailers and semi-trailers sector (34) is a net recipient of business R&D expenditure. In 2007, foreign affiliates which operated in the Japanese motor vehicles, trailers and semi-trailers sector spent 2.8 billion EUR on R&D while Japanese foreign affiliates abroad only spent 485 million EUR on R&D in foreign motor vehicles, trailers and semi-trailers sectors. On the other hand, both the Japanese agriculture, hunting and forestry sector (01-02) and the Japanese wholesale, retail trade and motor vehicle repair sector (50-52) are net senders of business R&D expenditure. In 2004, Japanese foreign affiliates abroad spent 16 million EUR on R&D abroad while foreign affiliates located in Japan only used around 3 million EUR on R&D activities in the Japanese agriculture, hunting and forestry sector. Moreover, in 2006, Japanese foreign affiliates abroad spent 149 million EUR on R&D abroad while foreign affiliates located in Japan only used around 60 million EUR on R&D activities in the Japanese wholesale, retail trade and motor vehicle repair sector.

Furthermore, to provide a better and more comprehensive sectoral picture for the USA and Japan, Figure 45 and Figure 46 zoom in on the respective country clusters mentioned above. The cluster of US sectors in the range of between 0% and 30% is depicted in Figure 45. It highlights that in addition to the wholesale, retail trade and motor vehicle repair sector (50-52) (see Figure 44 above), the non-metallic mineral products sector (26), the other transport equipment sector (35), the chemicals and chemical products sector (including pharmaceuticals) (24) and the pharmaceuticals sector (244) are obvious net recipients of business R&D expenditure. In particular, in 2007, US foreign affiliates in the non-metallic mineral products sector (26) spent only 34 million EUR on R&D abroad while foreign affiliates which operated in the US non-metallic mineral products sector spent 202 million EUR on R&D. Moreover, in 2007, US foreign affiliates in the other transport equipment sector (35) spent 435 million EUR on R&D abroad while foreign affiliated which operated in the US other transport equipment sector spent around 2.5 billion EUR on R&D. In 2006, US foreign affiliates in the chemicals and chemical products sector (including pharmaceuticals) (24) allotted 5 billion EUR to R&D while foreign affiliated which operated in the US chemicals and chemical products sector spent around 10 billion EUR on research activities. Finally, in 2006, the pharmaceuticals sector (244) was also a net recipient of business R&D expenditure since US foreign affiliates only spent 4 billion euro on R&D abroad while foreign affiliates located in the US pharmaceuticals sector used around 9 billion EUR on R&D activities.

Figure 45: A comparison of inward and outward business R&D expenditure for the USA (2004-2007) - excluding outliers



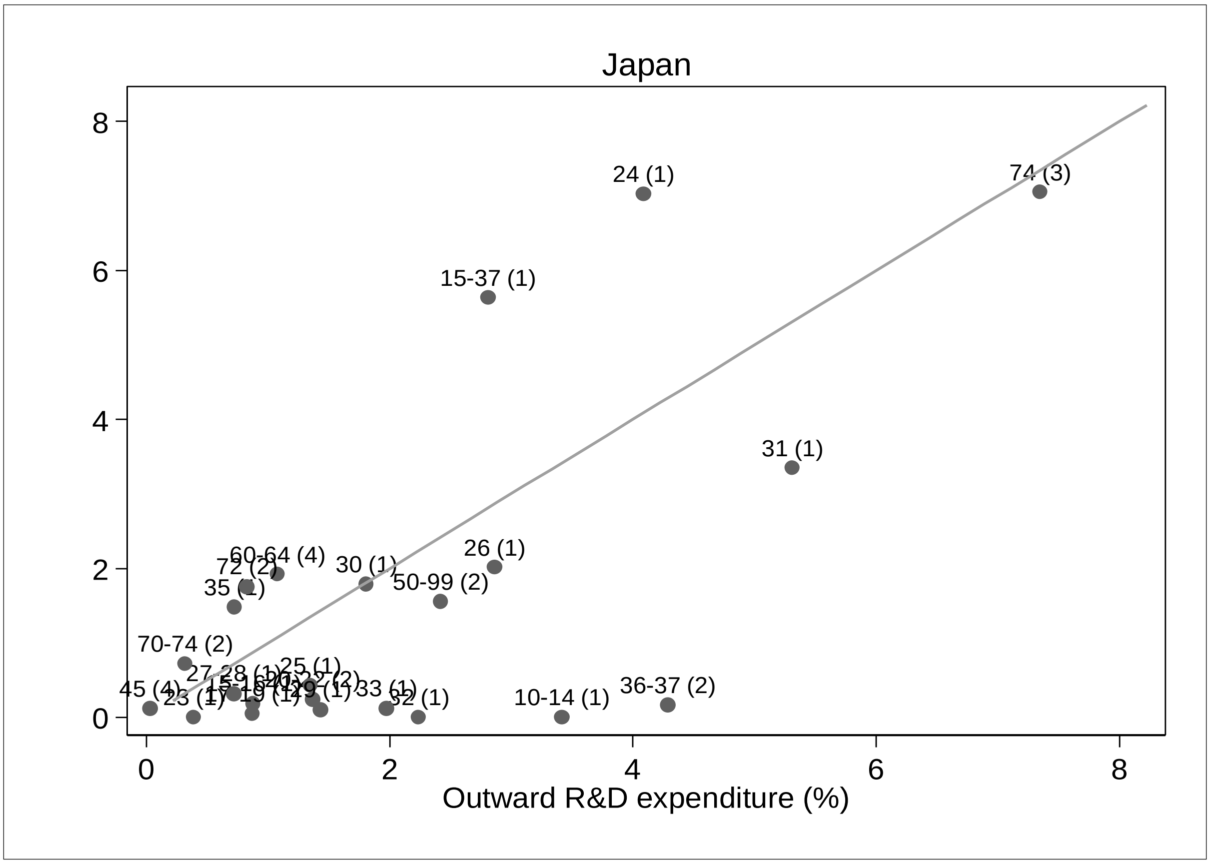
Note: (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

Source: OECD AFA, own calculations

A comparison across US sectors also reveals that in 2006, R&D activities were least internationalised in both the financial intermediation sector (including insurance) (65-67) and the construction sector (45) which both had the lowest inward and outward R&D shares. Specifically, with an inward R&D share of only 0.3% and an outward R&D share of only around 0.1%, research in the financial intermediation sector (including insurance) (65-67) was least internationalised. This was followed by the construction sector (45) whose inward R&D share was only 0.8% while its outward R&D share reached 0.5% only.

Finally, Figure 46 shows the cluster of Japanese sectors in the range of between 0% and 10% only. It stresses that in addition to the motor vehicles, trailers and semi-trailers sector (34) (see Figure 44), the chemicals and chemical products sector (including pharmaceuticals) (24) was also a net recipient of inward business R&D expenditure. Specifically, in 2007, Japanese foreign affiliates in the chemicals and chemical products sector spent only 527 million EUR on R&D while foreign affiliates in the Japanese chemicals and chemical products sector allotted 906 million EUR to research activities.

Figure 46: A comparison of inward and outward business R&D expenditure for Japan (2004-2007) - excluding outliers



Note: (1) refers to the year 2007, (2) to 2006, (3) to 2005 and (4) to 2004

Source: OECD AFA, own calculations

A comparison across Japanese sectors also demonstrates that R&D activities were least internationalised in the construction sector (45). In particular, in 2004 the sector's inward R&D share only amounted to 0.1% while its outward R&D share only reached 0.03%. Furthermore, Figure 46 also points at a series of Japanese sectors with zero or close to zero inward R&D shares but non-negligible outward R&D shares. Specifically, the following sectors did not receive any inward R&D expenditure: the mining and quarrying sector (10-14), the coke, refined petroleum products and nuclear fuel sector (23) and the radio, TV and communications sector (32). Additionally, the mining and quarrying sector (10-14) and the radio, TV and communications sector (32) also reported non-negligible outward R&D expenditure, rendering these sectors net senders of R&D expenditure. In particular, Japanese foreign affiliates in the mining and quarrying sector (10-14) allotted some 5 million EUR to R&D activities abroad while foreign affiliates in the radio, TV and communications sector (32) spent around 350 million EUR on research abroad.

In contrast, inward R&D shares lay below 1% in the food, beverages and tobacco sector (15-16), the textiles, fur and leather sector (17-19), the wood, paper, printing, publishing sector (20-22), the rubber and plastic products sector (25), the basic and fabricated metals sector (27-28), the machinery and equipment sector (29), the medical, precision and optical instruments sector (33), the furniture, other manufacturing sector (36-37) and the real estate, renting and business activities sector (70-74). In this regard, the furniture and other manufacturing sector (36-37) is of particular interest since in 2006, despite low inward R&D shares, the sector was characterised by comparatively high outward R&D shares. Specifically, the sector's outward R&D share was four times higher than its inward R&D share, rendering the furniture and other manufacturing sector (36-37) a net sender of R&D expenditure.

3.2. Econometric analyses of business R&D expenditure of foreign affiliates

The motives of firms to internationalise their research can be grouped into two main categories, namely *asset exploiting* strategies on the one hand and *asset seeking* strategies on the other. In particular, asset exploiting R&D strategies are determined and driven by the need to adapt products and production processes to consumer preferences, regulations or environmental conditions of foreign markets, which is often easier in proximity to potential clients (see e.g. Dunning and Narula 1995). In contrast, asset seeking R&D strategies are motivated by the existence of superior knowledge and more favourable framework conditions for R&D in the host country (Breschi and Lissoni 2001). Such superior knowledge may be found at universities or research institutes, in clusters or may be available from clients, suppliers or competitors.

In what follows, econometric analyses are conducted to shed light on potential drivers of business R&D expenditure of foreign affiliates. However, severe data limitations for non-European firms in the ERA do not allow for separate multivariate analyses for European and non-European countries. Instead, all ensuing analyses in this section use the overall sample (comprising both European and non-European countries) and, whenever possible and appropriate, form sub-groups comprising EU countries only, EU-15 countries only or EU-12 countries only. And while section 3.2.1 identifies characteristics of host countries only that attract R&D expenditure of foreign affiliates into host countries, section 3.2.2 takes a broader approach and determines both host and home country characteristics which are conducive or obstructive to R&D expenditure of foreign affiliates.

3.2.1. Host country determinants of R&D internationalisation

To identify potential drivers of inward business R&D expenditure at both country and industry levels the following econometric specification is estimated:

$$\ln RD\mathrm{inflow}_{ikt} = a_0 + \beta_z X_{zikt} + \varepsilon_{it} , \tag{6}$$

where $\ln RD\mathrm{inflow}_{ikt}$ is the log of inward business R&D expenditure for sector i in country k at time t and X_{zikt} is a matrix of z explanatory variables. In consideration of prevailing collinearities across explanatory variables (see correlation matrices in the Appendix 3 Drivers of R&D Internationalisation (Quantitative): Table 44 to Table 47), X_{zikt} comprises the following variables at both the country as well as sectoral level: Country-specific variables cover the log of total real national GDP (RGDP) to capture the size of the host economy, or equivalently, the host market. Specifically, firms may have to adapt their products and production processes to suit local demand patterns, consumer preferences or to comply with legal regulations and laws. Hence, firms 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. Hence, larger markets are expected to attract inward business R&D intended to expand and exploit prevailing sales potentials.

Moreover, empirical studies have pointed at the pivotal role a skilled labour force has in successfully conducting R&D and in generating product innovations and productivity-enhancing process innovations. Therefore, cross-country differences in the quality and size of a skilled workforce become an important determinant of across the border R&D flows: the shortage of high 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 attract inward R&D expenditure. This link between the quality and size of a skilled workforce and the inflow of R&D expenditure 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 (GRAD_T) as a proxy for a host country's scientific and engineering capabilities.

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 or research institutes determine locational advantages and influence internationalisation decisions of firms in R&D (Steinmueller 2010). As such, the share of government budget appropriations or outlays for R&D (GBAORD) in real GDP (covering all government outlays for R&D, for firms as well as for universities) is included to capture the role STI policies play in driving inward R&D expenditure (GBAORD_GDP).

However, the extent of inward business R&D expenditure is also shaped and determined by the very specific characteristics of sectors in host countries which render them more or less attractive for inward R&D expenditure. For example, some sectors are more productive and/or less labour-cost intensive than others, giving rise to low unit labour costs and cheaper R&D and production activities, the production processes of some sectors are more R&D intensive than that of others, requiring on average higher R&D expenditure, while some sectors are larger than others, to name a few differences. Therefore, 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 (LCVA). 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.

Moreover, the extent of inward R&D expenditure crucially depends on a sector's attractiveness to foreign investors in terms of foreign direct investments (FDI). Basically, the relationship between R&D expenditure and FDI has been subject to heated scientific debate. One school of thought focuses on the effect R&D has on FDI (see e.g. Dunning 1988 and 1998) while the other school of thought takes the reverse approach and discusses and analyses the effect FDI has on R&D (see e.g. Teece 1992 or Lall 1996). Generally, while both schools of thoughts differ as to the exact causality between R&D and FDI, both find conclusive evidence that R&D and FDI are related significantly. 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 has 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 partly 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 affiliates. This hypothesis is also supported by findings of the graphical analysis conducted in section 3.1 which highlights that, on average, business R&D expenditure of foreign affiliates (in terms of the share of R&D expenditure of foreign affiliates in value added of foreign affiliates) are positively related to business R&D expenditure of domestic firms (in terms of the share of R&D expenditure of domestic firms in value added generated by domestic firms).

In a similar vein, above graphical analysis of R&D and value added shares of foreign affiliates (see section 3.1.1) demonstrates that aside from a few outliers per sector, a positive relationship exists between inward R&D expenditures (in terms of the share of business R&D expenditures of foreign affiliates in total business R&D expenditures) and value added shares of foreign affiliates (as the share of value added of foreign affiliates in total sectoral value added). Hence, sectoral value added shares are included which capture above findings that, on average, production and R&D are characterised by similar degrees of internationalisation.[8]

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 affiliates. Hence, inward business R&D expenditure is expected to be higher in larger sectors.

And to also account for differences in the ability to attract inward business R&D across EU-15 and EU-12 member countries, dummy variables are included for both groups (with non-EU member countries as reference).

Finally, ε_{it} represents 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 this 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 from the *OECD Structural Analysis Database* (OECD STAN), available from 1970 up to 2009, while information on government budget appropriations or outlays for R&D stem from the *OECD Main Science and Technology Indicators*. The *OECD AFA* statistic is the source for information on value added of foreign affiliates. Finally, inward stocks on foreign direct investments (FDI) are taken from the *OECD International Direct Investment Statistics* (OECD IDI), available for the period from 1985 to 2008.[9]

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[8] Given non-negligible multicollinearities between variables, separate analyses were conducted for either domestic R&D intensities or value added shares of foreign affiliates as control variables. Results with value added shares as alternative control variable are presented in Table 43 in Appendix 3 Drivers of R&D Internationalisation (Quantitative).

[9] Table 48 to Table 51 (see Appendix 3) present descriptive statistics of the different samples that were subject of all analyses: the overall sample, the EU sample, the EU-15 sub-sample and the EU-12 sub-sample. Table 50 and Table 51 highlight that by comparison the majority of indicators is on average higher in the EU-15 sub-sample. In particular, the flow of inward business R&D expenditure is on average more than two times higher in the group of EU-15 countries than in the group of EU-12 countries, the log of real GDP and the share of tertiary graduates are only slightly higher in the group of EU-15 countries while labour cost over value added in the EU-15 far exceeds labour costs over value added in the EU-12. And sectoral R&D intensities in the EU-15 sub-sample are on average two times higher than sectoral R&D intensities in the EU-12 sub-sample. Finally, only the share of GBOARD in real GDP as well as sectoral FDI intensities and size are slightly higher in the sub-sample of EU-12 countries.

Generally, given data quality and availability, the ensuing econometric analysis focuses on the short unbalanced panel from 2004 to 2007 and analyses the overall sample (comprising a set of OECD and non-OECD countries)[10] on the one hand and three sub-samples on the other. The three sub-samples consist of 22 EU member countries, 13 EU-15 member countries (Austria (AUT), Belgium (BEL), Denmark (DNK), Finland (FIN), France (FRA), Germany (GER), Ireland (IRL), Italy (ITA), the Netherlands (NLD), Portugal (PRT), Spain (ESP), Sweden (SWE) and the UK (GBR)) and 9 EU-12 member countries (Bulgaria (BUL), the Czech Republic (CZE), Estonia (EST), Hungary (HUN), Latvia (LVA), Poland (POL), Romania (ROM), Slovakia (SVK) and Slovenia (SVN)) to identify differences in drivers across sub-groups. And due to scarce or altogether lacking data for the service sector, the analysis focuses on the manufacturing sector only.

Methodologically, to account for unobserved country-sector heterogeneity, both random and fixed effects models were estimated. However, the Hausman test rejected any systematic difference between the random and the fixed effects estimation coefficients. Furthermore, the Breusch-Pagan Lagrange multiplier test rejected the presence of any random effects so that a pooled OLS approach was chosen, both without and with time fixed effects. But, since the null hypothesis that the time dummies are not jointly significant is not rejected, a simple pooled OLS approach without time fixed effects was pursued eventually to throw light on potential drivers of inward business R&D expenditure.

Generally, results (presented in Table 7) highlight that the set of relevant drivers differs strongly between the group of EU-15 countries and the group of EU-12 countries. Specifically, with the exception of the EU-12 country sample, larger host markets that also promise larger revenues to investing firms give rise to higher business R&D expenditure of foreign affiliates. In particular, a 1% increase in the host country’s real GDP is found to increase inward business R&D expenditure of foreign 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 business R&D expenditure of foreign affiliates, but for the group of EU-12 countries only (column (4)). Hence, for the group of EU-12 countries, there is sound evidence of strong complementarities between skills and inward R&D expenditure such 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 real GDP, is relevant only for the overall sample and the EU-12 sub-sample. Hence, in contrast to EU-15 countries, STI policies matter for EU-12 countries and drive the extent of inward R&D expenditure.

Furthermore, some sectoral characteristics of host countries are of importance. Specifically, labour costs as percentage of value added which capture the relative cost and productivity of labour exert a significant positive effect on inward R&D expenditure in the group of EU-15

[10] The overall sample comprises the following 27 countries: Austria (AUT), Belgium (BEL), Bulgaria (BUL), Canada (CAN), the Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (GER), Hungary (HUN), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Latvia (LVA), the Netherlands (NLD), Norway (NOR), Poland (POL), Portugal (PRT), Romania (ROM), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), the UK (GBR) and the US (USA).

countries (column (3)) but a significant negative effect on inward R&D expenditure in the group of EU-12 countries (column (4)). Hence, high labour costs (relative to value added) which render both production and R&D activities more expensive are associated with higher R&D expenditure of foreign affiliates located in EU-15 countries but with lower R&D expenditure of foreign affiliates located in EU-12 countries. The emerging pattern 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.

Table 7: Results for host country determinants of R&D internationalisation (2004-2007)

Dep.Var.: log inward R&D expenditure	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

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.

Above results also consistently demonstrate that inward FDI and inward R&D expenditure are strategic complements. In particular, the higher sectoral inward FDI intensities in a host country, the higher are sectoral business R&D expenditure of foreign affiliates. This general finding is independent of sample analysed. However, by comparison, the effect is considerably stronger in the EU-12 sub-sample (column (4)) than in the EU-15 sub-sample (column (3)).

Furthermore, a sector's domestic R&D intensity plays a pivotal role in determining the extent of business R&D expenditure of foreign affiliates. Specifically, host country sectors that are inherently more R&D intensive (either due to more R&D intensive production processes or to a more pressing need for adaptive innovative processes) are also found to experience significantly higher inward business R&D expenditure. Interestingly, however, the effect of sectoral domestic R&D intensity is not uniform across samples analysed. In particular, sectoral domestic R&D intensities matter for all samples except the EU-12 sample, for which sectoral domestic R&D intensities are irrelevant for the extent of inward business R&D expenditure of foreign affiliates.

Related to that, Table 43 presents results with value added shares of foreign affiliates as alternative control variable. It highlights that irrespective of sample used a positive and significant relationship exists between business R&D expenditure of foreign affiliates and value added shares of foreign affiliates. Hence, sectors with higher value added shares of foreign affiliates (i.e. sectors that are characterised by higher degrees of internationalisation of production) also attract significantly higher inward R&D expenditure.

In addition, sector size is an important driver of business R&D expenditure of foreign 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 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 no significant difference emerges between EU-15 and EU-12 countries as to the extent of inward business R&D expenditure.

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

However, in shedding light on potential drivers of business R&D expenditure, the analysis discussed above only accounts for country-level or sector-level characteristics of host countries as potential drivers of inward business R&D expenditure. This unilateral approach therefore totally neglects the potentially pivotal role played by country-level or sector-level characteristics of the country of origin. This is a serious shortcoming as the distribution of inward R&D expenditure is shaped by both host and home country characteristics. Hence, a natural next step is to extend the analysis towards a bilateral approach and to account for both host and home country characteristics to identify drivers of inward business R&D expenditure.

For that purpose, a gravity model approach is pursued which helps identify both home and host country characteristics that are conducive or obstructive to inward R&D flows. In the empirical literature, gravity models are popular and well known 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, Melitz and Rubinstein 2008 for some empirical results). In essence, the gravity equation for trade says that trade flows between two countries are proportional to the two country's size (as proxied by GDP) but inversely related to the distance between them. Moreover, models also often account for physical or cultural proximity in terms of shared border, common language or colonial history, respectively. However, 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 flows is still scarce, a shortcoming the ensuing analysis seeks to remedy.[11]

Specifically, following the gravity-model tradition, the following econometric specifications are estimated to shed light on potential home and host country drivers of business R&D expenditure:

$$\ln RD_{ijt} = \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \ldots$$
$$\ldots + \delta_z X_{zijt} + \varepsilon_{ijt} \tag{7}$$

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

$$\ln RD_{ijt} = \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \ldots$$
$$\ldots + \beta_6 \ln POP_{it} + \beta_7 \ln POP_{jt} + \delta_z X_{zijt} + \varepsilon_{ijt} . \tag{7'}$$

$\ln RD_{ijt}$ is the log of business R&D expenditure of foreign affiliates of country *j* flowing in to country *i* at time *t.*

$\ln DIST_{ij}$ is the log of the geographical distance between country *i* and *j* as the simple distance between most populated cities (in km). In the empirical literature, distance is found to be a key determinant of bilateral (trade or FDI) flows between countries, curbing cross-border flows. Traditionally, as emphasised by Tinbergen (1962), distance is interpreted as a proxy for transportation costs or an index of uncertainty and information costs firms have to shoulder when penetrating foreign markets. In the case of overseas R&D, these costs include additional 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 (Sanna-Randaccio and Veugelers 2007; Gersbach and Schmutzler 2011). Hence, with growing distance, bilateral flows are expected to diminish.

$COMLANG_{ij}$ 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 are expected to further enhance cross-border flows in addition to distance. Various authors in international management stress that foreign firms have to master additional institutional and cultural barriers. This disadvantage is known as the 'liability of foreignness' (Zaheer 1995; Eden and Miller 2004) 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.

Furthermore, $\ln GDP_{it}$ and $\ln GDP_{jt}$ refer to the log of real gross domestic product in country *i* and *j*, respectively and are proxies for the economic size of countries *i* and *j*. The empirical literature points at the essential roles played by economic size of countries in fostering cross-border flows of goods, capital or people. In particular, larger economies represent larger markets characterised by a broad range of diversified products and superior market potentials and market prospects for foreign affiliates.

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

Account is also taken of the effect a country's standard of living has on the extent of business R&D expenditure of foreign affiliates (equation (7')). As such, economies that are on average wealthier than others (as proxied by their respective real GDPs per capita) may not only have a higher purchasing power, but may also be characterised by consumers with a stronger 'love for variety'. Hence, foreign 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 variables that are expected to affect inward R&D expenditure of foreign affiliates to different degrees. Particularly, to account for the pivotal role the quality of human capital plays in research, the analysis includes gross tertiary school enrolment rates in country i and j (ENR_TER). Specifically, empirical evidence highlights that cross-country differences in the quality and size of a skilled workforce is an important determinant of cross-border R&D flows as firms are found to relocate product development to other parts of the world if faced with a shortage of skilled science and engineering talent (Lewin et al. 2009) 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 (e.g. Hedge and Hicks 2008).

Moreover, 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 (PA_SHARE). Specifically, more inventive host countries are attractive for foreign affiliates seeking to harness prevailing local technology and innovation capabilities for the development of new products or processes.

Furthermore, cross-border R&D flows may also crucially depend on differences in countries' abilities to develop and produce internationally competitive high-technology products. In particular, countries with strong indigenous R&D and technological capabilities tend to specialise in high-technology industries and to generate high-technology products (and services) that more easily withstand fierce competition on the global arena. Hence, a high share of high-technology exports in GDP is indicative of an internationally competitive indigenous R&D base foreign affiliates can harness to successfully develop new products and processes or to adapt products and processes to local conditions and preferences. Therefore, 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 (HTX_SH).

Additionally, cross-country differences in the levels of technological development may also affect R&D flows across borders. Specifically, there has been a long-standing debate in the FDI literature on the existence and extent of technological spillovers from foreign direct investments with, however, lacking consensus. Some empirical studies lend support to the catching-up hypothesis put forward by Findlay (1978) and find that technological spillovers increase with a widening of the technology distance (e.g. Castellani and Zanferi 2003 or Peri and Urban 2006). Others suggest the opposite such that only a narrow technology distance is conducive to technological spillovers (e.g. Kokko et al. 1996 or Liu et al. 2000) as closer levels of technological development across countries renders them technologically more compatible, with sufficient absorptive capacities to benefit from each other's research efforts and successes. Hence, the technology distance between country i and j is included, in terms of a correlation coefficient which, by construction, lies between [0, 1] (TDIS). And the higher the coefficient, the smaller the technological distance between two countries and the higher the countries' technological compatibility.

Furthermore, a dummy for EU-membership is included which capture whether only country *i* is a member of the EU, whether country *j* is a member of the EU only, or whether both *i* and *j* are EU member countries.[12] This will show whether inward R&D flows are higher among EU member countries or between EU and non-EU countries. Boschma (2005) refers to institutional proximity to capture that a common institutional set-up of two countries may facilitate business activities of firms abroad.

Finally, equation (7) also accounts for country heterogeneity and includes fixed effects α_i and α_j for country *i* and *j*, respectively.

The empirical analysis is based on an unbalanced sample for the period between 2001 and 2007. Data for the analysis are drawn from different sources. Data on inward R&D expenditure of multinationals by investing country for the total manufacturing sector only are data that were collected from AIT and wiiw in the course of the project.[13] Furthermore, standard gravity indicators like distance ($DIST_{ij}$), common language ($COMLANG_{ij}$), common boarder ($COMBORD_{ij}$) are all taken from the databases created from 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*).

Descriptive statistics of all variables used in the estimations are provided in Table 60 and Table 61 in the Appendix 3. On average, between 2001 and 2007, a recipient country in the sample received about 98 million EUR per year and per partner country. However, annual inward business R&D expenditure shows a broad dispersion, ranging between 0 euro and 6.5 billion EUR. More specifically, in the period from 2001 to 2007, the following countries reported the highest R&D expenditure of foreign affiliates: with on average 2.7 billion EUR per year the USA reported the highest inward R&D expenditure, followed by Germany with on average 395 million EUR, Japan with on average 346 million euro and Canada with on average 203 million EUR. Moreover, between 2001 and 2007, the USA received the highest inward R&D expenditure from Germany (with on average 4.8 billion EUR), followed by the UK (with on average 4.3 billion EUR) and Switzerland (with on average 3.4 billion EUR). Germany reported the highest inward R&D expenditure from the USA (with on average 3.4 billion EUR), the Netherlands (with on average 1.7 billion EUR) and France (with on average 1.3 billion EUR) while Japan reported the highest inward R&D expenditure from France (with on average 2.4 billion EUR), followed by the USA (with on average 493 million EUR) and the Netherlands (with on average 435 million EUR). Finally, between 2001 and 2007, Canada reported the highest inward R&D expenditure from the USA (with on average 1.4

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[12] To identify important drivers of inward business R&D expenditure a series of different control variables was tested in the analysis. However, given partly strong multicollinearities between variables, these variables had to be left out from the analysis. These variables captured the extent of FDI in country i from firms located in country j, proxies for the innovative potential in a country (share of researchers (in R&D) in the labor force or the share of technicians (in R&D) in the labor force), various proxies for the extent of bilateral technology co-operations, labour costs as share of commercial profits, and the extent to which country i and j import ready-to-use production technologies (as a substitute for developing production technologies locally).

[13] This dataset covers 34 countries, however, since not all countries report R&D expenditure of foreign affiliates by investing country, the overall sample is reduced to 26 countries only, covering Austria (AUT), Belgium (BEL), Bulgaria (BUL) Canada (CAN), the Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (GER), Greece (GRC), Hungary (HUN), Ireland (IRL), Japan (JPN), the Netherlands (NLD), Norway (NOR), Poland (POL), Portugal (PRT), Romania (ROM), Spain (ESP), the Slovak Republic (SVK), Slovenia (SVN), Sweden (SWE), Turkey (TUR), the UK (GBR) and the US (USA).

billion EUR), the UK (with on average 187 million EUR) and Japan (with on average 82 million EUR).

The analysis pursues a step-wise procedure: in a first step, a simple gravity model is estimated and analysed; in a second step, the simple gravity model is extended to include additional technology-related drivers of cross-border R&D expenditure. Hence, first, a *simple gravity model* is estimated which includes all standard gravity indicators (distance, common language, common border and GDP of countries *i* and *j)* (equation (8)) as well as the size of the population to account for standard-of-living effects (equation (8’)):

$$\ln RD_{ijt} = \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \varepsilon_{ijt} \quad (8)$$

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

$$\ln RD_{ijt} = \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \ldots$$
$$\ldots + \beta_6 \ln POP_{it} + \beta_7 \ln POP_{jt} + \varepsilon_{ijt} \quad (8')$$

Results are presented in Table 8 for different estimation techniques: i) pooled OLS (columns (1) and (4)), ii) fixed effects for receiving and sending countries (columns (2) and (5)), and iii) random effects specific for bilateral country pairs (columns (3) and (6)). 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. Moreover, columns (4) to (6) also account for the effect of population size on inward business R&D flows, which, taken together with economic size as proxied by GDP, capture the effect of average wealth (i.e. GDP per capita) on inward R&D expenditure of foreign affiliates.

Table 8 highlights that the extent of inward business R&D expenditure decreases with distance. More specifically, if the distance between countries increases by 1%, inward R&D expenditure decreases by between 0.3% and 0.7%. This confirms results from network and descriptive analyses of most important countries of origin for inward R&D expenditure delivered in previous work packages: in many countries, the most important source of inward R&D expenditure is a neighbouring country.

Moreover, cultural proximity as proxied by common language is found to be conducive to business R&D expenditure of foreign affiliates. Hence, cultural ties greatly facilitate communication and therefore ease the exchange of information and knowledge and augment the scale of R&D expenditure. This supports the ‘liability of foreignness’ hypothesis.

Additionally, physical proximity appears to foster inward R&D expenditure. Hence, foreign affiliates located in neighbouring countries spend more on R&D than affiliates located farther away.

As a proxy for an economy’s size, the log of real GDP in either host or home country is positively and significantly associated with the extent of inward R&D expenditure between countries. Specifically, a 1% increase in both the host and home country’s real GDP increases R&D expenditure of foreign affiliates by between 1% and almost 2% (depending on the econometric specification). Moreover, results appear to suggest that the pull effect from an increase in a host country's real GDP is slightly stronger than the push effect from an increase in the home country's real GDP.

Table 8: Results for host and home country determinants of R&D internationalisation– a simple gravity model (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	-16.900***	-99.419***	-16.534***	-6.405***	-19.780	-5.408***
	(25.31)	(3.07)	(15.01)	(6.08)	(0.15)	(3.34)
Log distance	-0.648***	-0.276***	-0.655***	-0.596***	-0.282***	-0.532***
	(8.88)	(3.58)	(5.24)	(8.73)	(3.66)	(4.62)
Common language	0.967***	0.150	1.345***	0.479**	0.149	0.939***
	(4.93)	(0.87)	(3.74)	(2.56)	(0.87)	(2.83)
Common boarder	0.243	1.059***	0.162	0.641***	1.062***	0.573*
	(1.25)	(6.48)	(0.47)	(3.46)	(6.50)	(1.80)
Log real GDP HOST	1.040***	1.839	1.032***	1.685***	1.800	1.728***
	(28.12)	(1.30)	(16.35)	(21.21)	(1.24)	(14.75)
Log real GDP HOME	0.797***	5.077***	0.761***	1.575***	4.022**	1.414***
	(19.89)	(3.25)	(11.33)	(16.93)	(2.35)	(10.46)
Log population HOST				-0.931***	-5.752	-1.037***
				(9.05)	(1.02)	(6.84)
Log population HOME				-0.824***	5.910	-0.721***
				(9.35)	(1.31)	(5.62)
Observations	1,280	1,280	1,280	1,280	1,280	1,280
Adj. R^2	0.523	0.771		0.584	0.771	
Number of i			391			391

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

All regressions include time fixed effects. Estimation results in columns (1) and (4) are based on pooled OLS, results in columns (2) and (5) use country fixed effects for both receiving and sending countries while results in columns (3) and (6) use random effects specific for bilateral country-pairs.

Finally, account is also taken of the role average wealth or standard of living (as the difference between log real GDP and log population of either country i or j to proxy for real GDP per capita) plays for the extent of resources foreign affiliates spend on R&D activities (columns (4) to (6)). The results demonstrate that high standards of living in both host and home countries are conducive to R&D expenditure of foreign affiliates. Specifically, a 1% increase in the host country's standard of living increases foreign affiliates' R&D expenditure by between 0.7% and 0.8% while a 1% increase in the home country's standard of living pushes up foreign affiliates' R&D expenditure by around 0.8%.

Second, an *extended gravity model* is estimated which includes all standard gravity indicators (distance, common language, common border and GDP of countries i and j (equation (9))) plus the size of the population to account for standard-of-living effects (equation (9')), plus some additional technology-related variables included in X_{zijk} (tertiary school enrolment rates, high-technology exports, patent applications of resident and non-residents, total populations in country i and j, technology distance between country i and j and dummies for EU-membership):

$$\ln RD_{ijt} = \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \ldots$$
$$\ldots + \delta_z X_{zijt} + \varepsilon_{ijt} \qquad (9)$$

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

$$\ln RD_{ijt} = \alpha_i + \alpha_j + \beta_1 \ln DIST_{ij} + \beta_2 COMLANG_{ij} + \beta_3 COMBORD_{ij} + \beta_4 \ln GDP_{it} + \beta_5 \ln GDP_{jt} + \ldots$$
$$\ldots + \beta_6 \ln POP_{it} + \beta_7 \ln POP_{jt} + \delta_z X_{zijt} + \varepsilon_{ijt}. \qquad (9')$$

Results of the extended model are presented in Table 9, again for three different estimation techniques: i) pooled OLS, ii) fixed effects for receiving and sending countries, and iii) random effects specific for bilateral country pairs. Furthermore, account is also taken of the role standards of living of both home and host countries have on the extent of R&D expenditure of foreign affiliates.

In line with above results, distance matters as the flow of R&D expenditure across countries tends to decline with distance: in particular, a 1% increase in distance reduces inward R&D expenditure by between 0.4% and 0.7%.

Moreover, in line with results from the simple gravity model discussed above, cultural and physical proximity remain important determinants of inward R&D expenditure. Hence, cultural ties which facilitate communication and the exchange of information and knowledge are conducive to inward R&D expenditure. Moreover, physical proximity matters as foreign affiliates located in neighbouring countries are found to spend significantly more on R&D than foreign affiliates located farther away.

Table 9: Results for host and home country determinants of R&D internationalisation – an extended gravity model (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	-21.394***	-99.190**	-18.166***	-9.531***	103.426	-6.698**
	(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 HOST	-0.001***	0.000	0.000	-0.001***	0.000	0.000
	(3.41)	(0.16)	(0.42)	(3.37)	(0.20)	(0.50)
Share patent applications residents HOME	-0.001***	0.000	0.000	-0.001***	0.000	0.000
	(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

All regressions include time fixed effects. Estimation results in columns (1) and (4) are based on pooled OLS, results in columns (2) and (5) use country fixed effects for both receiving and sending countries while results in columns (3) and (6) use random effects specific for bilateral country-pairs.

Again, a significant size effect emerges: depending on the exact econometric specification, inward R&D expenditure increase by around 1% to 2% in response to a 1% increase in the host or home country's real GDP. Moreover, the observed size effect is slightly higher in the host than in the home country.

Moreover, columns (4) to (6) again account for the role the standard of living plays for the extent of resources foreign affiliates spend on R&D activities. In line with above results, a high standard of living in both host and home countries boosts R&D expenditure of foreign affiliates. Specifically, a 1% increase in the host or home country’s standard of living increases resources foreign affiliates allot to research by around 0.7% and 0.8%.

Finally, a number of additional variables are included to throw light on the role played by factors considered conducive to the scale of R&D activities of foreign affiliates. The analysis highlights that human capital (as captured by the host country’s tertiary enrolment rate) is a non-negligible determinant of R&D expenditure of foreign affiliates. In particular, in line with findings by Hedge and Hicks (2008), there is consistent evidence that strong technological capabilities in the host country attract business R&D into the host country, while, as indicated by Lewin et al. (2009), a strong human capital base in the home country appears to deter R&D expenditure of foreign affiliates.

Furthermore, there is evidence that the levels of inventiveness of both home and host countries are irrelevant for the scale of R&D expenditure of foreign affiliates.

In the same vein, resources foreign affiliates spend on R&D remain unaffected by countries’ abilities to develop and produce internationally competitive high-technology products and their underlying strong indigenous R&D and technological capabilities. Hence, in devising their research strategies, foreign affiliates appear to be unaffected by prevailing potentially superior technological knowledge and capabilities in host countries.

Additionally, cross-country differences in the levels of technological development also have no significant effect on the scale of R&D flows across borders.

Finally, light is also shed on whether R&D flows of foreign affiliates are regionally concentrated within the European Union. The analysis demonstrates that R&D expenditure of foreign affiliates is significantly higher if either the home country only or the host country only is a member of the European Union.

3.3. Summary and Conclusion

While it is far from a new phenomenon, the internationalisation of business R&D activities has sped up markedly more recently: between 1995 and 2003, R&D expenditure of foreign affiliates increased twice as rapidly as their turnover or their host countries' aggregate imports (OECD 2008a) which renders R&D activities of foreign affiliates one of the most dynamic elements of the process of globalisation.

Against the backdrop of intensifying internationalisation of R&D activities, above analysis started with a graphical account of business R&D expenditure of foreign affiliates in different manufacturing sectors of a set of OECD countries. Specifically, one set of graphs shows the relative degrees of internationalisation of both production and R&D and highlights that with a few exceptions only (i.e. the food, beverages and tobacco sector, the chemicals and chemical products sector and the basic and fabricated metals sector) production appears to be more internationalised than R&D for the sample of countries considered. Moreover, another set of graphs contrasts R&D intensities of domestic firms with R&D intensities of foreign firms and highlights that the majority of manufacturing sectors is characterised by similar R&D intensities of both domestic and foreign firms which suggests that R&D intensities of both domestic and foreign firms are complements. Finally, both graphical analyses also point at non-negligible within-sector cross-country heterogeneities as none of the sectors analysed is un-ambiguously more internationalised either in terms of R&D or in terms of production and in none of the sectors are R&D activities of domestic firms consistently higher or lower than R&D intensities of foreign firms.

In addition, econometric analyses were pursued to identify important drivers of R&D internationalisation that help explain the recently emerging patterns but also provide policy guidelines as to how national R&D policies may be used actively to join the bandwagon of R&D internationalisation. For this purpose, two different econometric approaches were chosen: a) a unilateral, cross-country approach which focuses on host country characteristics only, as well as b) a bilateral analysis of R&D flows between countries which looks at both host and home country characteristics.

The unilateral, cross-country analysis analyses a short unbalanced panel of the manufacturing sector (from 2004 to 2007) and demonstrates that several host country characteristics are conducive to business R&D expenditure of foreign affiliates. However, the set of relevant characteristics varies across samples considered and differs most strikingly between the group of EU-15 and of EU-12 countries. Specifically, except for the EU-12 sample, foreign affiliates tend to spend more on research in larger host markets which promise larger revenues and better sales prospects. Moreover, the host country's endowment with human capital is key only in the sample of EU-12 countries which indicates that strong scientific and engineering capabilities tend to increase funds foreign affiliates spend on R&D activities. In the same vein, public STI policies matter, but only for the group of EU-12 countries, whose public efforts in fostering R&D are rewarded by significantly higher business R&D expenditure of foreign affiliates. Furthermore, across all samples considered, consistent non-negligible complementarities between FDI and inward R&D expenditure emerge at the sectoral level which emphasise that host country sectors with higher inward FDI intensities also host foreign affiliates that allot significantly higher resources to R&D activities. Finally, except for the EU-12 sample, sizeable complementarities surface between inward R&D expenditure on the one hand and domestic R&D intensity on the other. Hence, host country sectors that are inherently more R&D intensive also experience significantly higher business R&D expenditure of foreign affiliates. In contrast, the analysis also throws light on potential factors that are obstructive to R&D expenditure of foreign affiliates. In particular, for the group of

EU-12 countries only, sectors with high labour costs curb funds foreign affiliates spend on research, as both production and research activities are relatively more expensive and consequently less profitable and attractive. The opposite holds true for the set of EU-15 countries.

By contrast, the bilateral analysis which seeks to identify host and home country determinants of inward R&D expenditure applies a gravity model framework and uses an unbalanced panel of the manufacturing sector from 2001 to 2007. It shows that starting from a simple gravity approach, once technology related indicators are added, results remain qualitatively the same. Specifically, geographical distance between countries, traditionally seen as a proxy for transportation costs, is found to curb cross-country flows of R&D expenditure: a 1% increase in distance reduces inward R&D expenditure by between 0.4% and 0.7%. Moreover, cultural and physical proximity remain important determinants of inward R&D expenditure. Hence, both, cultural ties which facilitate communication and the exchange of information and knowledge and physical proximity which renders neighbouring countries attractive R&D hubs are conducive to inward R&D expenditure. Furthermore, a non-negligible size effect emerges: a 1% increase in both host and home countries' real GDP increases inward R&D expenditure by around 1% to 2%. Additionally, the analysis demonstrates that human capital is a non-negligible determinant of inward R&D expenditure. Specifically, a strong human capital base in the host country attracts business R&D into the host country while a strong human capital base in the home country appears to deter R&D expenditure of foreign affiliates. In contrast, none of the remaining technology related indicators has a significant effect on the resources foreign affiliates spend on R&D activities: no evidence is found that the level of inventiveness of both home and host countries, their abilities to develop and produce internationally competitive high-technology products or cross-country differences in the levels of technological development matter for the scale of inward R&D expenditure. Finally, evidence is found that inward R&D expenditure is not significantly higher if both, home and host countries are members of the EU. Instead, R&D flows are regionally dispersed and not concentrated within the European Union.

4. DRIVERS OF R&D INTERNATIONALISATION – A CASE STUDY APPROACH

In contrast to quantitative analysis, case studies aim at gaining insight from the analysis of single occurrences. The case study approach is appropriate, because internationalisation of R&D can be traced back to the activities of a handful of MNE subsidiaries in a number of countries. Hence, country-wide patterns of internationalisation – in particular in small countries – may be explained by the activities of a small number of firms.

Case studies will be employed to examine R&D internationalisation at the sectoral and/or country level in much more detail than descriptive or econometric analysis can do. They will be targeted towards very specific questions, such as 'why is R&D internationalisation so strong in this country or sector?', or 'why do we see so little foreign R&D in that country?' Case studies, therefore, can test the assumptions on drivers (and impacts) of inward and outward R&D internationalisation from a different single-occurrence perspective and therefore complement the descriptive and econometric analysis.

In particular, the case studies address the following questions:

- What factors determine the extent of R&D undertaken by foreign subsidiaries in a particular country (and/or industry) (i.e. why are some countries more attractive to foreign R&D than others)?
- What factors determine the extent of linkages between country pairs?
- Does the pattern of R&D activities undertaken by foreign-owned affiliates simply follow the pattern of FDI flows?

Cases can be located at the firm, the regional, sectoral or the national level. They can deal with one entity or compare the activities of multiple entities. One case consists of a specific sector/country combination.

In accordance with the Terms of Reference, we included 8 sector and 15 country cases, which are covered in 10 case studies. Of those, seven case studies look at drivers and R&D activities of non-European firms in the ERA and three case studies on impacts of business R&D internationalisation.

The identification of promising cases was based on the analysis of patterns of R&D internationalisation, as well as on suggestions from the project team, the correspondents, or the European Commission. A potential case qualifies for a case study if it allows studying one or several drivers/impacts of R&D internationalisation in detail. Countries or sectors with a very high or very low degree of internationalisation or very strong linkages between two countries qualify for a case. A very strong relationship between two countries, for example, may be explained by high income levels, the availability of skilled personnel, but also geographical and cultural proximity or public policy that has created favourable investment opportunities. We aim for a balanced coverage of sectors including the service sectors and small and large countries.

Data for case studies come from a number of sources; existing scientific literature, consultants, newspapers and magazines, patent data, R&D data, company reports, company register databases, policy documents, interviews with governmental agencies, policy representatives, firms, etc. Case studies can use quantitative, qualitative or a mix of quantitative and qualitative data.

4.1. Internationalisation of R&D in the pharmaceutical industry

The pharmaceutical industry is considered to be the most important of the manufacturing sectors regarding the amount of inward BERD. It is furthermore one of the most internationalized sectors in terms of R&D location, and with the highest inward R&D intensity. In 2007, the pharmaceutical industry generated 16.4 bn EUR PPS inward BERD worldwide (see section 1.5 cross-sector analysis).

To better understand the exceptional role of the pharmaceutical industry in the process of R&D internationalisation, it is essential to consider some particularities of the pharmaceutical industry and its innovation processes. In contrast to most other industries, R&D expenditure covers a major part of the overall innovation cost structure in the pharmaceutical industry (Gassmann et al. 2008, p. 2). According to Pharma Information (2002), research, development and licensing account for a relative contribution of about 20-40% of the overall costs of a newly developed drug. Additionally, absolute R&D expenditure is increasing constantly. During the last decade (1998 to 2008), R&D expenditure of US pharmaceutical companies more than doubled (Phrma 2009). At the same time, the number of new molecular entities (NMEs) introduced into U.S. markets and approved by the Food and Drug Administration (FDA) decreased to about 20 to 30 per year (Comanor and Scherer 2011). As a consequence, R&D productivity in pharmaceutical innovation decreased in recent years, i.e. there can be found a tendency of increasing drug development costs per new drug approval (Gassmann et al. 2008, p. 2).

This cost increase[14] in turn can be attributed to various factors (see inter alia Leitner et al. 2011, p. 60; Congressional Budget Office 2006, p. 22): There is an increase in the percentage of drug projects that fail in clinical trials, which comes along with a trend towards bigger and lengthier clinical trials (partly due to increased targeting of chronic conditions that require longer trials) as well as a possible rise in the number of trials. Furthermore, branded generics give rise to a mixing up research and marketing costs. Likewise, advances in research technology and scientific opportunities in addition to a growing commercialization of basic research lead to increases in R&D spending: Only about one in six drug candidates that enter clinical trials are ultimately submitted to and approved by the FDA (Phrma 2011, p. 10). Of those approved, it takes about 10 to 15 years from the initial discovery to availability for treating patients (Phrma 2011; Di Masi 2001; Di Masi et al. 2003; Dickson and Gagnon 2004). Di Masi and Grabowski (2007) estimated the total capitalized costs per approved new molecule to be 1.3 bn USD on average. However, only two of ten marketed drugs return revenue that match or exceed R&D costs (Phrma 2011; Vernon et al. 2010).

Furthermore, the pharmaceutical industry is characterized by strong regulations in all major functions (Danzon 2000), deriving from uncertainty about drug safety and efficacy (Danzon 2006). Effects of those regulations are twofold: the industry’s cost structure as well as competition changes due to regulation of safety, efficacy and quality; whereas regulation of price, reimbursement and promotion affect demand and profitability (Danzon 2000, p. 1057). Therefore, requirements to pharmaceuticals further added to the intrinsically high cost of R&D and led to launch delays of new drugs.

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[14] For an overview over the research costs in the pharmaceutical industry see for example “Analysis of the evolution of the costs of research - trends, drivers and impact”, a Study commissioned by DG Research & Innovation (Leitner et al. 2011, p. 59ff)

4.1.1. Drivers of R&D internationalization in the pharmaceutical industry

The increased costs of R&D, which derive from the particularities of the pharmaceutical innovation process and the regulations mentioned above, have led to a favour of large over small firms (Danzon 2006). On the supply side of pharmaceuticals, one should distinguish between two types of producers: originator companies and generic companies. The former concentrate on research of new pharmaceuticals, whereas the whole range of the innovation process is covered; i.e. the development from the laboratory to marketing authorisation and selling them on the market. The originator companies range from very large multinationals to SMEs concentrating on niche products. The latter ones in contrast focus on the development of products identical or equivalent to originator products, which can be sold at much lower price than the original pharmaceutical. Generic companies – at least on the European market – tend to be significantly smaller than originator companies.

The number of the pharmaceutical industry's major (and large) companies, which are active in R&D has decreased over time and the sector became increasingly concentrated (Comanor and Scherer 2011). The goal of horizontal mergers was mainly to further exploit potential economies of scale, scope and risk-pooling (Danzon 2000, p. 1083). Due to the high R&D costs, companies only perform in areas in which they excel themselves, while outsourcing the remaining products and processes to firms that can handle theses better and cheaper. Thus, outsourcing occurs mostly vertically towards smaller companies, while horizontal cooperation is much less prevalent nowadays (they were frequent in the 1980s and 1990s). However, this concentration process is still continuing. In 2009, there were two large mergers: Pfizer's acquisition of Wyeth Laboratories and Merck & Co.'s acquisition of Schering-Plough. Based on each firm's R&D spending (in 2008), "the two merged entities would account for fully 51% of total US industry R&D spending and 39% of total world-wide spending" (Comanor and Scherer 2011, p. 4).

In addition, small firms are gaining importance in research and development of new tools for enhancing R&D productivity in the wake of the so-called biotechnology revolution. New drugs increasingly originate from small, often single-product firms, which frequently are start-up biotech firms (Comanor and Scherer 2011 p. 19). Though, large pharmaceutical firms play an essential role, from which follows a mutual dependence between large and small firms. While small firms specialize in discovery, and enjoy the advantages of a rapidly advancing scientific base, large firms have the resources and expertise to do the detailed and highly expensive clinical testing and commercialization[15]. This in turn offers strong incentives for collaborations, alliances, mergers and acquisitions (see inter alia Danzon 2000, p. 1083; Danzon 2006; Comanor and Scherer 2011, p. 20). It should nevertheless be mentioned that literature shows a predominance of declines in R&D spending, employment, and reductions in development projects resulting from these mergers (see inter alia Comanor and Scherer 2011; Ravenscraft and Long 2000).

These small biotechnology start-ups predominantly originate from academic research and emerge in clusters around universities and other research organisations. Hence, relevant knowledge and potential collaboration partners are also highly concentrated in a few regions around the world, such as Cambridge/UK, Boston/US, San Francisco/US, or Munich/DE. Take-overs of small biotechnology firms often take the form of cross-border mergers.

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[15] Cockburn and Henderson (2001) estimate that about two thirds of R&D expenditure is spent for drug development rather than drug discovery. Drug development is referred to as the „translation of new molecules into marketable products" (Comanor and Scherer 2011, p. 22).

All those factors mentioned can be seen as idiosyncratic drivers for mergers and acquisitions, collaborations, partnerships, and joint ventures – both cross-border and national. In turn, cross-border mergers and acquisitions have led to a high degree of internationalisation of the pharmaceutical industry's research and development activities. Additionally, one should bear in mind, that the pharmaceutical market is a global one and thus are research-based pharmaceuticals global products that are diffused world-wide through licensing agreements and local subsidiaries of multinational enterprises – not least because of the high R&D costs which force firms to worldwide commercialisation (Danzon 2000, p. 1056).

4.1.2. Firm-level evidence for R&D internationalisation in pharmaceuticals

An overview of investment projects in the pharmaceutical sector is obtained through information from the FDI Intelligence from the Financial Times. The period under observation covers the years 2003 to 2011. This is complemented with data from the EU Industrial R&D Investment Scoreboard for 2007, the reference year for all R&D expenditure data in this project. Investment projects referring to the business activities "research and development" and "design, development and testing" have been taken into consideration. The data include new projects as well as expansion of existing projects. It has to be noted that this data complements the data on R&D expenditure of foreign-owned firms; the data presented here are the 'flows', or new investments, while inward BERD represents the 'stocks' or R&D expenditure which is financed by flows, but also by internal means of the foreign-owned firm. Moreover, the definition of R&D here is broader and also includes design, development and testing.

As the pharmaceutical sector is one of the most internationalized worldwide and moreover counts for the highest R&D investments of all manufacturing sectors, it is not surprising that fdi Markets recorded more than 500 investment projects for the above mentioned business activities. In contrast to most other sectors, the leading activity is not "design, development and testing", but "research and development". There is an evident predominance of the research and development activity accounting for 84% of all investment projects (426 out of 512 projects in total); only 16% were "design, development and testing" projects. This may - at least to some part - be traced back to the nature of the innovation process of a newly developed drug, as it is difficult to distinguish what is actual development, as e.g. in the case of product testing.

The table below (Table 10) shows the ten largest source and destination countries in terms of the aggregated capital investments per country. The by far major source and destination country is the United States. Switzerland, which is ranked second as a source country of investment projects, not even accounts for one third of the aggregated sum of investments projects of firms from the United States. What most of the top ten source countries have in common is that they are home to some of the largest pharmaceutical MNEs, which mostly are originator companies, i.e. Pfizer, Johnson & Johnson, Eli Lilly and Wyeth in the U.S., Roche Group and Novartis in Switzerland, GlaxoSmithKline and AstraZeneca in the United Kingdom or Sanofi Aventis in France.

Referring to companies, the company most active in R&D internationalisation (in terms of the total number of investment projects) is Pfizer, a U.S. headquartered and world's leading biopharmaceutical company, and as they refer themselves the world's largest research-based pharmaceutical company[16]. In terms of the amount of capital investment, a Swiss company is heading the ranking: Novartis. Novartis was created in 1996 through the merger of Ciba-Geigy and Sandoz, with Ciba and Geigy being two Swiss chemical companies and Sandoz, a global leader in generics, which since 2003 is headquartered in Vienna, Austria. It should however be mentioned that Pfizer is close second after Novartis (see also Table 11 for a closer look at the ten companies with the largest R&D expenditure).

The company with the single largest capital investment is also an American corporation – Charles River Laboratories. A new investment project was implemented in August 2007, focussing on research and development creating 1000 jobs in Canada. Charles River Laboratories aims at accelerating drug discovery and development for their partners and customers (leading pharmaceutical, biotechnology, government, and academic organizations) by providing them with high-quality research models and preclinical and clinical support services[17].

Table 10: Source and destination countries with largest R&D FDI in pharmaceuticals (2003 – 2011)

Rank	Source country	capital investment	investment projects	Destination country	capital investment	investment projects
1	United States	10536,14	234	United States	5001,47	95
2	Switzerland	3063,14	43	China	2533,99	53
3	United Kingdom	2237,55	55	Singapore	1984,65	30
4	Germany	1069,76	22	India	1860,69	49
5	Ireland	927,56	14	United Kingdom	1382,03	46
6	France	721,60	24	Canada	1266,65	19
7	India	586,70	21	Ireland	869,11	19
8	Japan	518,46	20	France	681,48	19
9	Canada	508,10	16	Belgium	652,29	13
10	Denmark	304,00	10	Germany	315,17	14

Note: capital investments are in million USD. Projects with the activities "research and development" and/or "Design, development and testing" included.

Source: FDI Intelligence from Financial Times Ltd (fDi Markets database), January 2012

The United States account for 234 investment projects[18], of which 72 are implemented in EU-27 member states; out of these, in turn, only 10 investment projects are implemented in EU-12 countries, such as Romania, Bulgaria, the Czech Republic, Hungary or Poland. It has to be admitted, that the United States and Europe are no more the only major regions competing in the pharmaceuticals industry; Asia is taking its place. Of the remaining investment projects of companies headquartered in the United States, 76 have been implemented in Asia in the years 2003 to 2011. In this context, the most important countries to be mentioned are China, India, and Singapore; together they were able to attract 132 investment projects from 2003 to 2011.

[16] Information available at http://www.pfizer.com/home/

[17] Information available at http://www.criver.com/en-US/Pages/home.aspx

[18] It has to be mentioned that the fdi Markets database also includes 47 investment projects, for which the United States are shown as both source and destination country.

Considering the leading business activity in these countries, accordingly to the global pharmaceutical industry, is “research and development” accounting for a share of 84% of total investment projects. Nevertheless, China still is the country where the majority of investment projects aiming at “design, development and testing” are implemented. These numbers, however point to the fact that developing countries, such as China, India and Singapore have caught up with the European Union and the United States regarding research excellence, skilled workforce, and research infrastructure. Furthermore, the competitive advantage in terms of R&D costs is obvious. Asia offers large and new markets for the pharmaceutical industry, which additionally attracts companies to invest in research there.

Table 11: FDI in research of the 10 companies with the largest R&D expenditure

Company	Source Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total capital investment
Pfizer	US	CN	BE ES	CN IE ES	FR KR	FR IL US	BE FR SG UAE UK US	IE US	BE US	UK US	1528,74
Johnson & Johnson	US		BE	BE				ES	CN		190,10
GlaxoSmithKline (GSK)	UK	IE ES TW US	BE CN IE IN SG		IE	CN	FR SG	US	TW	RO	815,56
Sanofi-Aventis	FR			HU	HU US	ES IN	CA CN				250,68
Roche Group	CH	IN	CN			CN	US	SG		FR CA	560,60
Novartis	CH	KR	EC SG CN		IN SI CN	IT		TW US CN	US	CA	1851,37
Merck & Co	US	CA CO	IE			IE		IN	PL	IE IN SG	1395,50
AstraZeneca	UK	SE US	CA ES IN SE	IN SE	CN	CA CN US	SE			PL RU	676,20
Eli Lilly	US	UK CN	DE			SG CN	PR		US		481,70
Wyeth	US					IE MX					107,10

Note: (1) the ten largest R&D spending companies worldwide were chose according to the 2008 EU Industrial R&D Investment Scoreboard; (2) total capital investments are in million USD. Projects with the activities “research and development" and/or "Design, development and testing” included.

Source: FDI Intelligence from Financial Times Ltd (fDi Markets database), January 2012

4.1.3. Regional Analysis

As the pharmaceutical industry is highly internationalized, and there are barely countries, where the pharmaceutical industry does not significantly contribute to an economy's R&D investments, it seems appropriate to take a closer look at the most important regions, rather than countries.

Northern America:

The lion's share of R&D is both spent and conducted in the United States (see Figure 47). In 2007, eight out of fifteen largest R&D spenders worldwide (according to the 2008 EU Industrial R&D Investment Scoreboard[19]) are from the United States, which points to the high concentration of relevant knowledge in the sector. It is likely that this share may even increase through further mergers of some of the large US-owned pharmaceutical corporations, which subsequently could lead to closures of international R&D sites, as it has been announced in Pfizer-Wyeth merger, where one major Pfizer laboratory will be closed and another one substantially downsized. Similarly, Merck, after its merger with Schering-Plough, announced to close at least three R&D sites (Comanor and Scherer 2011, p. 35).

When taking a look at investment projects in the pharmaceutical R&D sector, Pfizer, the largest R&D spending company in the pharmaceuticals sector, shows a large amount of capital investments abroad, although, there are various projects implemented in the United States itself. This may point to Pfizer's R&D internationalization strategy, which seems to be global on the one hand, but is concentrated in the home country on the other hand. Pfizer's largest research and development site is located in Groton, Connecticut. Knowledge obtained through foreign research is transferred back to the head office, as further development is mainly done in the U.S.

Johnson & Johnson's location choice for their investment projects seems to show a strong focus on Europe (Belgium and Spain), although lately (in 2010) China has been the sole destination country. However, the reason for Belgium as a destination country is given through external factors, i.e. historical reasons: Janssen Pharmaceutica joined the Johnson & Johnson Group in 1961. Janssen Pharmaceutica is running a large development centre at Beerse, Belgium.

Canada is ranked sixth of the top ten destination countries for project investments (in terms of aggregated capital investment) after the United States, the three most important Asian countries China, India and Singapore and the United Kingdom. Reasons might be that Canada's pharmaceutical market is the eighth largest in the world and the fourth fastest growing pharmaceutical industry after China, the US and Spain. A large part of pharmaceutical firms in Canada are conducting research for generic drugs rather than branded drugs.

Europe:

Switzerland is home to two of the world-wide largest pharmaceutical MNEs, Novartis and Roche. Novartis has established research locations in the US, India, China, Japan, Italy and the UK and has furthermore implemented project investments in South Korea, Ecuador, Singapore, Taiwan and Canada. The focus seems to be on reducing R&D costs, when looking at the Asian economies. Likewise Roche invested the major share of projects in the Asian

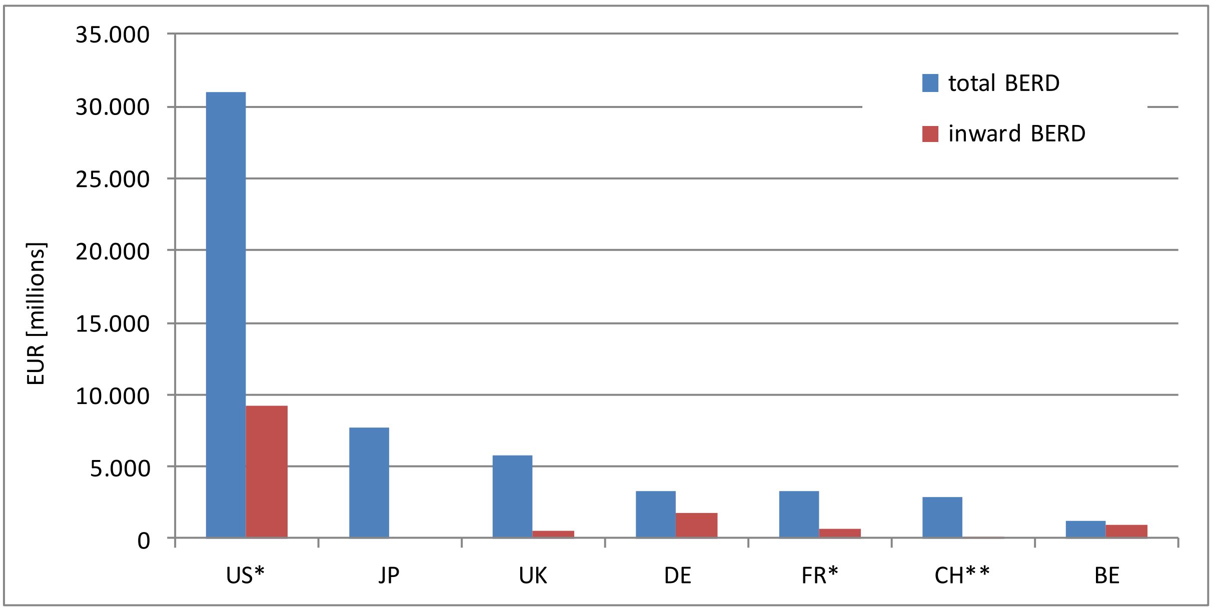
[19]Available at: http://iri.jrc.es/research/scoreboard_2008.htm

economies China, Singapore and India. The amount of research (in terms of BERD) conducted in facilities in Switzerland is considerably lower than the amount of R&D investments of Swiss-owned firms conducting R&D abroad, e.g. in the United States. Outward BERD in the pharmaceutical industry accounts for 230% of domestic BERD in Switzerland. The amount of R&D expenditure spent in Switzerland comes close to what is spent in the US.

Inward BERD data from the UK, Switzerland and France (see Figure 47) may point to a low ability of these countries to attract inward BERD from foreign-owned firms; it may also indicate that there is no need to attract large foreign-owned firms, as the pharmaceutical industry covers a large part of the manufacturing industry in these countries. Indeed, some of the largest R&D spending firms are located there, such as GlaxoSmithKline and AstraZeneca in UK, Roche and Novartis in Switzerland and Sanofi-Aventis in France. All those corporations mentioned are highly internationalized with a worldwide presence of R&D locations[20].

The case of Germany (Figure 47) shows the other side of the same coin. Numerous pharmaceutical firms were purchased by mergers: for example Boehringer-Mannheim by Hoffmann-La Roche in 1997; Hoechst-AG by Rhone-Poulenc Rorer in 1998; Knoll (BASF Pharma) by Abott in 2000; Schering AG by Bayer Healthcare Pharmaceuticals in 2006 and Schwarz AG by UCB also in 2006. Most R&D facilities have been kept throughout these mergers, which may explain the considerable higher share of inward BERD in Germany than in most other countries, besides the US.

Figure 47: Total BERD and inward BERD per country in the pharmaceutical industry (2007)



Note: * 2006 instead of 2007; ** 2008 instead of 2007; no inward data available for Japan

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

[20] GlaxoSmithKline has R&D sites in UK, France, Spain, US and China; AstraZeneca in UK, Sweden, France, US, Canada, India, China and Japan; Roche in Switzerland, Austria, UK, Germany, US, China, Japan and Australia; Novartis in Switzerland, Italy, UK, US, India, China and Japan; Sanofi-Aventis in France, Germany, Italy, Hungary, Spain, UK, US, Canada and Japan (this information is available at the companies' homepages)

In Belgium (Figure 47), a major share in the pharmaceutical sector is attracted from foreign-owned firms, i.e. more than 75% of total BERD in Belgium, of which almost 45% are US-controlled and another 30% are UK-controlled. That is, “the pharmaceutical sector is almost an exclusively Anglo-Saxon matter” (Teirlinck 2009, p. 18). No other country shows a greater inward intensity than the Belgian pharmaceutical industry. This may be first of all due to historical reasons, e.g. the merger of Johnson & Johnson with Janssen Pharmaceutica in 1961 and the presence of GlaxoSmithKline Biologicals[21]. Further reasons for Belgium’s ability to attract foreign-owned pharmaceutical firms are manifold. These refer inter alia to the availability of skilled human capital, the availability of physical infrastructure, the existence of knowledge centres and the proximity to the European market (de Doncker 2006 p. 32). Furthermore Belgium has the fastest drug approval process in Europe[22] (Business Monitor International 2010), which gives a strong incentive for early-stage development in the country.

[21] Jannssen Pharmaceutica (merged with the US-owned Johnson & Johnson) and GlaxoSmithKline (from UK) are the two largest R&D spenders in the Belgian economy.

[22] Approval for Phase I and II trials can be obtained in 18-26 days

4.2. Internationalisation of R&D in knowledge-intensive business services

Knowledge-intensive services and knowledge-intensive business services (KIBS) in particular came into focus of policy in recent years. One reason for this attention is the growth performance of these services. KIBS grow faster than most other sectors. According to data from EUKLEMS (Timmer et al. 2008), employment in KIBS (defined here as renting, computer services, R&D services and business activities, NACE Rev. 1.1 71-74[23]) in the EU25 increased from 14.4 Mio persons in 1995 to more than 24.6 Mio persons in 2007. In contrast, employment in manufacturing decreased from 36.8 Mio persons to 33.8 Mio persons in the same period.

A second reason for the increased attention for KIBS is the growth effect of KIBS in downstream sectors. Manufacturing as well as service firms utilize services as inputs for their production processes and as complementary assets for their investments.

Before we discuss the drivers of inward BERD in KIBS, it is important to have a closer look what KIBS exactly are. KIBS can be divided into three sub-groups. The first sub-group are computer services (NACE 72), which include software development (NACE 72.2), as well as hardware-related consulting (NACE 72.1); data processing and database activities (NACE 72.3 -72.4) such as the provision of internet-based services and also the maintenance and repair of office and computer machinery (NACE 72.5).

A second sub-group is research and development (NACE 73). Here we find organisations that provide R&D services to third parties on a commercial basis. This group includes contract research organisations, but also R&D units affiliated to a multinational company group which are organized as independent firms. Examples are the Novartis Institutes for BioMedical Research, Shell Research Ltd, Procter & Gamble Technical Centers, or Microsoft Research Ltd, the latter three located in the UK. The activities of such a corporate R&D centre are assigned to NACE 73, and not to the industry of the parent company group, even if the centre only performs R&D only for one single client, its company group. This makes it sometimes difficult to reveal the nature of activity on NACE 73. NACE 73 only includes two sub-groups, R&D on natural sciences and engineering (NACE 73.1) and R&D on social sciences and humanities (NACE 73.2).

Finally, the third sub-group, other business services (NACE 74.1-74.4), consists of two broad sub-categories. They include, on the one hand, legal and economic consulting activities (NACE 74.1) and advertising (NACE 74.4). Moreover, NACE 74.1 also includes the activities of holding companies, for example regional headquarters of multinational firms.

On the other hand, other business services include technical consultancy such as architectural and engineering activities (NACE 74.2) and technical testing and analysis (NACE 74.3). Since we cannot split up NACE 74 in our data, labour recruitment (NACE 74.5), security services (NACE 74.6) and industrial cleaning (NACE 74.7) and is also included in KIBS.

Readers should recognize that the boundaries between the three sub-sectors are fluid, and do not match with the activities of KIBS firms to a considerable degree. Large IT consulting firms usually also provide computer services, and software firms increasingly provide also consultancy services in the implementation process of a new software. Boundaries between IT consultancy and management consultancy, and between advertising and ‘new media’ firms are blurred as well. It is not possible to assign activities in NACE 73 to a technology field, even if the firm is assigned to a company group active in a particular industry or technology

[23] In the remainder of this section, NACE refer to NACE Rev. 1.1.

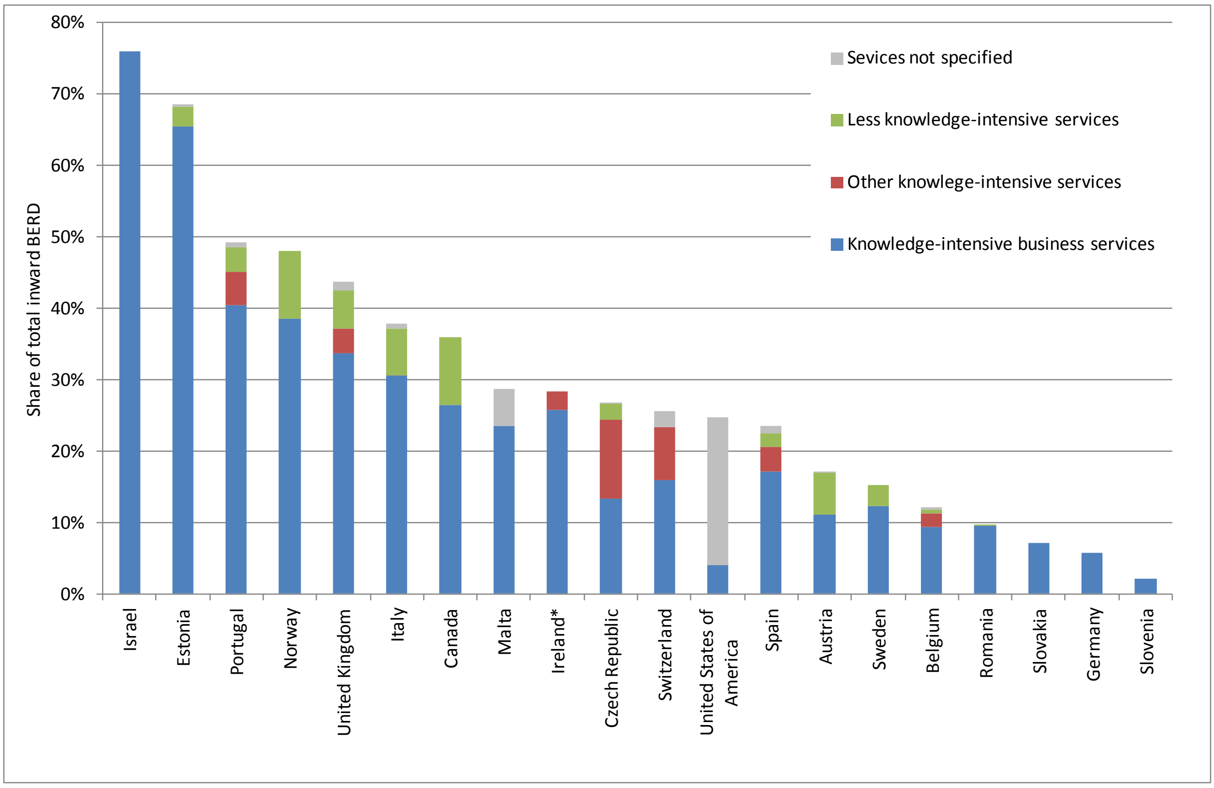
field. Moreover, there are also close links between computer services and other KIS industries, such as finance, communication and the media industries.

4.2.1. The role of KIBS in the internationalisation of R&D

Besides the contribution of KIBS to growth, another striking feature of KIBS is their role in the internationalisation of R&D. KIBS account for the bulk of inward BERD in the service sector. In some countries inward BERD in KIBS is even higher than inward BERD in manufacturing (see Figure 48 below).

Two countries stand out in the internationalisation of R&D in KIBS. First, the United Kingdom (together with the US) attracts the largest amount of inward BERD in KIBS (see also Figure 20). In 2007, inward BERD in KIBS in the UK was 3.1 billion EUR. In contrast, Germany as the largest attractor of total inward BERD, only attracts 0.6 billion EUR of inward BERD in KIBS. Most of the inward BERD in the UK goes into in research and development services (NACE 73) and computer and related services (NACE 72).

Figure 48: Share of various service industries on total inward BERD, 2007



Note: KIBS includes NACE 1.1 sections 70-74; other KIS 64.2 and 65-67; LKIS 50-52 and 55; other services the service sector (50-99) except KIBS, other KIS and LKIS. Due to data constraints 65-67 is included in KIBS and not other KIS in Germany, Sweden and Canada. KIBS only includes 73 in Switzerland, 72, 73, 74.1 and 74.3 in the United States and 72 and 73 in Israel; * 2005 instead of 2007

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

Second, Israel has the largest share of KIBS on inward BERD of all countries (Figure 48). KIBS account for more than 75% of total inward BERD in the country. We will therefore focus on the UK and Israel in this case study.

In addition to the UK and Israel, Estonia is the third country to be included in this case study. Estonia has also a very high share (65%) of KIBS on inward BERD. Moreover, it is the only EU-12 member state where inward BERD in services is higher than in manufacturing industries. This pattern of internationalisation is fundamentally different from the pattern we observed in the Czech Republic, Hungary or Slovakia (see the case study on the internationalisation of R&D in the automotive sector of the Czech Republic, Hungary, Slovakia and Romania in section4.5).

Before we discuss the drivers of inward BERD in KIBS in the UK, Israel and Estonia, it is important to have a closer look at the three KIBS sub-sectors. In Estonia, inward BERD in KIBS is almost completely found in computer services (NACE 72). In Israel, the share of computer services is about 40%. The remaining 60% are in research and development services (NACE 73). In the UK, inward BERD in KIBS is mainly found in research and development services (65%) with smaller shares in computer services (20%), and other business services (13%).

4.2.2. Drivers of internationalisation of R&D in KIBS

The internationalisation of KIBS in general and the internationalisation of R&D in KIBS were driven by both general and country-specific factors in recent years.

A general driver of internationalisation in KIBS is the usage of information and communication technologies (ICT) in services provision. Services are often characterized by intensive relations between client and service provider, which often requires that both parties stay in the same place and have face-to-face conversation (Hauknes 1998). Hence, many KIBS have been traditionally geographically bound, and service provision over distance was only possible if client or service provider moves to the place of the other party.

ICT opened new ways of service provision over distance to many KIBS firms (van Welsum and Vickery 2005). As a consequence, the use of ICT has increased the tradability of services, in particular of services dealing with the exchange, storage, processing and retrieval of standardized, digitized and codified information (UNCTAD 2004, p. 148 f). This has opened new ways for service providers to meet the growing demand for services due to offshoring and to serve clients outside their town or region. As a consequence, foreign direct investment and trade in knowledge-intensive services have flourished since the 1980s (Biege et al. 2011). ICT also opened new ways for decentralized R&D in KIBS firms.

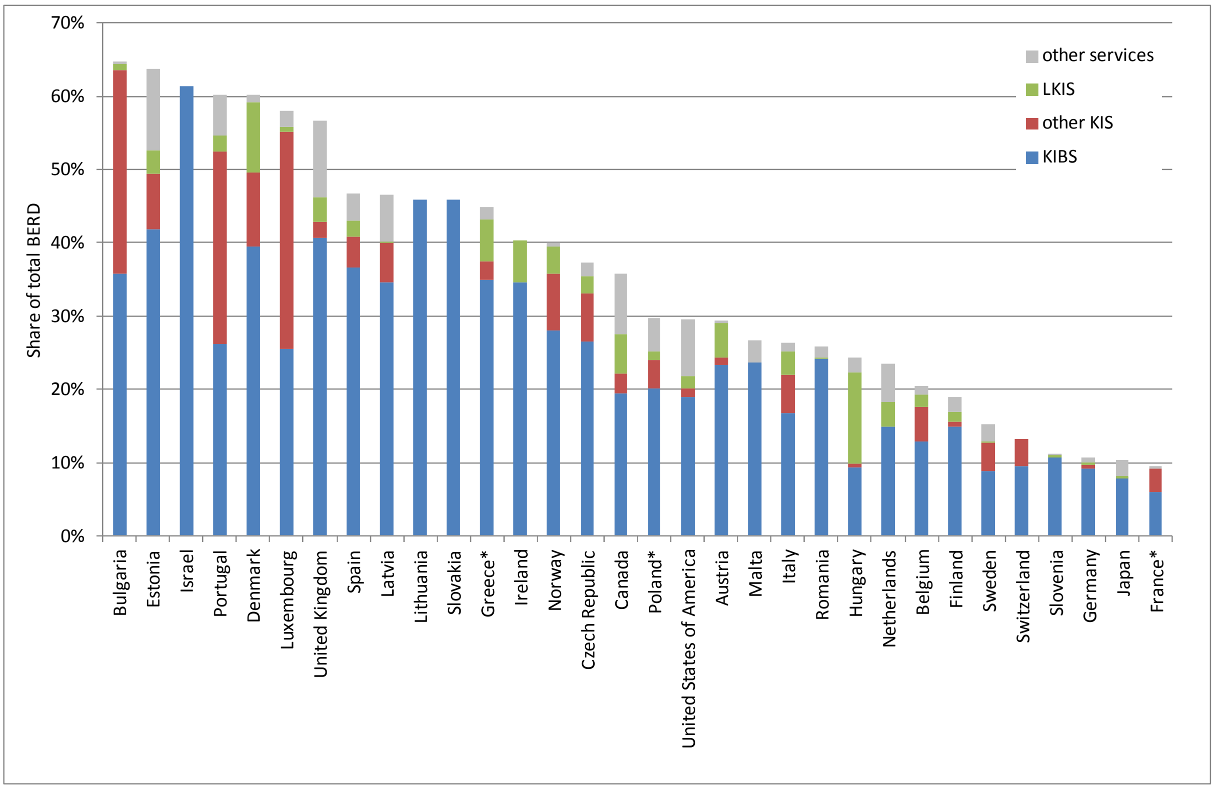
New technological opportunities have been met by growing demand. The growth of KIBS is largely fuelled by intermediate demand - the use of KIBS by other firms for the production of goods (Peneder et al. 2003; Savona and Lorentz 2006).

These two general drivers, however, do not explain the considerable differences in the share of KIBS firms on inward BERD between countries illustrated by the figure above. Hence, there must be other, country-specific drivers.

One of these country specific drivers is industrial specialisation. We measure specialisation by the share of KIBS in total BERD (see Figure 51). The corresponding shares of KIBS on sectoral employment or value added give a similar picture. The figure suggests a positive relationship between the share of KIBS on total BERD and on inward BERD; foreign-owned KIBS firms invest predominantly in R&D in countries which also have a high share of their total BERD in KIBS. In Estonia and the United Kingdom, KIBS account for more than 40% of total BERD, while the share of KIBS on total BERD even exceeds 60% in Israel.

It has been argued that R&D activities of foreign-owned firms are also attracted by agglomeration advantages, which may explain the uneven distribution of inward BERD across regions (Cantwell and Iammarino 2000; Teirlinck 2005; De Backer and Hatem 2010). These agglomeration advantages include, for example, the availability of a large pool of experts in ICT, the existence of universities specialized in ICT, which can provide skilled personnel and expertise in co-operations, or the existence of key users of KIBS and ICT such as banks or corporate headquarters. Moreover, De Backer and Hatem (2010) argue that firms in agglomerations increasingly specialize in R&D and other headquarter functions.

Figure 49: Share of various service industries on total BERD, 2007



Note: KIBS includes NACE 1.1 sections 70-74, other KIS 64.2 and 65-67, LKIS 50-52 and 55, other services the service sector (50-99) except KIBS, other KIS and LKIS. KIBS only includes 73 in Switzerland, 72, 73, 74.1 and 74.3 in the United States and 72 and 73 in Israel; * 2005 (Greece) and 2006 (Canada, France, Poland) instead of 2007

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

Agglomeration advantages play an important role in the locational choices of KIBS. Moreover, KIBS are attracted by urban regions in particular, since they rely on proximity to key clients (Wood 2002). Additionally to the aforementioned availability of skilled labour, a large pool of potential clients in some locations, such as the City of London or other parts of the UK fosters the location of additional R&D activity. Single actors are of main importance as a comparable small number of companies account for large shares of total R&D in KIBS. There is also some evidence that agglomerations increasingly specialize along their functions and not traditional industrial sectors: R&D but also headquarter services or marketing activities tend to locate in agglomerations with a large presence of the respective activities instead (De Backer and Hatem 2010).

In the following sections we will take a closer look on the three countries considered in this case study - the United Kingdom, Israel and Estonia - and investigate drivers in more detail country by country.

4.2.3. Country analysis

United Kingdom

The role of agglomeration advantages in attracting inward BERD in KIBS is most obvious in the example of the UK. The UK is a huge market for KIBS, and one of the world-wide centres of R&D in KIBS. As mentioned before, the UK is the most important location for R&D in KIBS in the EU-27, both in terms of inward investment but also in terms of total R&D expenditure in KIBS. This also includes R&D expenditure by formerly public R&D labs, which have been privatized. Worldwide, the UK is only second behind the by far larger United States. KIBS firms in the UK have spent about nine billion EUR on R&D in 2007, foreign-owned firms account for about one third or three billion EUR.

A considerable share of these activities is located in London. The City of London is one of the largest agglomerations of financial services and KIBS in the world, and has a strong market position in the UK and world-wide (Wood and Wojcik 2010). This London KIBS and financial services cluster offers an extraordinary pool of skilled personnel, a large potential for the development of specialized services and a high number of potential clients among financial services as well as corporate headquarters.

In addition to market size and a critical mass of R&D in KIBS, the UK also offers a large pool of technological expertise and specialized scientific staff. Based on the results of the WEF Global Competitiveness Report (2011), the United Kingdom is ranked number seven worldwide in terms of the availability of latest technologies, ranked number three worldwide in the quality of scientific research institutions and on the second place in terms of university-industry collaboration in R&D. The United Kingdom is also able to attract talented people as the best performing EU-27 country in this respect and worldwide only outperformed by Switzerland, Singapore and the United States (WEF 2011).

A second driver that helps to understand the high share of KIBS in inward BERD in the UK is the role of the country as the preferred location for the European headquarters for non-European firms. The UK has the advantage of English being the dominant international language of business, and English law being the most used contract law in international business (Wood and Wojcik 2010). The country can also build on its special relationship with the United States and its close historical relationships with many countries in Asia, Africa and the Middle East.

Regional headquarters of non-European multinational firms in the UK may also induce the location of headquarter functions, such as marketing, product development and R&D in the UK. This can explain the high share of inward BERD in NACE 73, research and development services, which also includes corporate R&D centres if they are organized as independent legal entities.

The fDi Markets-database allows a closer look at inward investment in the UK. It includes a total of 120 R&D investment projects in the UK with a total volume of almost two bn USD since 2003. Only eight are in business services. The vast majority (112) is in software and IT services. Unfortunately the largest sub segment of KIBS in the UK, R&D services, is not included in the database. However, although only roughly on third of the KIBS sector is included, the overall picture is still similar to the results based on inward BERD data. US companies are of outstanding importance accounting for 69 out of the 120 projects. Other important countries are on the one hand other large EU countries including Germany (10 projects) and France (8 projects) but also India (8) Japan (6) and Canada (4). In particular the engagement of Indian companies in KIBS R&D projects in the UK is interesting. Close historical and cultural ties and the above mentioned function of the UK as a gateway to the European market may be main reasons.

Surprisingly, the single most important UK town for the projects included in the fDI Markets-database is Belfast with 38 projects by 25 different companies. In contrast, only 10 companies performed 11 R&D projects in London. However, this might be caused by the fact the mostly R&D in software and IT services are included in the sample and also that only investment flows since 2003 are covered and not investment stocks.

Israel

R&D in KIBS is in Israel of outstanding importance for the country's gross domestic R&D expenditure. KIBS account for about three quarters of inward BERD and about two thirds of total BERD in Israel. Besides this high importance of R&D in KIBS, Israel is also the country with the highest R&D intensity in the OECD (OECD 2011b). According to the Global Competitiveness Report of the World Economic Forum (WEF 2011), the quality of Israel's research organisations is the highest worldwide, and a particular specialisation of these organisations is on ICT. Breznitz (2005) discusses reasons for the rise of the Israeli software and computer industry. He points out the industry's ability to focus on R&D intensive activities, and close ties to university and governmental research in the field.

In addition, 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 (Senor and Singer 2009). The availability of venture capital is the second best in the world, only outperformed by Quatar (WEF 2011).

These three factors account for the high attractiveness of Israel as a location of ICT-related R&D activities of multinational firms. The high levels of internationalisation in KIBS in Israel are driven by MNEs establishing subsidiaries and research laboratories in Israel by the acquisition of Israeli ICT firms.

US MNEs are of outstanding importance, as can be seen in the fDi Markets-database. The database includes a total of 38 investment projects in Israel since 2003, most of them (36) in software and IT services. 28 projects have been established by US firms and another four by German firms. The estimated total volume of these projects is more than 600 million USD.

Within Israel, Tel Aviv is attracting one quarter of all projects. The vast majority of the projects can be classified as new projects (32). Only six are expansions of existing projects. This is an important difference to inward investments in other countries, for example Ireland, where most R&D-related investment projects are extensions of existing production activities.

While the single largest investor is Indian Tata Group (one project worth 62 million USD) and the third largest investor SAP from Germany (three projects with a total of 60 million USD) all other top 10 companies are US companies, including most major player in the software and IT industry with Google, IBM, Hewlett-Packard EMC Corporation, Microsoft, Juniper Networks each investing between 20 and 61 Mio USD on R&D projects in Israel since 2003.

Estonia

With a share of more than 40% of KIBS on total inward BERD, Estonia ranks among the countries where KIBS are of relative largest importance. However, it should be noted that this share of 40% corresponds to an absolute R&D expenditure of only 14.6 million EUR in 2007, which is small compared to the countries discussed before. Nevertheless, Estonia has the highest share of inward BERD in KIBS among all EU-12 countries, and only the Czech Republic receives more inward BERD in KIBS in absolute terms.

The high share of inward BERD in KIBS in software services in particular is even more remarkable if we look at the size of the ICT sector in Estonia. Even if the whole ICT sector is considered, which includes also the manufacturing components, ICT only accounts for 3.8% of all Estonian companies and 4.1% of the employment. While the share of the sector on profits (6.4%) and value added (6.8%) is already significantly larger than the employment, the sector accounts for almost half (44.4%) of the total R&D expenditure in the country. Computer related and financial intermediation activities account for 49% of the private sector research personnel in Estonia in 2009. Software and computer services are the sector with by far the highest R&D intensity in the Estonian economy (Kalvet and Tiits 2009).

According to the WEF Global Competitiveness Report 2011, Estonia is the most competitive country out of the EU-12 countries and ranked as the 33rd best performer worldwide. Estonia performs particularly well regarding various indicators measuring the quality of higher education, the efficiency of labour markets, technological readiness and innovation, especially compared to other EU-12 countries. Estonia performs best of all EU-12 concerning the availability of latest technologies (rank 34 worldwide) and extent of firm level technology absorption (rank 36 worldwide). The quality of math and science education is considered to be the 20th best worldwide. Wage determination is the most flexible in the EU-27 and pay and productivity are closest related of all EU-27 countries. However, brain drain is considered to be an issue as Estonia is only ranked number 56th worldwide in the ability to retain and attract talented people (WEF 2011). The intensified utilisation of the widely available skills is therefore a focus of the Estonian Research and Development and Innovation strategy (Rannala and Männik 2010).

However, even more important than locational factors are in the case of Estonia the R&D strategies of one single company, Skype. Skype has been founded in Estonia, and the first version of the Skype software was developed in 2003 by three Estonian programmers. Skype was bought by eBay in 2005. After eBay’s retreat in 2007 Microsoft bought Skype in 2011.

Today, Skype is by far the most important multinational software company active in Estonia, with the global development headquarter being located in the country. Almost 400 people work for Skype in Estonia, about half of Skype’s total workforce (Kalvet and Tiits 2009).

Given that there were just 1,313 researchers (full-time equivalent) in the Estonian business sector in 2009 (OECD 2011a), and foreign-owned firms account for a quarter of Estonia’s total BERD, it is easy to recognize that Skype is responsible for the bulk of inward BERD in KIBS in Estonia.

In contrast to the above discussed countries, the fDi Markets-database includes for Estonia only five R&D investment projects in the software and IT services sector and none in business services. Three of these projects are by the UK online gaming software supplier Playtech, the world’s largest publicity traded company active in this field (Kalvet and Tiits 2009). The other two projects are by US software producer Microsoft and Australian Seven Networks. Skype is not included in the fDi Markets-database. As a true global company, Skype is headquartered in Luxembourg, while the main sales office is located in the United Kingdom. The company develops the products in Estonia while the Irish affiliate of Skype is responsible for the copyright protection (Kalvet and Tiits 2009). This may explain which why Skype is not included in the database.

4.2.4. *Conclusions*

R&D in KIBS constitutes a main fraction of total business R&D in a number of countries and this importance tends to grow in the most recent years. Along with this growing importance goes an increasing internationalisation of research in KIBS, reflected in the amount of inward BERD in KIBS. In this course of internationalisation some countries are able to attract significant amounts of inward R&D investments in KIBS while other countries play a comparably small role. We took a closer look at three countries which have at least two things in common: a) KIBS contributes a far above average share on total BERD in these countries, and b) KIBS are also a sector of outstanding importance for R&D investment by foreign-firms.

The three countries have in common that they all possess agglomeration advantages such as the skilled labour force needed to attract inward BERD in KIBS and, more generally speaking, a business environment favourable for investments in R&D. However, while these factors are of importance, country specific factors as well as the tendency of existing specialisations to maintain also play an important role.

Estonia is an excellent example of a country which is able to attract MNC to invest in R&D in KIBS in the country by offering skilled labour combined with an overall competitive business environment. The case of Estonia also shows the importance of one firm, Skype, for overall inward BERD. In contrast, Israel heavily relies on its leading technological position in a number of high tech sectors, this position at the technological forefront leads to a constant stream of investments by MNCs in both, the takeover of domestic start-ups and the set up of research labs in Israel. The United Kingdom is home of a well established large KIBS sector attracting further investments. Additionally, the United Kingdom acts as a gateway to the European market for non-European companies, which also implies that corporate R&D centres for the European market are located in the UK.

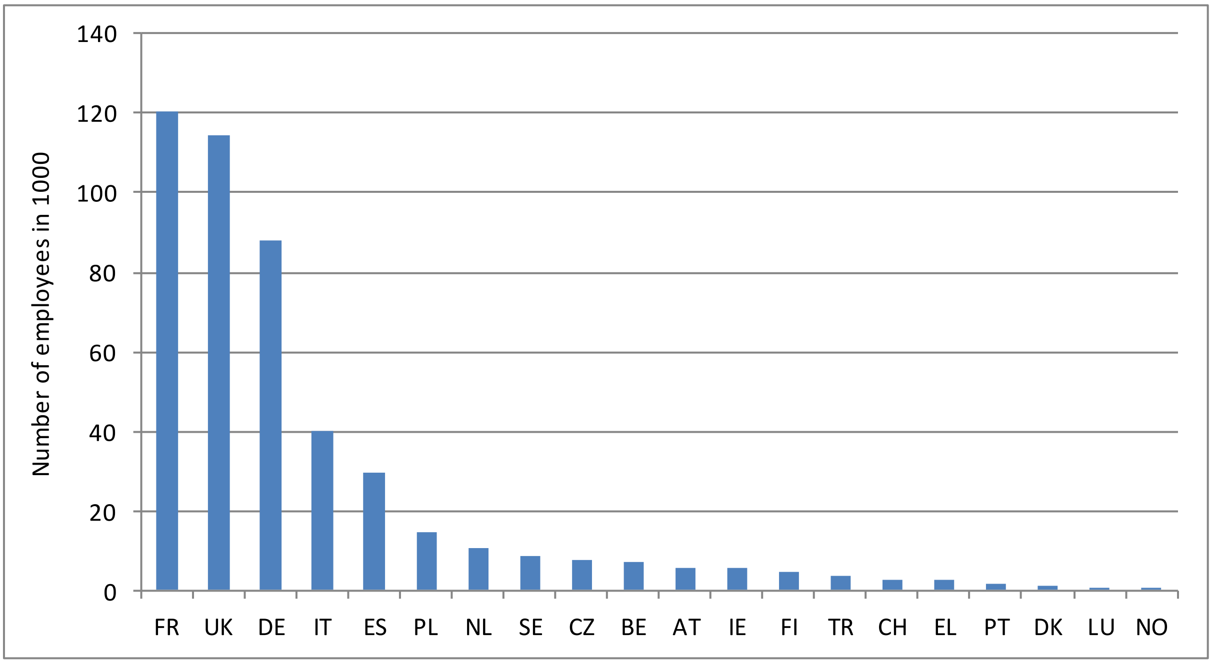
Although the countries have the good availability of skills in common, out of the three countries considered only the UK is a country which is able to attract talented people from other countries while Israel and Estonia are rather suffering a brain drain to certain extends. However, this is also a sign for the good availability of skilled workers in the latter two countries.

4.3. Internationalisation of R&D in the aerospace sector

A sector where internationalisation of R&D can be largely explained by the activities of a small number of firms is the aerospace sector. This case study will look at the actors in this field and how they spread R&D activities over countries, in particular Germany, France, the Netherlands and Spain. From a statistical point of view the aerospace industry is defined by OECD and Eurostat as NACE Rev.1.1[24] 35.3 or the manufacture of aircraft and spacecraft. It includes the manufacture of aeroplanes for the transport of goods and passengers, for use by the defence forces, for sport or other purposes; manufacture of helicopters; manufacture of gliders and hang-gliders; manufacture of dirigibles and balloons; manufacture of spacecraft and spacecraft launch vehicles, satellites, planetary probes, orbital stations, shuttles; manufacture of parts and accessories of the aircraft (as fuselages, wings, doors, control surfaces, landing gear, fuel tanks, helicopter rotors, motors and engines etc); manufacture of aircraft launching gear, deck arresters; and manufacture of ground flying trainers. The aerospace sector can be divided in various sub industries: the civilian aerospace industry, the defence or military aerospace industry and the space industry.

The aerospace industry on the one hand is one of the highly internationalized sectors in Europe; on the other hand, there is a strong concentration on only a handful of countries – France, UK, and Germany (see Figure 50). Employment in these countries amounts to almost 70% of total employment in the European aerospace industry. This - inter alia - arises due to various particularities of this high-technology industry, as aerospace manufacturers are obliged to deal with high technological, financial and market barriers (Esposito 2004).

Figure 50: National contributions to direct European aerospace industry employment (2007)



Note: Total employment in the European Aerospace Industry (including civil and military aerospace industry) amounts to 471 600 in 2007.

Source: ASD Facts and Figures 2007

[24] In the remainder of this section, NACE refers to NACE Rev.1.1.

4.3.1. Motives and drivers of the internationalisation of R&D in the aerospace sector

The aerospace industry[25] is distinguished by a very high technological level and complexity of - widely homogenous - underlying technologies. A wrong positioning in the technology matrix could therefore lead to large financial losses and subsequently to losses of competitiveness. The high technological complexity implies limited possibilities to control all underlying technologies of current aircraft configurations. Additionally, complexity and the high technological level indicate that large R&D efforts are needed for small technological improvements. This, in turn, leads to considerably high and further increasing development costs[26]. Long periods until break-even points are reached and small markets moreover characterize the aerospace industry. Thus, no single country or aircraft manufacturer is able to meet the needs of both supply and demand. These risks and obstacles can be strategically reduced through collaboration and cooperation agreements with other firms, both within and across national borders (inter alia European Commission 2009; Esposito and Raffa 2006; Pinelli et al. 1997; Hayward 1994).

Moreover, in the aerospace industry there is a high interdependency between civil and defence markets. States cover the major part of development costs in the military markets; firms operating in both civil and military aeronautics may benefit from developments supported by governments. This in consequence may lead to a bias in research funding of single firms, as e.g. the US department of Defence “explicitly funds dual-use technology development in order to support the strategic goal of economic leadership for the US industry” (European Commission 2009, p. 22). The aerospace industry is further seen as a strategically important sector of the economy and therefore enjoys widespread governmental support. Reasons for this phenomenon traditionally are “(i) military autarky, (ii) spill-over and external effects of this high-tech industry and (iii) the need to prevent monopoly power of other countries in this field” (European Commission 2009, p. 22).

Above-mentioned particularities may explain the collaboration and consolidation process in the European aerospace industry (to compete with the American aerospace and defence industry), which has led to a complex network of relationships among firms. These relationships may open up possibilities to tap into new markets, followed by foreign production and R&D facilities, which resulted from a widespread and still ongoing internationalisation process (Niosi and Zhegu 2005; Esposito 2004). In the beginning of the 1990s the aerospace sector included 30 companies from six European countries (Sweden, United Kingdom, France, Germany, Italy and Spain); in 2003 the number of major players has decreased to only eleven[27] (ASD 2003). Today, various crossholdings, joint ventures, international consortia and partnerships form the worldwide aerospace industry[28], fostering both collaboration and competition (Niosi and Zhegu 2005). This network is not related to the European Aerospace industry anymore, but has expanded globally.

[25] The following paragraphs rely on the “Competitiveness of the EU Aerospace Industry” (European Commission 2009) and Esposito and Raffa (2006).

[26] Cost estimates for the development of the Airbus A380 go from USD 12 to 15 billion (FI/DMS, 2001; Teal Group 2001)

[27] These include Saab AB, the SI Group, BAE Systems, Rolls Royce, Dassault Aviation, Alcatel, Thales, Snecma, EADS, Augusta Westland and Finmeccanica. In 2005, Snecma merged with Sagem to SAFRAN; Snecma now is a subsidiary of SAFRAN (Hollanders et al. 2008).

[28] See Hollanders et al. (2008) for an overview of the Consolidation process of the European Aerospace industry (p. 12) and the structure (major European Aerospace and Defense Industry Crossholdings) of the European aerospace industry (p. 13).

4.3.2. Recent motives and drivers of R&D internationalisation

A general overview over recent investment projects in the aerospace sector can be obtained by analysing FDI flows, for which the fDi Markets database (FDI Intelligence from the Financial Times) was used. This database provides information on individual investment projects based on press reports. It therefore covers new projects, expansions and co-locations by both source and destination country.

As business activity of companies from the aerospace industry, both "research and development" and "design, development and testing" were selected to refer to both asset-seeking and asset-exploiting motives. Overall, in the period between January 2003 and December 2011, 70 investment projects were recorded in the aerospace sector for the two business activities mentioned worldwide. Similarly to most other industries, and in line with existing literature, we found that 69% of the investment projects refer to "design, development and testing" rather than to "research and development" (31% of total investment projects).

Table 12 shows that there are barely investment projects for which Germany, France or Italy are chosen as destination country of FDI flows. We can explain this by referring to historical reasons, i.e. the consolidation and collaboration process of the European aerospace industry. This however does not mean that there are no cross-country FDI flows within the European Union. For example, Innovation works is a global network of technical capability centres of EADS[29] dedicated to research and development to guarantee the company's technical innovation potential on the long term. There are seven thematic transnational technical capability centres, such as regarding composite technologies; metallic technologies and surface engineering; structures engineering, production and aeromechanics; or engineering, physics, IT, security services and simulation. EADS Innovation works has two main research sites in Suresnes/Paris (FR) and Ottobrunn/Munich (DE), proximity centres in Toulouse and Nantes (FR), Hamburg, Bremen and Stade (DE), which support knowledge transfer to local business units. Moreover, EADS maintains research centres in Singapore, Newton and Filton (UK), Getafe/Madrid (ES), and most recently in Bangalore (IN). Furthermore, EADS operates a liaison office in Moscow (RU), to better connect to local Russian research and scientific institutes.

The country which could attract most investment projects during this period was India, accounting for a share of 26% of total investment projects. In 18 out of 70 investment projects, India was chosen as destination country from both European and United States headquartered firms. Aggregating all Asian countries, 30 investment projects were conducted there. Still, Europe and Northern America (particularly the United States) are attracting a considerable number of investment projects. 20 investment projects were attracted by various European countries, of which the United Kingdom alone accounts for 10 projects.

Nevertheless, a focus of international collaborations should be set on the emerging and developing economies of China, Russia and India, which are even promoted by the European Commission (Acare 2008) in order to strengthen the position of the European players. European aircraft industry in the past has sold a small number of aircrafts to these new economies. On the one hand, European and US industries tapping into these new markets requires presence in local markets, as well as partnerships and collaborations with local

[29] http://www.eads.com/eads/int/en/our-innovation/innovation-works/What-we-do.html

companies[30], referring to the major players Airbus and Boeing here. On the other hand, the emerging and developing economies aim to "supply their own market with indigenous products" (Acare 2008, p. 44). Therefore, the presence of e.g. Airbus or Boeing fosters alliances and partnerships with local companies, and furthermore may lead to acquisitions of specialized technology (skilled labour and assistance in setting up aircraft development and production) through collaborations with European and US partners (Acare 2008; Esposito 2004).

Table 12: Destination country analysis – R&D investment projects per year

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
EUROPE										**20**
France			2	1						3
Germany	1					1		1		3
Italy					1					1
Poland								1		1
Romania							1			1
Turkey		1								1
United Kingdom	1			3	1	1	1	3		10
EU-15										*17*
NORTH AMERICA										**8**
Canada			1							1
United States	1				2	1		3		7
SOUTH AMERICA										**5**
Brazil								1		1
Mexico				2			1			3
Puerto Rico		1								1
ASIA										**30**
China		1						1	1	3
India	1			3	1	2	2	3	6	18
Japan	1									1
Malaysia			1							1
Philippines	1									1
Russia					1				1	2
Saudi Arabia								1		1
Singapore		1		1						2
Taiwan	1									1
ROW										**7**
Australia	1					1	1	2	1	6
New Zealand				1						1

Note: Projects with the activities "research and development" and/or "Design, development and testing" included.

Source: fdi market database

[30] Airbus (as well as Boeing) maintains production and research sites, inter alia, in those countries mentioned. For further information see http://www.airbus.com/company/worldwide-presence/ (Airbus) and http://www.boeing.com/worldwide.html (Boeing).

Considering the source countries of international investment projects a clear picture emerges. Table 13 confirms the geographical and economic concentration of the aerospace industry arising from the long-lasting collaboration and consolidation process. Europe still covers the major part of projects (56%) and invested capital (73%). EADS (Netherlands) conducts the lion's share of projects, both in terms of number of projects and in terms of capital investment. One should however bear in mind that no actual activity, i.e. production or research is done in the Netherlands, and only EADS is headquartered there (see also Figure 50 for the national contributions to direct European aerospace industry employment). Globally, the Unites States account for the largest number of investment projects, although in terms of capital investment, Netherlands still is topping the list.

Table 13: Source country analysis of R&D in the aerospace industry

Source country	No. of projects	% of total projects	capital investment	% of capital investment
EUROPE	**39**	**56%**	**4767,1**	**73%**
Netherlands	17	24%	3802,7	58%
France	6	9%	219,2	3%
Germany	5	7%	144,4	2%
Sweden	4	6%	196,9	3%
United Kingdom	3	4%	247,7	4%
Italy	2	3%	102,7	2%
Belgium	1	1%	6,5	0%
Switzerland	1	1%	47	1%
AMERICA	**31**	**44%**	**1777,2**	**27%**
United States	29	41%	1763,4	27%
Canada	2	3%	13,8	0%

Notes: (1) Capital investments are displayed in million USD. (2) Capital investments are estimated for most projects. Projects with the activities "research and development" and/or "Design, development and testing" included.

Source: fdi market database

When taking a closer look at EADS (see

Table 14), it reveals that likewise EADS is investing to a large part in India and other emerging economies like Singapore, China and Russia. The location choice of Russia, as already stated above, is based on a foremost strategic decision of EADS. Generally, the amount of capital invested in EADS Innovation Works indicates that these sites may mainly refer to an overall knowledge management and knowledge transfer; the actual research and development may however take place in production sites of the respective companies themselves, i.e. Airbus or Eurocopter, where the major part of money is spent.

Table 14: EADS – R&D projects per year by destination country (2003 – 2011)

Investing Company	2004	2005	2006	2007	2008	2009	2010	2011	capital investment
Airbus	CN	FR	UK SG IN				US UK IN	IN	955,55
Eurocopter	SG						IN		102,70
Premium Aerotec						RO			92,00
EADS Innovation Works						IN	UK	RU	13,40
EADS (n.e.c.)			IN UK						2639,08
Total EADS									*3802,73*

Note: (1) There are no EADS related investment projects in 2003. (2) Source country is always Netherlands, as EADS is headquartered there. (3) Capital investments are displayed in million USD. (4) Capital investments are estimated for most projects. Projects with the activities “research and development" and/or "Design, development and testing” included.

Source: fdi market database

4.3.3. Country Analysis

Despite the international R&D partnering in aerospace and defence is well above the average compared to other high-technology industries (see inter alia Hagedoorn 2002), this industry is still characterized by a high geographic and economic concentration. Focusing on the European market, there are only a few competitors acting in some main clusters in Europe, namely in the UK (Bristol, Lancashire, Farnborough), France (Toulouse, Bordeaux, Ile-de-France) and Germany (Bavaria, Hamburg, Bremen), which together account for over 70% of the European aerospace employees (see Figure 50). Another player is Italy; however, data on inward BERD at the sectoral level is scare for Italy, so we focus on the aforementioned countries. Conversely, it has to be mentioned, that almost all of the EU-15 countries have some aerospace activity due to historical reasons (Niosi and Zhegu 2005). This issue can be approached by the following two figures (Figure 51 and Figure 52).

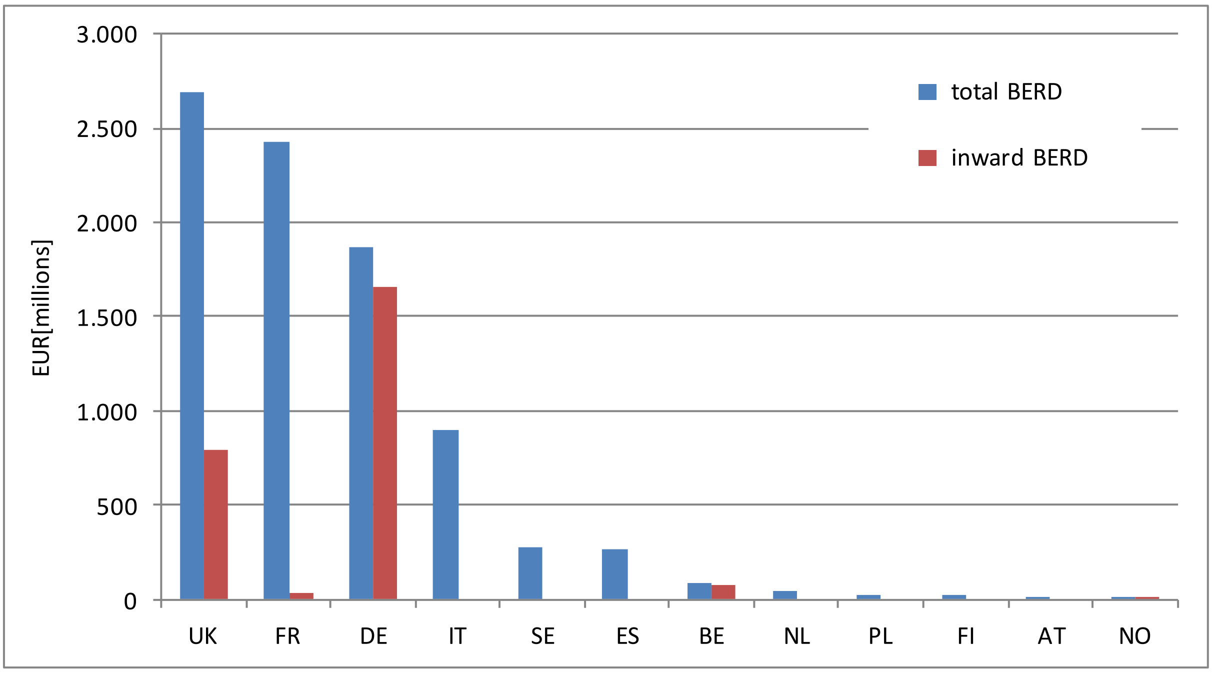
Differences between both figures regarding the countries where BERD and R&D investment are attributed to using different measures of research activities: BERD (Business expenditure on R&D) focuses on “measuring and aggregating expenditures by R&D performers at the national level, using a territorial principle based on where money is spent” (Azagra Caro and Grablowitz 2008, p. 4; Godin 2005; Lepori 2006). In contrast, R&D investments from the EU Industrial R&D Investment Scoreboard focus on “who does the research, thus measuring how much a corporate actor […] invests in R&D instead of using a territorial perspective on where the research is done” (Azagra Caro and Grablowitz 2008, p. 4). Accordingly, BERD provides data which may be aggregated at the level of countries or economic sectors (macro level); the Scoreboard data refers to individual data at the firm level (micro level), with additional information on country and economic sector of the firm so that data can be aggregated[31].

[31] For more detailed information on the characteristics and comparability of BERD and Scoreboard data, the reader is referred to “Data on Business R&D: Comparing BERD and the Scoreboard” (Azagra Caro and Grablowitz2008).

The large amount of total BERD in France (Figure 51) points towards the existence of large aerospace clusters in France (see also Figure 50), where Astrium, Eurocopter and Airbus, as well as Dassault Aviation (all of them fully or partially[32] belonging to the EADS Group) are headquartered. Nevertheless, it seems that data in the case of EADS is not correctly reported here. The EADS Group is headquartered in Netherlands, but there is no aerospace R&D activity in Netherlands itself. All R&D expenditure undertaken by the enterprises mentioned (in France) is attributed to be domestic BERD. They should however be reported as inward BERD, since the ultimate owner of most of these companies active in R&D in France is EADS in Netherlands.

The large amount of inward BERD in Germany may likewise mostly refer to R&D expenditure of the EADS Group, although being transferred from French headquarters to German R&D facilities, which again is actually transferred from Netherlands to German production and research sites. There is barely aircraft and spacecraft activity not belonging to the EADS Group in Germany. This explains the small amount of domestic R&D investments in Germany (Figure 52). Inward BERD in UK may be mainly assigned to the international Eurofighter joint venture. This joint venture is owned by BAE Systems (UK), EADS Deutschland (DE), Alenia (IT) and EADS CASA (ES) with a with a majority of the foreign partners, so it is considered as a foreign-owned firm. Subsuming, Figure 51 might better depict the location of R&D in aircraft and spacecraft, i.e. where R&D expenditure is spent, but not who – as the ultimate owner - invests in R&D. Nevertheless, data seem not be reported correctly at least in the case of EADS.

Figure 51: Total BERD and inward BERD per country in the aircraft and spacecraft industry (2007)

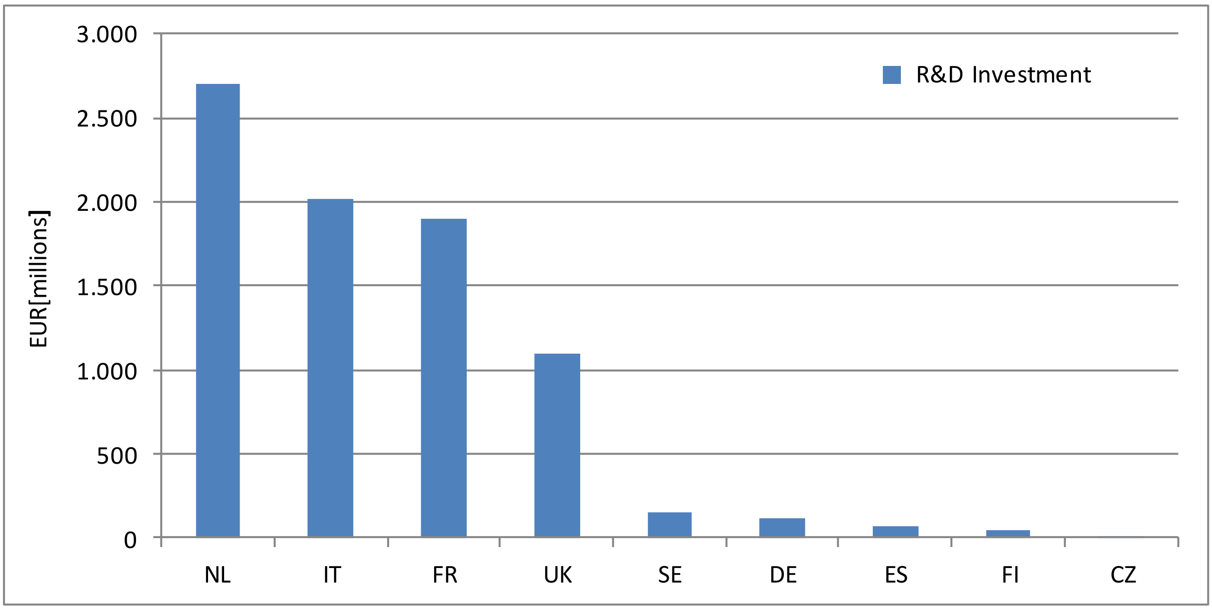


Note: total BERD 2006 instead of 2007: UK, FR, NL, FI; inward BERD: FR (2006), NL (2001); inward BERD no data available/confidential for NACE 35.5 Aircraft and spacecraft: IT, PL, AT; there is no inward BERD in the aerospace industry in Sweden, Netherlands and Finland

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

[32] EADS holds its interest of 46.32% in Dassault Aviation through EADS France.

Figure 52: Aggregated R&D investments per country in the aerospace and defence industry (2007)



Source: R&D ranking of the top 1000 EU companies by industrial sector - 2008 EU Industrial R&D Investment Scoreboard, own calculations

France versus India – two major players in the aerospace industry?

In the aerospace industry, like in most high-technological manufacturing industries, scientific excellence, a skilled workforce and low-cost labour are of major importance for location decisions. In France[33], high-level science and therefore a highly skilled workforce have led to a continuous growth of the aerospace industry. There are a number of major players in the worldwide aerospace industry located in France: Airbus, as a part of EADS, which can be assigned to be the leader in civil aircraft manufacturing (for the 6th year in a row); the Safran Group, including Turbomeca, the world's largest manufacturer of helicopter engines and SNECMA, a leading aerospace engine manufacturer; Eurocopter, also part of the EADS Group, the leading helicopter producer of the world; Dassault Aviation, the global leader in the high-end executive aviation market and major player in military aviation; Arianespace, a leading company in launching geostationary satellites; Thales Group, a global player in critical information systems in the aerospace, defence and security markets; and Thales Alenia Space, Europe's leader in satellite solutions and major player in the orbital infrastructure field. Besides the presence of world leaders and global players in the aerospace industry, its competitiveness has been further increased through numerous European cooperation programs and the presence of public bodies active in research, particularly the ONERA (National Aerospace Research Office, employing 2.000 people, of which 1.500 are research scientists), the CNES (National Space Exploration Centre, which participates in the European Space Agency programs), and CNRTs (National Centres for Specialized Research and Technologies). The quality of workforce is furthermore forced through highly regarded specialist schools (e.g. the ISAE and ENAC in Toulouse and ENSMA in Poitiers). France's strength in the aerospace sector has not only let to a growth of French aerospace firms, but has also attracted a large amount of foreign companies. These include foreign manufacturing

[33]The following mainly relies on information from the Invest in France Agency, and there on „France's centres of excellence: Aerospace industry 2009_10" (Invest in France 2010)

companies like Finmeccanica (IT), Goodrich, Honeywell or Rockwell Collins (all US), subcontractors and independent suppliers, accounting for nearly half of the sector's turnover (Invest in France 2009).

India's aerospace sector[34] seems to grow significantly in the following years, when looking at the foreign investment projects, both in terms of number and amount of capital invested. This, on the one hand refers to a combination of increased defence spending, a growing commercial aviation market (both civil and military) and rising technological and manufacturing capabilities; on the other hand the government is very keen to create a manufacturing hub in this sector. This rapid growth has attracted major global players from the aerospace industry; almost every large Western aerospace company is recently setting up their presence or already have built up sites in India. India's competitive advantage to a large part derives from its highly skilled workforce paired with low labour cost. This, however, is not only particular for the aerospace sector. Although, bearing in mind the immense cost of research in this sector, this actually is of major importance. Furthermore, India's geographical location between the major markets in East Asia, Middle East and Europe are in favour for an Indian location decision. Additionally, there is one more locational factor, which may be still gaining importance: the capabilities of Indian's information technology firms. Indian software companies such as HCL, Infosys, Infotech, Tata Consultancy Services and Wipro have already been active in the aerospace industry for several years. They are in turn benefitting from engineering service outsourcing programmes, helping India to evolve from IT and low-end business process outsourcing to high-end design services.

[34] For an overview of the development of Indian's most recent aerospace industry, see http://www.flightglobal.com/news/articles/indian-aerospace-industry-opens-up-338656/

4.4. R&D activities of foreign-owned firms in China

China has attracted a lot of R&D activities of foreign multinational firms in recent years. However, both data on outward BERD to China and on China's inward BERD is scarce. We further investigate the R&D activities of foreign-owned firms in China with some additional data that complements inward BERD data presented in the country fiche for China (see Deliverable 6, Part 3, section 5.1). Moreover, this case study will focus on R&D in the electronic and telecommunication sector, transport equipment, electrical machinery and equipment and non-electrical machinery.

4.4.1. R&D activities of foreign-owned firms in China measured by outward BERD

Only very few countries report R&D expenditure of their affiliates abroad (outward BERD), as demonstrated in section 1.3of this deliverable. Only four countries report R&D expenditure of their affiliates in China, namely Japan, the USA, Sweden and Italy. Slovenia reports outward BERD data, but there seems to be no Slovenian firm active in China. Israel reports 14.6 million EUR outward BERD to Asia in aggregate (including China, India, South Korea and Japan) for the year 2007. Only the USA and Sweden provide data for a longer period starting in 1998/1999. Japan reports outward BERD for the period 2003-2007, and Italy for a single year (2003) only (see Table 63 in Appendix 4).

From this data, the following broad picture emerges: The R&D expenditure by foreign enterprises in China is rising significantly over time; it increases faster than total outward BERD of the respective countries, but still takes a relative small share of around 4% of total outward BERD in the four countries. The relative importance of China as a location for R&D has increased most and reached the highest level for Japanese companies. In 2007, 5.2% of total outward BERD of Japanese firms were spent in China. However, given the very small number of countries, we cannot draw any conclusions on the development of aggregate outward BERD to China and there is also no information at the sectoral level available from this data source.

4.4.2. R&D activities of foreign-owned firms in China measured by inward BERD

We now turn to another source of information, which is inward BERD as reported by the Chinese authorities. There exist basically three sets of data on BERD in China. The Ministry of Science and Technology (MOST) calculates the R&D expenditure of *all business enterprises* (total BERD). However, this data set includes no corresponding data on R&D expenditure of foreign enterprises (inward BERD). The second data set is provided by the National Bureau of Statistics (NBS) for Census years only (2004, 2008/09). BERD is reported for *industrial enterprises above designated size*, i.e. enterprises from the mining & quarrying, manufacturing and the utilities sectors and with annual business revenue from principal activity of five million RMB (about 500,000 EUR) and above. Approximately 90% of total BERD is spent by these enterprises. R&D expenditure of domestic and of foreign enterprises (inward BERD) is presented separately (see Table 63 in Appendix 4). However, the most detailed data on inward BERD over a longer period of time (2004-2010) exist in a third data set only for *large and medium-sized industrial enterprises*, which were responsible for 80% of total BERD in 2008 (see Table 63 in Appendix 4).

All data sets show a similar strong increase of both total and inward BERD. Between 2004 and 2008, inward BERD nearly tripled, growing at an annual average rate of 28.8% (enterprises above designated size) and 29.7% (large and medium-sized enterprises). These rates are significantly higher than those of aggregate *outward* BERD to China during a comparable period (2003-2007), but compare well with the average annual growth rates of 'late-comer' Japan (31.3%); see Table 63 in Appendix 4[35]. The high growth rates of inward BERD in China seem to be the result of a low base level on the one hand and the dynamic development of general R&D activities on the other. Only in the case of large and medium-sized enterprises, inward BERD rose somewhat faster than total BERD and its share increased slightly from 27.0% to 27.2%, but declined again in the course of the global financial and economic crisis, standing at 26.1% in 2010.

Important source countries

Who are the foreign investors spending increasing amounts for R&D in China? NBR data for large and medium-sized enterprises show that firms funded from *Hong Kong, Macao & Taiwan* are typically responsible for about 30% of total foreign BERD. Unfortunately, beyond this, no break-down of R&D expenditure according to source countries is given by the Chinese statistical authorities. But we may draw on the information provided by a research team at Tsinghua University (Beijing), investigating the R&D activities of multinational enterprises (MNEs) in China, 2004-2006, using a questionnaire survey and interviews. The population studied are the Business Week Global 1000 (2004), supplemented by 12 Korean companies from the Fortune Global 500 (2003). Finally, 289 MNEs with business operations in China were contacted[36]. Out of these, 117 MNEs (41%) had some kind of R&D organisations in China and several had more than one. All together, 215 research organisations were identified. Out of these, 59 were classified as internal R&D units (27%) and 107 were described as autonomous R&D centres (50%)[37]. For the latter, a break-down by countries of the parent companies is presented (OECD 2008c, Table 5.11). The vast majority of parent companies are located in the USA (48.6%), followed by Japan (21.5%) and Europe (20.6%)[38]. South Korea is also an important source of R&D investments (8.4%), which 'seems to be closely related to the rise of high-tech industries, especially the IT industry, with key players such as Samsung and the globalisation of Korea's companies (OECD 2008c, p.280 and Table 5.11).

In the second stage of the research project, a more detailed investigation in Beijing and Shanghai followed. In Shanghai, 172 R&D organisations were contacted (including 66 internal R&D units and 105 independent R&D centres)[39]. Their parent countries were found to be more diverse than in the sample described before[40] and show a substantial share of MNEs from Hong Kong and Taiwan (20%) and 'other countries' (15%), including various Asian countries but 'tax havens' in the Caribbean (Virgin Islands, Cayman Islands etc.) as well. Accordingly, the share of US parent companies is considerably smaller than in the first sample (33%), although still dominant. Japanese and European companies show lower shares as well, of about 15% each (OECD, 2008c, Table 5.17). Korean companies take a share of

35 The USA, an 'early bird' with respect to R&D in China also realised much higher growth rates in the beginning with an annual average growth rates of outward BERD to China at about 95% over the period 1998-2002.

36 For a concise description of the project see Berger and Nones (2008), pp. 105 f. For more details see: Lan and Zheng (2007), pp. 35-51 and OECD (2008c), pp. 278 f.

37 Six of the R&D organisations were still under construction (3%) and the rest of 43 were characterised as 'R&D organisations jointly built with universities, science and research institutes and some technology centres or laboratories which have an R&D function' (OECD 2008c, Table 5.10).

38 United Kingdom, France and Germany (10.3%), Northern Europe, consisting of Denmark, Sweden, Norway Finland and Iceland (5.6%), other European countries (4.7%).

39 One does not fit in either category.

40 In 8 cases the parents were not identified, bringing the sample down to 164 firms

3%. This distribution of source countries is more in line with that observed for inward FDI in China, but nevertheless confirms the over-proportionate role of the 'Triade', and especially of the USA, in the globalisation of R&D found in earlier studies (e.g. Gassmann and von Zedtwitz 1998).

Discrepancies between inward and outward BERD

For comparison, we take the year 2007, for which most information on outward BERD is available. In that year, inward BERD of large and medium sized enterprises, which will include most western foreign firms, amounted to 61.5 billion RMB (around 6.1billion EUR). The aggregate of outward BERD calculated for that year comes up to 1.1 billion EUR, explaining 18% of total inward BERD only – despite the fact that major investors (USA, Japan) are among the reporters. Considering outward BERD of the USA (856 million EUR) and of Japan (110 million EUR) separately, gives shares in China's inward BERD of 14% for the USA and of 1.8% for Japan. Both look much too small in the light of the survey results from the Tsinghua University research team presented above and earlier findings according to which the USA, Western Europe and Japan are the main source of R&D investment[41] from abroad in China. We may thus conclude, that either outward BERD to China is significantly under-reported or inward BERD is over-estimated – or probably both. A thorough comparison of the methodologies and definitions for generating these figures is needed[42].

Ad hoc, the following reasons for a possible over-estimation of China's inward BERD can be given:

1. In case of a Chinese-Foreign Joint Venture, the full amount of R&D expenditure of that firm may be reported as inward BERD by the Chinese Statistical Office. JVs still comprise more than half of all foreign enterprises in China. To avoid that problem, some researchers take only wholly foreign-owned companies into account (In 2007, inward BERD would thus come up to 2.3 billion EUR instead of 6.1 billion EUR, see Table 1).
2. 'Round – tripping': this refers to the practice of Chinese investors to set up special purpose entities in territories outside China, including Hong Kong, for the purpose to invest in China and so benefit from financial incentives offered to foreign investors.[43] This may lead to an overestimation of foreign activity.
3. Deliberate over-reporting: as R&D activities often are a necessary condition for government support, foreign enterprises declare part of their activities related to product development as R&D[44].
4. Sometimes no clear distinction is made between realised and prospective R&D expenditure.

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[41] We are fully aware of the limited comparability of the survey results. But given the broad spectrum of investors identified in Shanghai and assuming that MNEs of the prominent countries spend more per R&D organisation than smaller countries, the percentage shares of this survey can be considered as lower bounds to the relative engagement of western MNEs in whole China rather.

[42] A similar discrepancy can be observed regarding the number of R&D centres in China: According to the Chinese Ministry of Commerce, there were more than 936 foreign R&D centres of various forms in China by the end of 2006. According to western researchers, the number was possibly around 350-450 by early 2007 (OECD 2008c, p. 273).

[43] However, the practice may be in decline as a result of the abolition of many foreign investment incentives from 2008 (Davis 2010, p. 3)

[44] Liefner (2006) presents the results of a survey covering 121 foreign high-tech enterprises in Shanghai in 2003. To be classified and officially acknowledged as a high-tech enterprise, the enterprise has to develop and to produce new products. But only 52% of the companies surveyed stated that they were in fact doing R&D (Berger and Nones 2008, p 110).

4.4.3. Sectoral analysis – R&D expenditure by ERA countries in China

There is no break-down according to individual sectors available for outward BERD of US or European firms to China. For China's inward BERD, a break-down by industries is given only for *manufacturing* business enterprises above designated size in Census years (2004 and 2008). As manufacturing enterprises are responsible for around 95% of total BERD of industrial enterprises and most foreign enterprises will be 'above designated size', the sample is quite representative. The Chinese industrial classification corresponds closely with the NACE rev. 1 classification, but has a stronger focus on electronics. In 2008, as presented in Deliverable 6, Part 3,Section 5.1, most inward BERD went to the electronic and telecommunication sector (30%), followed by transport equipment (16%), electrical machinery and equipment (11%) and non-electrical machinery (10%, including general purpose and special purpose machinery). The ranking was the same in 2004, but the electronic and communication equipment had attracted an even higher share (40%) in that year. These four industries were therefore chosen for a more detailed analysis. Together they were responsible for 66% of inward BERD in 2008[45]. In addition, we will include 'software and IT services' which do not belong to the manufacturing sector, but are known to attract a large amount of foreign R&D as well.

In our analysis, we will draw on the information provided by the FDI intelligence from the Financial Times[46] mainly (see Table below). This database refers to individual investment projects by source and destination country.

Table 15: Industry analysis: Number of R&D projects by sector

Sector	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total	Sharesi n %
Communications	1	10	6	4	5	7	1	3	2	39	22.8
Software & IT services	3	3	7	5	4	7	3	3		35	20.5
Automotive Components	1		6	2	2	3	1	4	3	22	12.9
Industrial Machinery, Equipment & Tools		2	2	1	3	3	4	2	4	21	12.3
Semiconductors		7		1	1	1	1	3	1	15	8.8
Automotive OEM	1	1	3			1	1	3	4	14	8.2
Consumer Electronics	1	1	3		1		1		2	9	5.3
Electronic Components	1			1	1			2	1	6	3.5
Engines & Turbines	1		1		1			1	2	6	3.5
Business Machines & Equipment			1					2		3	1.8
Aerospace		1								1	0.6
Overall Total	9	25	29	14	18	22	12	23	19	171	100.0

Note: Projects with the activities "research and development" and/or "Design, development and testing" included.

Source: FDI Intelligence from Financial Times Ltd (fDi Markets-database)

The information is based on press reports and may not be complete, but allows for the most up-to-date analysis possible (August 2011)[47]. Also, data concerning the size of the

[45] These industries were also among the top with respect to overall R&D 'input intensity' (ratio of R&D expenditure to business revenue from principal business) according to the Communiqué on National Expenditures on Science and Technology in 2008, p. 1

[46] fDi Markets database http://www.fdimarkets.com

investments and the employment generated are scarce and not all projects may be realised in the way, they were announced in the press. We have selected ‘research & development’ *and* ‘design, development and testing’ as relevant business activities for our analysis. However, the distinction between them is not always clear. The industries included were: communications, electronic components, semiconductors, consumer electronics, business machines & equipment; automotive OEM, non-automotive transport OEM, aerospace, automotive components; industrial machinery, equipment & tools, engines & turbines and software & IT services. The period covered is January 2003 to August 2011. The investor countries comprise ERA countries only.

Between January 2003 and August 2011, fDi Markets recorded a total of 171 investment projects of 100 companies. The leading activity was design, development and testing (68%), compared to R&D (32%). This suggests that so far ‘asset exploiting’ rather than ‘asset seeking’ is the main driver of ERA firms’ activities in China[48]. The leading sector was communications, with a total of 39 projects (23%), followed by software & IT services (20%), automotive components (13%) and industrial machinery, equipment and tools (12%). The number of projects in communications and software & IT services seem on a relative decline while projects in the automotive industry increased over time (see Table 15). This development is in line with the Census data cited before and reflects China’s rising role as a market for automobiles (in 2010, it has overtaken the USA to become the largest auto market of the world). As regards the source countries, Germany took the clear lead, with 53 investment projects (31%), followed by France (14.6%), the UK (14%), Finland (9.4%) and Sweden (8.8%). Switzerland (7.0%) and the Netherlands (5.9%) figure relatively prominently as well[49]. German projects cover a broad spectrum with a strong focus on the automotive sector and industrial machinery to a lesser extent. France concentrates on communications and on software & IT services with some prominent investments in automotives and machinery as well. UK concentrates even more on communications and also on software & IT. Finland has projects in communication and software & IT only. Sweden, too, has many projects in communications and few in industrial machinery, in consumer electronics and in the automotive sector. The projects of Swiss companies are more diverse with a certain focus on semiconductors. Firms from the Netherlands concentrate on semiconductors as well, but have a relative high share of consumer electronics, too. Table 16 gives a list of the 10 companies with most R&D projects reported in the period 2003 to 2011. Siemens takes the lead, followed by Nokia and Ericsson.

Regarding the size of investment, we have to confine ourselves to the information available on ‘committed’ investments as reported or estimated by fDi Markets for the different projects[50]. According to this rather vague indicator for the actual size of investment, Germany again turns out as the top investor, with 2.3 billion EUR investment committed for R&D and ‘design, development and testing’ projects between January 2003 and August 2011. The second rank is taken by Finland (1.4 billion EUR – ranking 4th by the number of projects), followed by France (788 million EUR). Sweden, like Finland, seems to engage in relatively large projects (557 million EUR) and is ranking 4^{th,} before the UK (547 million EUR). All together, fDi Market data suggest that ERA countries’ investment commitments related to

47 On the other hand, some double-counting of projects occurs as well.

48 A possible exception is ‘Communication’, where most R&D projects were reported, and where China has become the ‘lead market’ of the world.

49 The information on source countries and their shares in total projects is drawn from the fDi Markets data list of investments.

50 Unfortunately, this data is a mixture of committed initial investments (the company will invest 5 Mio USD in a new technical center), cumulative investments (the company will invest 10 Mio USD until 2014) and sometimes annual investments (the company will continue investing 1 Mio USD annually).

research & development respectively design, development and testing in China came up to 7.2 billion EUR in the period 2003-2011.

Table 16: Company analysis: R&D projects by year

Company	Source Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Siemens	Germany		2	2	1	1				1	7
Nokia	Finland		1	3	1					1	6
Ericsson	Sweden		2	2			1		1		6
Robert Bosch	Germany			4			1		1		6
SAP	Germany	1	1	1	2						5
Infineon Technologies	Germany		2		1	1			1		5
France Telecom	France		3				1				4
picoChip	UK		1		1				2		4
STMicroelectronics	Switzerland		3		1						4
Valeo	France	2			1					1	4
Other Companies		6	10	17	6	16	19	12	18	16	120
Overall Total		9	25	29	14	18	22	12	23	19	171

Note: Projects with the activities "research and development" and/or "Design, development and testing" included.

Source: FDI Intelligence from Financial Times Ltd (fDi Markets-database)

For illustration, the profiles of some recent research projects by ERA companies in China are presented in Appendix 4

4.5. Internationalisation of R&D in the automotive sector of the Czech Republic, Hungary, Slovakia and Romania

The automotive industry is classified as a medium-high technology industry based on its R&D intensity, thus accounting for a large share of total R&D. In addition, the sector is highly internationalised. In the EU-12 (former 'new member states') the automotive industry benefited from strong inflow of foreign direct investment which provided a strong impetus for inward business expenditure on research and development (inward BERD). Looking more deeply at the Czech Republic, Slovakia, Hungary and Romania, we will examine the importance of the automotive sector for FDI and R&D internationalisation in these four countries: Have R&D activities undertaken by foreign-owned affiliates simply followed the pattern of FDI flows? We will then look at what factors determine the extent of R&D undertaken by foreign subsidiaries and examine why some countries are more attractive than others.

4.5.1. The automotive sector and its R&D internationalisation pattern in the EU-12

The automotive sector, defined according to the NACE rev.1. classification system as section 34 'motor vehicles, trailers and semi-trailers', is the most important manufacturing sector in the Czech Republic, Hungary and Slovakia where it accounts for production shares of 19%, 18% and 21% respectively. Only in Romania, the automotive sector is comparably smaller and has only a share of 6%. Here the food, coke and basic metals industries are relatively more important (see Table 17). Overall, the inflow of foreign investment has shaped the automotive industry in the EU-12. Today, the automotive sector accounts for 25% of manufacturing inward stock of foreign direct investment (FDI) in the Czech Republic, 23% in Hungary and Slovakia and 11% in Romania. In the first three countries, the automotive industry is the major recipient of foreign investment, while in Romania it is again on the fourth place (see Table 17).

Table 17: Overview of the automotive industry (NACE rev.1: 34), 2008

	Production, in % of total manuf.	**FDI inward stock, in % of total manuf.**	**BERD, in % of total manuf.**
Czech Republic	19.3 1)	24.9	39.1
Hungary	17.6	23.1 1)	13.8 2)
Romania	6.3 2)	10.6 1)	25.2 2)
Slovak Republic	21.0	23.4	0.0 2)

Notes: 1) NACE 34+35.- 2) 2007

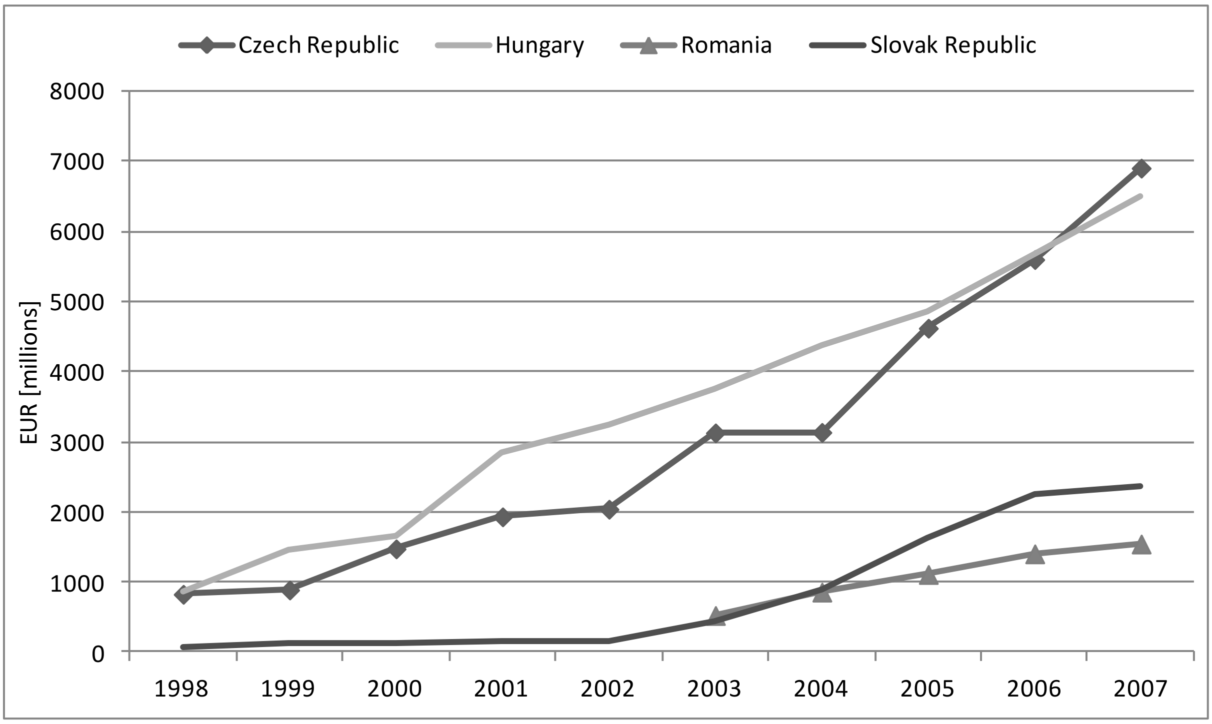
Source: wiiw Industrial Database, wiiw FDI Database, EUROSTAT BERD statistics.

Since the collapse of communism in 1989, the inflow of foreign direct investment shaped the automotive industries in the EU-12 and transformed it into a competitive, export-oriented industry. The first foreign company to arrive was Volkswagen in the Czech and Slovak Republics in 1991 (still Czechoslovakia then). Volkswagen formed joint-ventures with already existing companies which became Škoda Auto and VW Bratislava respectively (Hanzl 1999). However, foreign investment climate was unfavourable in these first years in the Czech Republic and Slovakia, other than in Hungary. Hungary opened its economy for foreign investors soon after 1989 and automotive investors arrived quickly in the country: Opel (engines) and Suzuki came in 1992, Audi (engines) in 1993 – all by means of green-field investments – and suppliers soon followed. In Romania, Daewoo from South Korea formed a joint-venture in 1994, Renault acquired 51% of Automobile Dacia Piteşti in 1999 with whom it had a long-time licence agreement (see Hanzl 1999).

After this first wave of privatization and investments in the 1990s, the automotive industry continued to attract FDI in the 2000s as well: Choosing Slovakia, PSA Peugeot Citröen announced to build a green-field plant in 2003; Kia Motors in 2004. Production started in both plants in 2006. Locating in the Czech Republic, Toyota Peugeot Citröen made an investment decision in 2002 and started production in early 2005. Hyundai announced to invest in the Czech Republic in 2005, following its sister company KIA, and the plant was completed in 2008. Finally in Hungary, Mercedes decided to build an assembly plant in Kecskemét in 2008. Production is to begin in 2012. Only in Romania, the investment path was not that smooth: Due to the collapse of the main parent company Daewoo, the Romanian company got into troubles and the state took over shares from the Automobile Craiova company in 2006. Stakes of the company were sold step-by-step to Ford between 2007 and 2009.

Thus the stock of FDI in the automotive sector in the Czech Republic and Hungary climbed from 800 million EUR in 1998 to 6.9 billion EUR and 6.4 billion EUR in 2007 respectively (see Figure 53). In Slovakia, the stock was quite low until 2002 (around 140 million EUR) but started to rise afterwards. In 2007, it already reached 2.3 billion EUR. For Romania, data are only available from 2003 onwards. Here we observe a slight increase and a stock of 1.5 billion EUR in 2007.

Figure 53: FDI inward stock in the automotive sector (NACE rev.1: 34)



Notes: 35+45 for Hungary and Romania.

Source: wiiw FDI Database.

Looking now at patterns of R&D in the automotive industry and internationalisation, generally the automotive sector belongs to the sectors with the largest investment in R&D (see e.g. UNCTAD 2005; European Commission 2011). Furthermore, internationalisation of R&D, i.e. the growing role of foreign affiliates in host-country R&D, is important in the automotive industry as well (see e.g. UNCTAD 2005; OECD 2008a). Also in the EU-12, the automotive industry accounts for a large share of total business expenditure on R&D within total manufacturing (see Table 17): it is highest in the Czech Republic with 39%, 25% in Romania and 14% in Hungary. For Slovakia, data was zero for the year 2007. Internationalisation of R&D is strong in the EU-12 as well: the automotive industry's share in total inward BERD (i.e. the simple inward sector penetration rate, see Table 18) stood at 40% in the Czech Republic in 2007, at 26% in Hungary but was lower in Slovakia and Romania.

Table 18: Indicators on BERD and inward BERD (in million EUR) in motor vehicles, trailers & semi trailers (NACE rev.1: 34)

	BERD	Inward BERD	Inward sectoral R&D intensity, in %		Simple inward sector penetration, in %	
	2007	2007	2003	2007	2003	2007
Czech Republic	289.8	275.7	95.5	95.1	56.0	40.4
Hungary	49.9	53.5	81.6 1)2)	100.0	16.3 1)	25.7
Romania	35.0	0.3	7.6 1)	0.9	11.6 1)	0.4
Slovak Republic	0	(c)	.	.	0 1)	3.9 3)

Notes: 1) 2004; 2) Total BERD includes only manufacturing; 3) 2006.

Source: EUROSTAT BERD statistics, Czech Statistical Office, EUROSTAT FATS statistics.

It is interesting to compare total amounts of R&D expenditure with FDI-figures stated above: Although the stock of FDI is nearly the same in the Czech Republic and Hungary, R&D expenditure is six times higher in the Czech Republic positioning the country as the hub of automotive R&D in the region. R&D is, however, dominated by foreign investors, as the figures for the inward sectoral R&D intensity in Table 18 suggest (nearly 100% in the Czech Republic and Hungary). R&D internationalisation is small in Romania and fluctuating over years. For Slovakia, data for BERD as well as for inward BERD are confidential in some years, but zero for others. This is striking as the motor vehicles industry is a major recipient of FDI in the Slovak Republic which is not reflected in the data on inward BERD. This suggests that large automotive companies do not perform R&D activities in the Slovak Republic but rather transfer technology from their home countries.

4.5.2. Motives and drivers of R&D internationalisation

Various motives and drivers for R&D internationalisation are cited in the literature. The most often mentioned ones are (see UNCTAD 2005 or Deliverable 1): the adaptation of products and processes to local market characteristics (demand-side, asset-exploiting behaviour), and the presence and costs of highly skilled labour force (supply-side, asset-seeking behaviour). Often, policy-factors are mentioned as well (e.g. tax breaks or subsidies). In order to investigate the importance of these motives and drivers for the automotive industry in the EU-12, we use a range of sources: scientific literature, the fDi Markets database, information from investment agencies and company case studies. In this section we will provide some general remarks on motives and drivers, followed by an analysis based on fDi Markets database, while the next section goes into detail per country.

Generally one has to acknowledge the specific history of the EU-12, starting with the heritage of the communist regime, its collapse in 1989 and the transition period following thereafter. Transformation encompassed the change to market systems, the opening up of trade and privatisation. Prospects for EU-accession shaped the economy and policy thereafter including e.g. the adoption of the EU acquis. With accession to the EU on 1st May 2004 for the Czech Republic, Hungary, and Slovakia and on 1st January 2007 for Romania, again framework conditions changed. A variety of European funds and programmes became accessibly for these countries, the support for science and research increased. Regarding these factors – which themselves can be seen as motives and drivers – general motives and drivers for R&D internationalisation were subject to change during this long time period.

We can broadly group motives and drivers into three groups: (1) heritage from communism, (2) historical motives, mainly encompassing the 1990s and (3) recent motives, encompassing the period from 2000 until today.

Indeed, Kubeczko et al. (2006) stress the importance of “R&D histories” as a result of path dependencies. Thus, recent patterns of R&D in the automotive sector can partly be explained by specialisation patterns already existing during the communist regime. Under the Council for Mutual Economic Assistance (CMEA) division of labour, the Czech Republic specialised on cars (Škoda), Hungary on buses and on components, Slovakia on lights trucks. Romania was not integrated in the CMEA system and tried to produce everything (companies Dacia and Oltcit, see Hanzl 1999).

Based on sectoral case studies on the motor vehicles and pharmaceutical industries, Kubeczko et al. (2006) conclude that foreign investment in R&D in the EU-12 was driven by three main factors (thus relating to historical reasons): the quality on human resources, the labour costs and the access to local markets. Especially the long-run tradition of the automotive industry in the Czech Republic is highlighted, as well as the availability of highly qualified R&D personnel. On the other hand, favourable framework conditions including tax incentives were found to be overestimated.

Overall, historical reasons can change, e.g. the abundance of qualified labour which can turn into a shortage of qualified personnel today. Overall, the FDI analysis in the next section provides a picture on recent motives and drivers.

4.5.3. Recent motives and drivers

An overview of investment projects in the automotive R&D sector can be provided with the help of information from the FDI Intelligence from the Financial Times (fDi Markets database[51]). This database draws on press reports and presents individual investment projects by source and destination countries. It goes back until January 2003 and is very up-to-date (September 2011 at the time of writing). For individual projects, the investment sum, the employment generated and – although only in a few cases – the reason for investing is provided. Investment projects include new ones, expansion and co-location. Although the database may not be complete, it provides a recent overview of the sector.

[51] Available at http://www.fdimarkets.com

The automotive sector was defined as automotive OEM plus automotive components, while for the business activity we selected “research and development” as well as “design, development and testing”. Overall, in the period between January 2003 and September 2011, fDI Markets recorded 29 investment projects from 16 companies in the automotive sector for these 2 business activities in the Czech Republic, Hungary, Romania and Slovakia. The main results are:

- The leading activity was “design, development and testing” accounting for 79% of all investment projects, only 21% were “research and development” projects. These latter projects were announced only by automotive components suppliers and *not* by OEMs and were mainly registered for Hungary (67%), 17% for the Czech Republic and 17% for Slovakia and none for Romania.
- Within the automotive industry, the majority of projects were done by automotive suppliers, with 72% of all investment projects. Only 28% were done by OEMs with a strong focus on Romania (Renault, also Ford), less on the Czech Republic (VW, Daimler Chrysler).
- Regarding the source country of investment, Germany accounted for the highest number of investment projects (55%), followed by France (21%), the United States (14%), the UK (7%) and Sweden (3%).
- Looking at the country attracting the greatest number of projects, 34% of all projects were registered in Hungary (Robert Bosch with 4 projects), 31% in the Czech Republic, 28% in Romania and 7% in Slovakia (meaning only 2 investment projects!, see Table 19).
- Referring to companies, Robert Bosch was the most active in the region (with 4 projects is Hungary and 2 in the Czech Republic), followed by Renault with 5 projects in Romania (see Table 20).

Table 19: Destination country analysis: projects per year

Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total	Total in %
Hungary			1	3	1	4		1		**10**	34.5
Czech Republic	2	3		2	1			1		**9**	31.0
Romania				2	1	1	1	2	1	**8**	27.6
Slovakia		1				1				**2**	6.9
Overall Total	**2**	**4**	**1**	**7**	**3**	**6**	**1**	**4**	**1**	**29**	100.0

Note: Only projects with the activities “research and development" and/or "Design, development and testing”

Source: FDI Intelligence from Financial Times Ltd (fDi Markets database), September 2011.

Within the fDI Markets database only a few information is provided on the motives for investing. In our sample, reasons for 5 investment projects were available (see Box 1 below). In four cases (representing all four countries!), the availability of skilled workforce was mentioned. Infrastructure & logistics, the presence of suppliers or joint venture partners, the proximity to markets or customers and lower costs were each mentioned two times. The domestic market growth was only referred to in Romania, financial incentives were also mentioned only once (also in Romania).

Table 20: Company analysis: projects per year per country

Company	Source Country	2003	2004	2005	2006	2007	2008	2009	2010	2011	Total
Robert Bosch	Germany		CZ	HU	CZ, HU		HU		HU		**6**
Renault	France				RO	RO	RO		RO	RO	**5**
Continental	Germany						HU	RO			**2**
ZF Friedrichshafen	Germany				HU	CZ					**2**
Visteon	United States		CZ				SK				**2**
Knorr Bremse	Germany						HU, HU				**2**
Ricardo	UK		CZ								**1**
Volkswagen	Germany				CZ						**1**
Ford	United States								RO		**1**
Valeo	France	CZ									**1**
Other Companies		CR	SK	0	RO,HU	HU	0	0	CZ	0	**6**
Overall Total		**2**	**4**	**1**	**7**	**3**	**6**	**1**	**4**	**1**	**29**

Note: Only projects with the activities "research and development" and/or "Design, development and testing"

Source: FDI Intelligence from Financial Times Ltd (fDi Markets-database), September 2011

Box 1

Reasons for investing

Romania (2008): Infrastructure and logistics, presence of suppliers or joint venture partners, skilled workforce availability

Hungary (2008): Lower costs, proximity to markets or customers, skilled workforce availability

Romania (2006): Domestic market growth potential, finance incentives or taxes or funding, Investment Promotion Agency or government support, lower costs

Slovakia (2004): Infrastructure and logistics, proximity to markets or customers, regulations or business climate, skilled workforce availability

Czech Republic (2004): Presence of suppliers or joint venture partners, skilled workforce availability

Source: FDI Intelligence from Financial Times Ltd (fDi Markets-database), September 2011

4.5.4. Country analysis

This section provide information on the R&D in the automotive industry itself, provides motives and drivers promoted by investment agencies today and as well as historical facts. Information is supplemented by company case studies.

Czech Republic

Today, there are more than thirty R&D companies in the Czech automotive sector including Porsche Engineering Services, Mercedes-Benz Technology, Ricardo, Idiada, Swell, Valeo, Visteon, Aufeer Design, Valeo, Visteon, Bosch, Continental, Honeywell, Siemens, TRW, ZF Automotive and many others (Czech Invest 2011). The Czech investment agency CzechInvest promotes the following factors for R&D establishment: the well-established automotive market, high-level technical education, local industrial tradition and highly skilled engineers. There is only one automotive cluster in the Czech Republic, the Moravian-Silesian Automotive Cluster (Janosec 2010).

During the 1980s, only the former Czechoslovakia and East Germany were developing their own passenger cars, other car manufacturers in the region were producing under licences from West European firms. With the collapse of communism, privatisation decided over the future of R&D departments, with some companies closing or scaling down their R&D activities. According to Pavlinek et al. (2010), the majority of factory-related R&D centres in the Czech automotive industry survived. The most successful privatisation was that of Škoda Auto, where R&D was maintained and later further extended. In fact, Pavlinek et al. (2010) stress the concentration of Czech automotive R&D on Škoda Auto, which holds more than 75% of total R&D in the sector (see company case study below). In 1998, the government introduced a system of investment incentives for foreign and domestic investors. In 2004, a number of companies decided to build R&D centres (Siemens Automotive Systems, Robert Bosch, Behr Czech Ltd.). Since 2005, R&D is supported indirectly through a new tax regulation which allows deducting R&D expenses from the tax base (Kubeczko et al. 2006). Overall, Pavlinek et al. (2010) state, that between 1995 and 2007, the number of larger automotive R&D centres with 100 and more employees raised from 4 to 5 only, that of small R&D facilities with less than 20 employees, however, increased from 35 to 88 during this period. Thus, Škoda Auto retained its dominant position but the importance of large foreign-owned first-tier suppliers grew. Pavlinek et al. (2010) concludes that suppliers concentrate R&D on technical support, adaptation, testing and development of vehicle part and not on applied and basic research.

Čadil et al. (2007) distinguish between historical motives and still present motives for setting up R&D activities in the Czech Republic: Historical motives include the start of the privatization process as a main milestone for R&D investment, second the high quality and low cost of human resources due to long industrial tradition, and third, the strategic location of the Czech Republic with its proximity to Germany together with good infrastructure. Čadil et al. (2007) also see a shift of localisation motives from low cost strategy to sophisticated intensive strategies, based on the quality of domestic R&D infrastructure including universities and research institutions today. In addition, investment incentive schemes are "now considered as one of the most important factors for establishment of R&D activities" (Čadil et al. 2007, p. 27). From the historical motives, skilled labour force, industrial tradition and geographical position are still relevant. However, also certain drawbacks are mentioned. These are the lack of qualified labour today, low quality of R&D management, low level of corporation (research institutes and multinationals), as well as low support of R&D activities in large multinationals (see Čadil et al. 2007). Pavlinek et al. (2010) mention a number of factors prevailing recently for foreign companies to develop automotive R&D in the Czech Republic. These include the well-developed supplier sector, industrial tradition, level of technical education, government investment incentives and the need for first-tier suppliers to cooperate closely with assemblers on R&D (Pavlinek et al. 2010, p. 486).

Škoda Auto: Taken over by VW at the beginning of the 1990s, Škoda Auto maintained its brand and its pre-1989 R&D facilities. Later on, further functions were developed and some routine R&D operations were transferred to the company e.g. computer aided design in 1999. Motives for these steps included the cheaper and skilled R&D labour force as well as its abundance. "The basic goal is to adapt VW technologies for Škoda models and to design Škoda models based on VW Group's platforms" (Pavlinek et al., 2010). Besides opening a design centre, Škoda Auto established a technology centre in Mladá Boleslav in 2008 that delivers R&D solutions for the entire Volkswagen Group (Czech Invest, 2011). Thus, the number of R&D employees rose from 600 in 1991 to 1420 in 2005 and 1563 in 2008 (see Kubeczko et al. 2006, p.53).

Box 2

Why the Czech Republic?

The Czech Republic has become the hub of automotive R&D expenditure in the region, thanks to one company – that is Škoda Auto. Pavlinek et al. (2010), state that Škoda Auto accounts for more than 75% of Czech automotive R&D. "Without Škoda Auto, the Czech automotive R&D expenditures would be only slightly higher than those of Hungary" (see Pavlinek et al. 2010). The authors cite two reasons: First, integration in the VW structure, retaining its brand and maintaining previous R&D facilities and second, the cheap and skilled R&D labour force. A previous study of Ženka and Čadil (2009, cited there) also stress the existence of pre-1989 R&D centers, surviving the transition period. Finally, Pavlinek et al. (2010) concludes that

"a relatively strong automotive R&D in Czechia compared to other CE countries can be explained by the presence of Škoda Auto, a tier two focal firm, and by the path dependent nature of the Czech automotive R&D (i.e. the majority of large factory-related R&D centres had been established before 1990. After 1990 they were acquired and further expanded by transnational corporations)".

Thus, Škoda Auto has retained more competencies than other car manufacturers in the region. For comparison, VW Bratislava has been relatively smaller and Slovak car companies do not perform R&D activities but rather transfer technology from their home countries i.e. mother companies. Hungary has built up certain R&D capabilities in automotive components (in which it was already specialised before 1990).

Hungary

Several multinationals have set up R&D centres in Hungary e.g. Audi, Bosch, Knorr-Bremse, Magna-Steyr, ThyssenKrupp, Arvin Meritor, Denso, Continental, Visteon, WET, Draxlmaier, Edag, Temic Telefunken, DENSO and ZF. The Hungarian Investment and Trade Development Agency (ITDH 2010) considers the following factors favourable for locating automotive R&D in Hungary today: (a) Hungary's strategic position, together with developed logistics and infrastructure (four trans-European motorways running through Hungary). Reaching the Balkan, Ukraine and Russia are also mentioned. (b) Membership in the EU implies taking over the EU-acquis (concerning safety and quality regulations, data security or intellectual property rights) but also a market of 483 million people. (c) A pool of already present suppliers, with "fourteen of the world's top 20 Tier-1 suppliers already being in Hungary" (ITDH 2010). In addition, "Hungary is the regional leader in the production of petrol engines" (ITDH 2010). (d) Highly skilled and cheap labour force together with academic and university infrastructure carrying out automotive-related R&D. (e) And finally a supportive government policy (see ITDH 2010). Overall, ITDH also stresses the history of automotive inventors in Hungary. In addition, several clusters were established, i.e. the Pannon Automotive Cluster (PANAC), the North Hungarian Automotive Cluster (NOHAC), and the Hungarian Vehicle Development Cluster (MAJÁK).

During the last twenty years, foreign investors have faced different environments in Hungary leading to different behaviour. Inzelt (2000) distinguishes two periods for FDI in R&D: The first period, from late socialism in 1988[52] to 1996/1997, as a phase of "acquaintance and adjustment" and a second period from 1996/1997 onwards as a phase of "feeling at home". The environment during the first period was characterized by opening up the economy, mass privatization and building of a market economy. "The acquisition of an R&D laboratory was usually an accident. The laboratory was part of the privatized company's package" (Inzelt 2000, p. 250). Foreign investors were reluctant to set up new laboratories and the "role of host countries was technology adoption" (Inzelt 2000, p.248). At the beginning of the second period, the Hungarian government encouraged FDI in R&D by launching of direct measures including tax concessions, co-financing schemes for setting up competence centres, and university-industry cooperative research laboratories. Motivated by this incentive programme,in addition to cheap and skilled labour, Audi and Knorr-Bremse established R&D units in Hungary (OECD 2000). Hence, Inzelt (2000) sees a new trend in this second period with a new behaviour of investors and an increase in investment in R&D. Also Kubeczko et al. (2006) state that, "some foreign investors have also realized the world-class knowledge of Hungarian scientists and engineers, and setting up either in-house R&D units or joint research groups with universities" (Kubeczko et al. 2006, p. 30). In addition to cost advantages, a new R&D scheme launched in 2006 encouraged R&D.

Knorr-Bremse: Knorr-Bremse already established contacts to Hungary in 1969 when it had a licence contract for brake systems for the Hungarian IKARUS bus producer. In 1989, it formed a joint venture called KB-SZIM but became the whole owner in 1993. In 1995, the R&D centre was established in Budapest for electronic development and a R&D group in Kecskemét. In 1999, a new R&D centre was built (see Palkovics 2010). Knorr-Bremse had a good cooperation with Budapest Technical Univestity from the beginning (Biegelbauer et al. 2001). The main motivations of Knorr-Bremse to found R&D in Hungary were (see Palkovics 2010): a high level university system with world-wide accepted schools for vehicle system dynamics in Hungary; original ideas leading to innovate products; a proper attitude of engineers and high efficiency; lower development costs; long term scientific cooperation between Knorr-Bremse and research place in Hungary; availability of highly qualified personal (in contrary to Western Europe at that time); active personal contacts in the past; cultural issues not forming a barrier and government level support. R&D investment schemes approved by the government in 1997 also contributed to the new investment in 1999 (Business Eastern Europe August 24, 1998).

Romania

R&D in the Romanian automotive industry has particularly developed since 2005. Selected foreign companies have invested in Romania such as Continental, Siemens, Ina Schaeffer etc. The establishment of Renault Technology Romania significantly increased R&D expenditure in Romania (see also below).[53] Factors speaking in favour for investing in the Romanian automotive industry in general include its strategic position with great development potential, engineering tradition, technical education and built domestic R&D network, presence of car manufacturers and suppliers, cheap and relatively high qualified labour force and a positive attitude of the government to foreign investments in the automotive industry (see Švač et al. 2010). There is one automotive-cluster in the country.

[52] In 1988, there was already an act on the investment of foreigners in Hungary passed by the parliament (see Inzelt 2000, p. 245).

[53] See ACEA – European Automobile Manufacturers' Association http://www.acea.be/index.php/country_profiles/detail/romania (download November 21, 2011)

Selected automotive R&D investments:

- Renault Technology Romania (RTR): The engineering centre was set up in 2006 by Renault (France). Main fields of RTR's activity are designing and improving vehicles and adapting engines and powertrains. It is located at three sites: Bucharest (design offices), Piteşti (engineering services at body assembly and powertrain plants) and Titu, where a testing centre was opened in 2010. According to Renault, "to be competitive, Renault needs to be close to local customers and to fast-changing consumer tastes on the new markets".[54] In 2009, RTR employed about 2,200 people, with the announcement of an additional 800 to be added.[55]
- Continental Automotive (Germany): Overall, Continental has three R&D centres in Romania (Timişoara, Sibiu and Iaşi). In 2000, Continental Automotive Timisoara (former Siemens VDO, acquired by the Continental corporation in 2007) started its activities in Timisoara with an R&D centre. The Continental Automotive Divisions added in 2006 an electronic unit plant in Timisoara and an R&D centre in Iaşi. The Automotive divisions in Sibiu inaugurated the same year a new R&D centre.[56]
- Ford: US car maker Ford planned to build a technical centre in Craiova, Romania, in November 2010, where it will develop new models. The company will invest several hundred million Euros into the facility, which will create a brand new concept and feature a technological and innovation centre. Ford hopes that its new facility will rival that of Renault Technologie Roumanie's centre located in Titu (FDI Intelligence from Financial Times Ltd September 2011).

Slovak Republic

Today, main R&D centres in Slovakia are Johnson Controls Engineering Centre Trenčin, R&D LEONI Autokabel Slowakia Trenčin, Continental Automotive Systems R&D Centre Zvolen, ON Semiconductor Bratislava Development Centre, Technolgy Lab Siemens Žilina or ZKW Slovakia R&D centre Krušovice (SARIO 2011). The Slovak Investment and Trade Development Agency (SARIO 2011) presents the following key facts that speak in favour of Slovakia as a location for R&D: highly qualified human resources at affordable costs; presence of production plant operation in high-tech and medium high-tech industries; presence of foreign R&D centres and technology clusters; a broad domestic R&D and innovation network; established cooperation between industries and domestic universities and R&D incentives. There is one automotive cluster in Slovakia, the Automotive Cluster-West Slovakia.

Selected automotive R&D investments:

- Johnson Controls (United States) runs one of the biggest technology centres in Slovakia for design of automotive components, system and modules. It opened in 2004 and now employs 500 employees, in order to "extend the engineering network to include the Eastern European growth markets and to respond to customers' growing presence

[54] http://www.renault.com/en/groupe/renault-dans-le-monde/pages/renault-en-roumanie.aspx (download November 21, 2011)

[55] http://www.autoevolution.com/news/renault-to-launch-200-new-logan-trim-versions-4258.html (download November 21,2011)

[56] http://www.conti-online.com/generator/www/com/en/continental/pressportal/themes/press_releases/2_corporation/locations/pr_2010_06_11_10years_automotive_romania_en.html (download November 21, 2011)

there".[57]Reasons for investing include: infrastructure and logistics, proximity to markets or customers, regulations or business climate, as well as skilled workforce availability (FDI Intelligence from Financial Times Ltd September 2011).

- Continental Automotive Systems R&D centre Slovakia (Germany): Gerhad Baucke, the plant manager, states the following reason to invest in Slovakia (SARIO 2011): "The main reason why we decided to establish R&D in Slovakia is the fact that Slovakia is still considered to be a Best-Cost-Country; secondly the region of Banska Bystrica we chose offers well educated and qualified young engineers and furthermore our plant in Zvolen is in the closed proximity to the Technical University of Zvolen".[58]
- ZKW Slovakia, affiliate of the Austrian ZIZALA Lichtsysteme GmbH, planned to build a technology centre in 2010 for EUR 2.3 million, creating 32 new jobs.[59]

4.5.5. Conclusions

Overall, the automotive industry is an important manufacturing sector in the EU-12, reshaped by massive inflow of foreign direct investment. The sector accounts for large share of R&D business expenditure, except in Slovakia, where R&D is generally very low. Internationalisation of R&D is pronounced in the Czech Republic and Hungary. In these two countries foreign affiliates are responsible for nearly all R&D expenditure in the automotive industry. Overall, the Czech Republic has positioned itself as the hub for automotive R&D in the region, thanks to one firm.

Although the share of FDI in total manufacturing for the automotive sector is nearly the same in the Czech Republic, Hungary and Slovakia, and investment stock is nearly the same in the Czech Republic and Hungary, the amount of inward BERD significantly differs between these countries, ranging very high in the Czech Republic, to a sixth in Hungary and practically zero in Slovakia. Hence, a high amount of FDI does not mean that R&D is "simply" following. The presence and willingness of a large automotive assembler to transfer R&D activity to the region turned out to be of vital importance. However, this transfer occurred gradually – from assembly to high tech products to R&D – mainly acknowledging the presence of skilled labour force.

Overall, old specialisation patterns turned out to be an important localisation motive for R&D in the automotive industry in the EU-12 in terms of providing skilled labour force. In addition, low labour costs as well as government incentives seem to be crucial in the 1990s, while a learning process and a shift of strategies and behaviour of investors took place at the end of 2000s. Besides the skilled and cheap labour force, adaptation of technologies plays a role, the geographical position and logistics, government invectives and path dependencies e.g. the building up of a supplier-network in these countries are of importance. 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.

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[57] See Johnson Controls-Homepage www. jci.cin (download November 11, 2011)

[58] SARIO lists the investment of Continental Systems in R&D in the year 2009.

[59] http://portal.wko.at/wk/format_detail.wk?AngID=1&StID=554266&DstID=0&titel=Slowakei:, ZKW,Slovakia,will,Technologiezentrum,um,2,3,Mio.,Euro,bauen

5. R&D ACTIVITIES OF NON-EUROPEAN COMPANIES IN THE ERA

5.1. 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, we were only able to add Swiss and Norwegian data to the EU-27 aggregate. Other ERA countries are not available and not included. US firms account for 82.5% of the BERD of all non-European companies in the ERA. However, the outstanding role of the US is discussed separately in section 1.4. In the following figure we therefore focus on the remaining 17.5% or 2.9 billion EUR of BERD investments in the ERA in 2007.

Looking at the countries of origins of non-European companies performing R&D in the ERA (Figure 54) reveals that 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 investments, and Canada with over 600 million EURO or a share of 3.8% in 2007. Together with US firms, the top three non-European countries account for more than 93% of total inward BERD in the ERA. The next ranked country, India, has with 132 million EUR or 0.8% already a comparable small importance. 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.

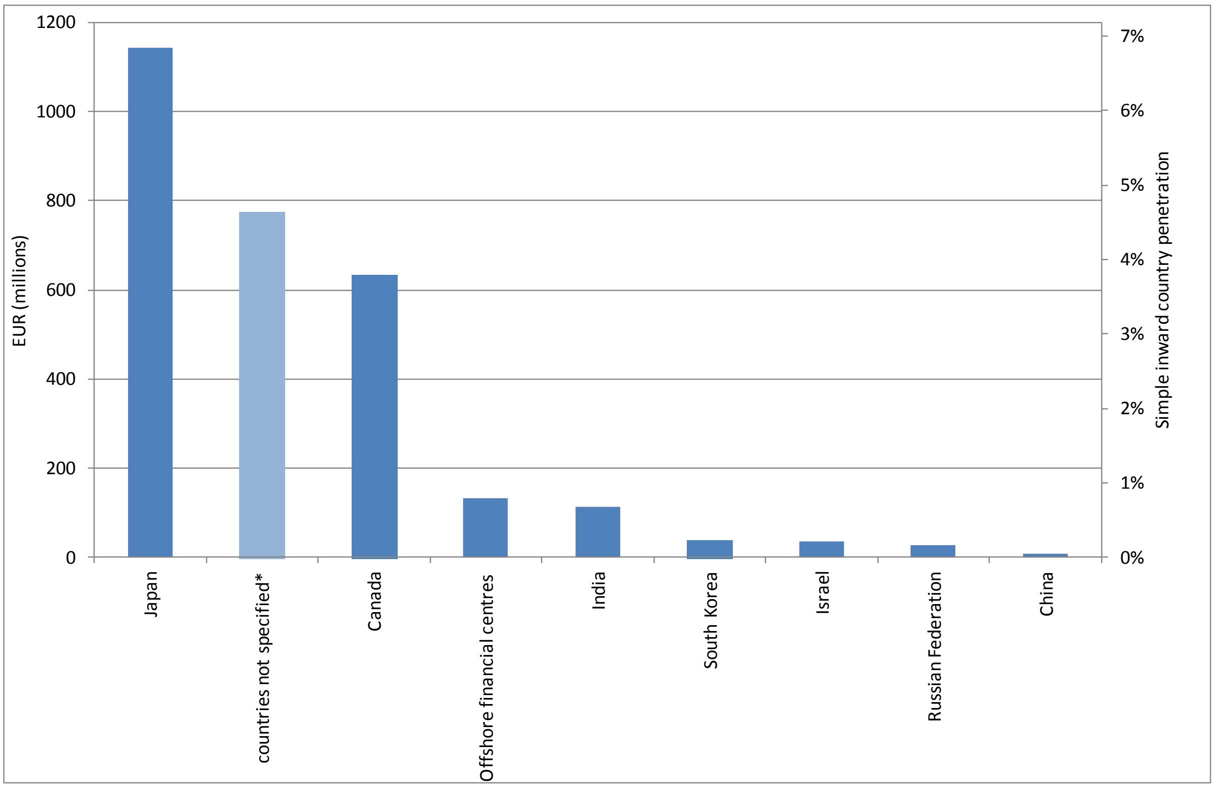
The figure also reveals one main limiting factor for the analysis of BERD by non-European firms: the huge portion of inward BERD summarized under the term "countries not specified", which accounts for 4.6% of total inward BERD or almost 800 million EUR. Countries not specified include all inward BERD 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 in a reporting country and the sum of the values for the countries of origin in the same reporting country, summed up over all reporting countries.

This limitation is important to keep in mind when looking at the very small inward BERD values of all countries listed except Japan and Canada. China, for example, only accounts for 8.7 million EUR of inward BERD in 2007. This value is equal to the inward BERD of Chinese firms in Germany because no other European country provides any positive and non confidential data for Chinese firms. We know that there is null Chinese inward BERD in most countries but there is no data available for France, Switzerland, Austria, the Netherlands and Poland. In addition, the values for Chinese R&D expenditure in Malta, Slovenia and Slovakia are confidential. So we know that there is more inward BERD by Chinese firms in Europe than the value reported in the figure, but we cannot say how much it is.

India appears in some inward statistics of European countries as a home country. Indian inward BERD 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, again the values for a number of countries including France, Switzerland, Austria, Netherlands, Poland, Ireland, Hungary, Malta, Portugal, Finland and Sweden are not available and in some other countries, including, Romania and Slovakia, they are confidential.

Even the magnitude of inward BERD of Canadian firms, the third most important non-European BERD investor in Europe, may be underestimated in the figure. 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 fully covered in all European inward statistics.

Figure 54: Countries of origin of inward BERD from non-European firms (EUR Mio, 2007, excluding US)



Note: * 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

To overcome this shortcoming of inward BERD statistics, 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 will overcome the issue of confidential data at the level of individual member states and give a more appropriate picture of R&D activities of non-European firms in the EU.

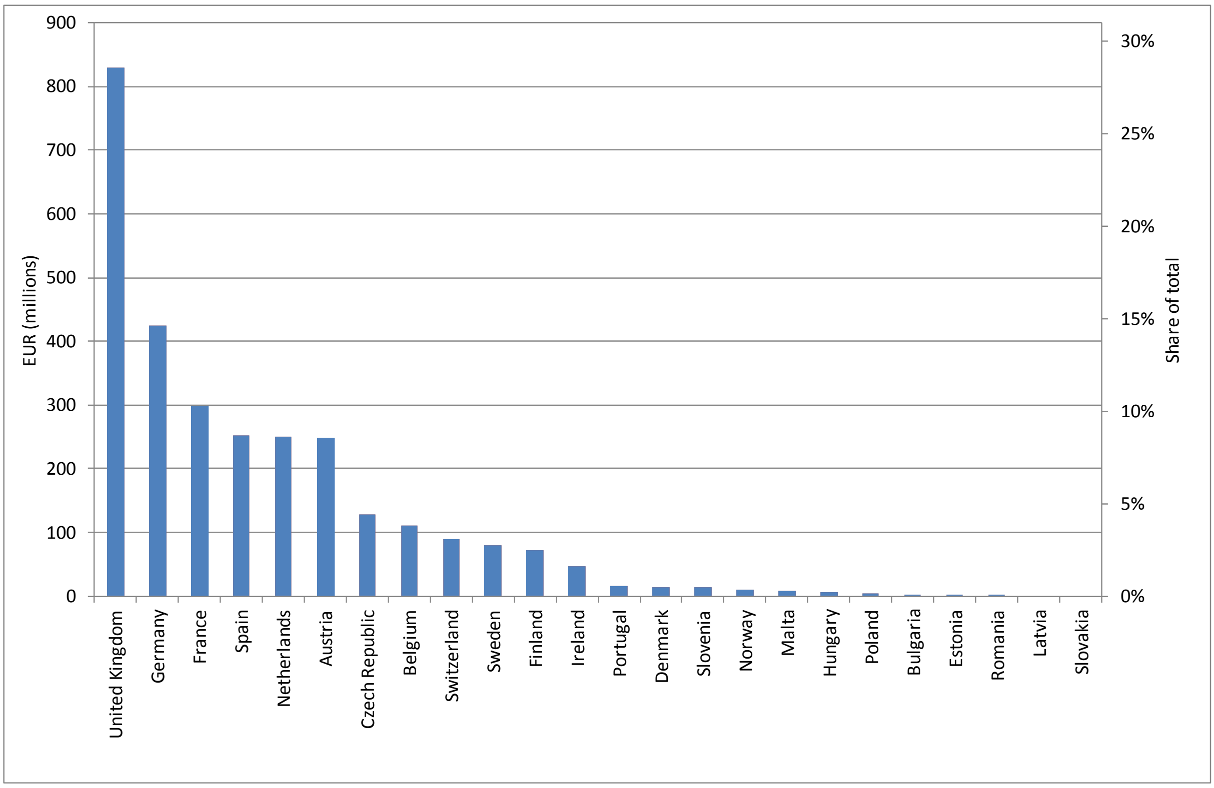
Figure 55 shows the distribution of inward BERD of non-European firms (also excluding US firms) in the ERA by host country. One country, the United Kingdom, stands out with inward BERD of more than 800 million EUR in 2007, a share of almost 30% on total BERD investments in Europe by non-European firms. This share is similar to the share of inward BERD by US firms in the United Kingdom (section 1.4 in this deliverable describes the EU-US relationship in detail).

The United Kingdom can be regarded as 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. About 2/3 of all inward BERD of Indian companies in Europe is located in the UK. About 3.6% of total BERD in the UK is performed by these non-European companies, this equals to about 9% of total inward BERD.

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.

Four more countries each report between 250 and 300 million EUR, France, Spain, the Netherlands and Austria. That is equal to 8 to 10% a share of total non-European inward BERD in the ERA and the top six host countries account for a cumulative share of almost 80%. Other countries attracting significant amounts of inward BERD are in decreasing order the Czech Republic (128 million EUR), Belgium (110 million EUR), Switzerland (90 million EUR), Sweden (79 million EUR), Finland (71 million EUR) and Ireland (47 million EUR). The remaining European countries each attract less than 15 million EUR or 0.5% of total inward from non-European countries

Figure 55: 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

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. There are some exceptions to this rule: Canadian firms are more important than Japanese firms in Spain, 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.

As a preliminary conclusion, we see that R&D activities of non-European firms in the ERA, if US firms are excluded, are small compared to the activities of firms from other European countries and the US. The two by far most important countries of origin are Japan and Canada. Investments from all other countries, including China and India, are reported to be comparably small. The most important European host country is the United Kingdom, but also a number of other ERA countries attract significant inward BERD of non-European firms, in particular Germany, France, Spain the Netherlands and Austria. Compared to total inward BERD, expenditure of non-European firms excluding the US have the highest relative importance in the Czech Republic, Austria and Spain.

5.2. The relationship between foreign direct investment and outward BERD

The literature reviewed in deliverable 2 of this project assumes 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.

The following section examines this relationship in more detail by comparing outward BERD and outward FDI stocks for the US in the year 2007 by host country and by sector. The US is the only country where the data allows such a comparison. Outward data in a sector and host country breakdown is available for the US and Japan, but Japanese data shows large fluctuation across sectors and host countries over the most recent years. Therefore, a similar analysis for Japan would rather reflect the selected reference year than differences across host countries or sectors.

The analysis employs two different data, outward data on BERD and outward data on FDI stocks, which 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 statistic compared to the outward BERD data set.

A good example for possible implications of this difference is the company Skype described in the case study on R&D internationalisation in KIBS (section 4.2): As the company is owned by Microsoft, a US company, it is clearly an US outward investment. Skype's contribution to US outward BERD will be mostly allocated to Estonia as this is the location of Skype's main R&D facility. However, as Skype's (non R&D active) headquarter is located in Luxembourg, Skype will appear entirely as an investment in Luxembourg in the US outward FDI stock statistics.

We start with the distribution of outward BERD and FDI stocks by host country. Figure 56 compares the shares of various host countries on the corresponding total values. Some countries with considerable stocks of US outward FDI but no outward BERD are not included in the figure. These countries are mostly offshore financial centres with Bermuda and Cayman Islands being the two most important which together account for more than 10% of total US outward FDI stocks.

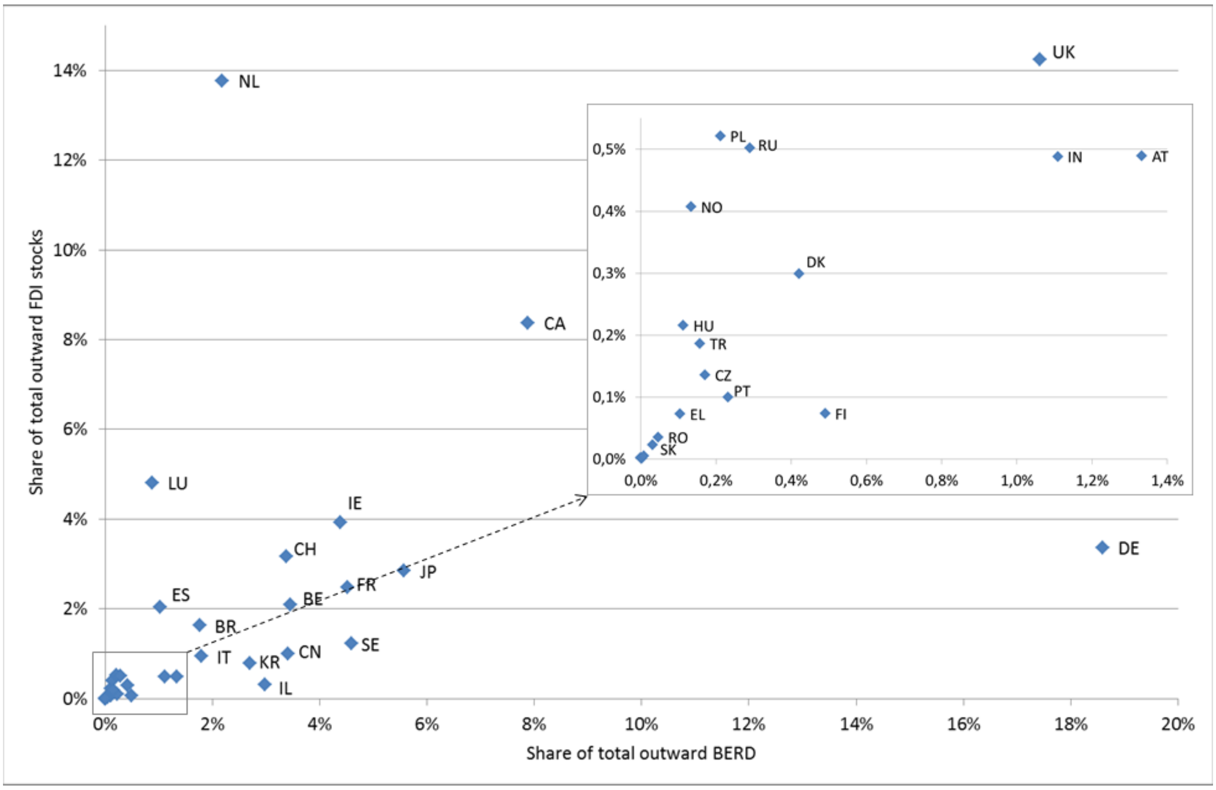
Most interesting are two outliers, the Netherlands and Germany. Germany has much higher shares on outward BERD than FDI, the opposite is true for the Netherlands. This may reflect the role of the Netherlands as a location for the European headquarters of many US multinationals, while Germany's position may mirror the favourable framework conditions for doing R&D in the country. The UK ranks high as a recipient of both, outward BERD and outward FDI.

Only three of the countries with a share of more than one percent of total US outward BERD have higher shares on outward FDI than on outward BERD: the Netherlands, Luxembourg and Spain. The explanation for Luxembourg may be the same as in the case of the Netherlands. Other countries with higher shares on FDI stocks than outward BERD include Russia, Poland, Norway and Hungary.

Five more countries attract shares of more than one percent of total US outward BERD and have corresponding shares on US outward FDI stocks. With the United Kingdom, Canada and Ireland, three of these five countries share a common language with the US and account together for almost 30% of US outward BERD and about 27% of US outward FDI stocks. Brazil, another American economy, also belongs to this group. The fifth country of this group is Switzerland, similar to the Netherlands and Luxembourg the relative high share on total outward FDI stock may again reflect the role as a hub for US activities in Europe. Additionally, a number of countries with comparable small shares on both, outward FDI stocks and outward BERD, have similar shares in both respects including Denmark, the Czech Republic, Turkey, Greece, Romania and Slovakia.

All remaining countries with significant share on US outward BERD have a smaller corresponding share on total US outward FDI stocks. This includes some large and medium sized EU economies including Germany, Sweden, France, Belgium, Italy, Austria, Finland and Portugal but also Asian economies including Japan, China, Israel, Korea and India. While these countries together account for more than 50% of total US outward BERD, their corresponding cumulative share on total outward FDI stocks is only about 16%. Israel stands out in this group with a share of 3% on outward BERD, but only little outward FDI stocks. This indicates that Israel is as a location for R&D activities without the usual linkage to production and sales. The case of Israel is examined in more detail in section 4.2.

Figure 56: Country shares of total US outward BERD and FDI stocks (2007)



Source: OECD, own calculations

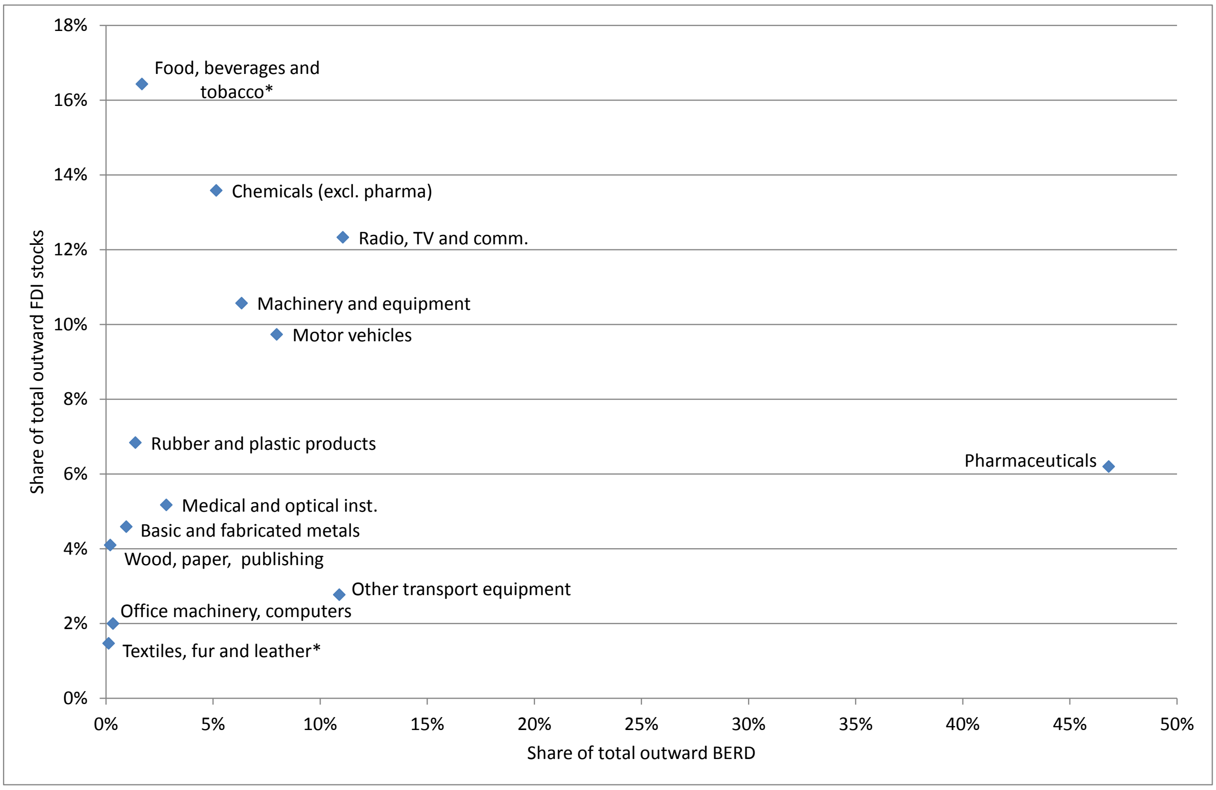
A first inspection of the data at the sectoral level reveals that two service sectors, financial intermediation and other business activities account for more than half of the US outward FDI stocks but have no outward BERD at all. This may lead to considerable distortions in the presentation of the data, so we exclude these two sectors and focus on manufacturing.

Figure 57 takes a look on the sectoral distribution of US outward BERD and outward FDI stocks in manufacturing. A large number of sectors have shares on outward FDI stocks above the corresponding shares on outward BERD. This includes all low-tech or medium-low-tech sectors, most notable food, beverage and tobacco with the largest share of outward FDI stocks, but with chemicals (excl. pharma), medical and optical instruments and office machinery and computers also some medium-high-tech and high-tech sectors. Together these sectors account for more than half of total US outward FDI stocks but only about 13% of total outward BERD.

In contrast the two sectors with larger shares on total outward BERD than on total outward FDI stocks, pharmaceuticals and other transport (incl. aircraft and spacecraft), together account for almost 60% of total US outward BERD but for less than 10% of the US outward FDI stocks.

The three remaining sectors, radio, TV and communications, machinery and equipment and motor vehicles are all high-tech or medium-high-tech industries and combine high shares on total US outward BERD with also high shares on total outward FDI stocks. Together these three sectors account for about ¼ of total outward BERD and 1/3 of total outward FDI stocks.

Figure 57: Sector shares of total US outward BERD and FDI stocks (2007, only manufacturing)



*2006 instead of 2007 (outward BERD)

Source: OECD, own calculations

To sum up, the distribution of US outward FDI stocks and outward BERD shows some striking differences when looking at host countries and sectors. While some countries, in particular other English speaking countries, have about the same importance in terms of outward BERD and outward FDI stocks, most countries are of different relative importance in these two respects. Offshore financial centres and a few European countries, most notable the Netherlands and Luxemburg, show by far higher FDI stocks than 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.

5.3. 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 Safe Centre in December 2011.

The sample includes more than 170,000 firms from 23 European countries[60]. 16,862 of them are foreign-owned firms. It should, however be noted the United Kingdom and some small and medium sized EU countries are not included in the sample. Since the UK is the most important attractor of inward BERD from outside the EU, the magnitude of extra-EU internationalisation may be underestimated by the data.

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 (this group has a share of 6.3% and mainly includes Swiss and Norwegian firms), the EU-12 (2.9%), Japan (2.3%), and firms from a number 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 chapter is on the R&D activities of firms from emerging economies such as India and China in the ERA. Case study evidence suggests that some firms from these countries are just about to set up R&D activities in the European Research Area (see 5.4).

The share of firms from China, India and other emerging economies is even smaller than the share of the aforementioned groups. Only 0.2% of all foreign-owned firms in the sample are Chinese-owned, and another 0.3% of the firms belong to an Indian multinational firm. The shares of Russian, Turkish, or Korean firms are approximately in the same range. 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 the engagement of firms from emerging economies in the ERA is still in a very early stage. The predominant mode of presence of firms from emerging economies in the EU is exporting, not foreign direct investment. 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).

Firm-level data allow some comparisons of the characteristics of foreign-owned firms from different countries of origin in the ERA. First, we see considerable differences in sectoral affiliation. 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,

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

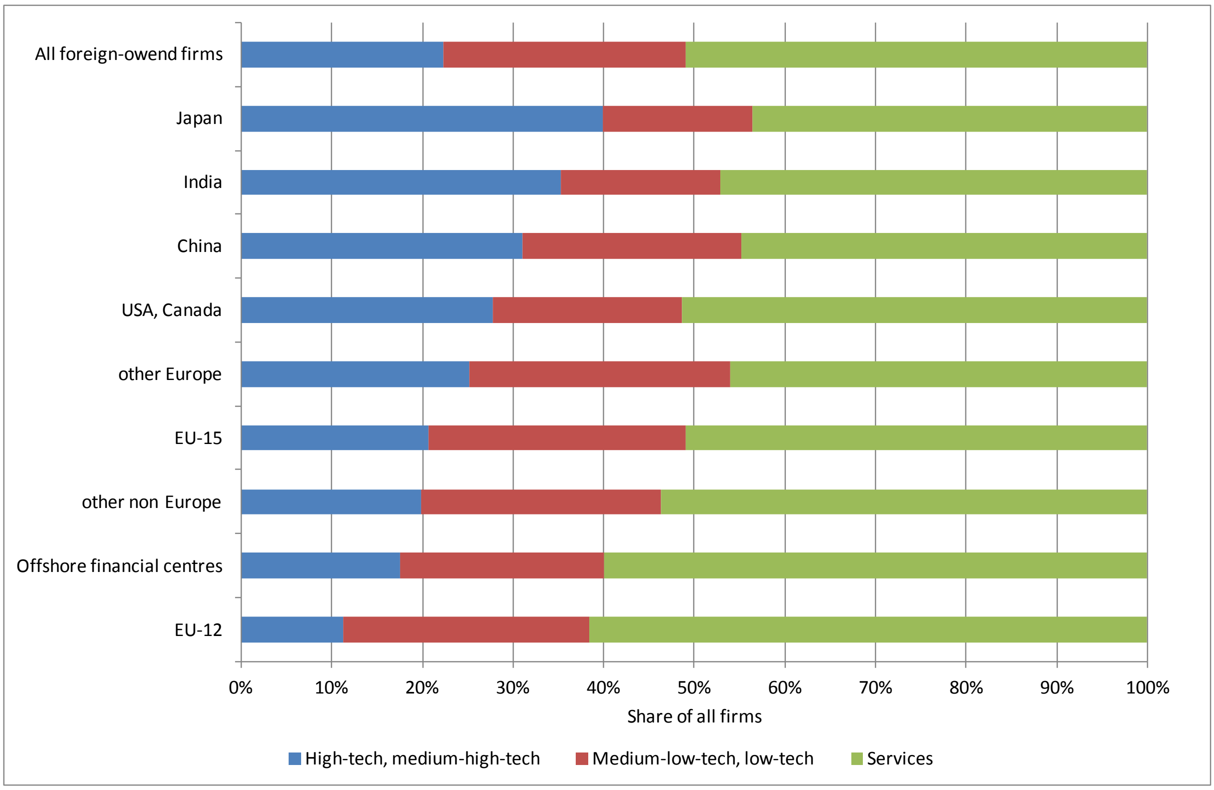
compared to 22% for all foreign-owned firms. This may indicate that locational factors related to R&D and innovation is an important determinant for the investments of Chinese, Indian and Japanese firms.

Quite contrary, FDI from the EU-12 reveals much higher shares of medium- and low-technology sectors. Only 11% of the EU-12 firms in the CIS sample are active in high- and medium-high-technology manufacturing sectors. We also see that the share of firms from services 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 median and mean employment and turnover than Indian firms as well as larger than the median or mean firm of the total sample. Indian firms, in contrast, are smaller than the total sample median or mean firm size. Japanese firms are the smallest 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.

Figure 58: Sectoral affiliation of various groups of foreign-owned firms in Europe (2008)



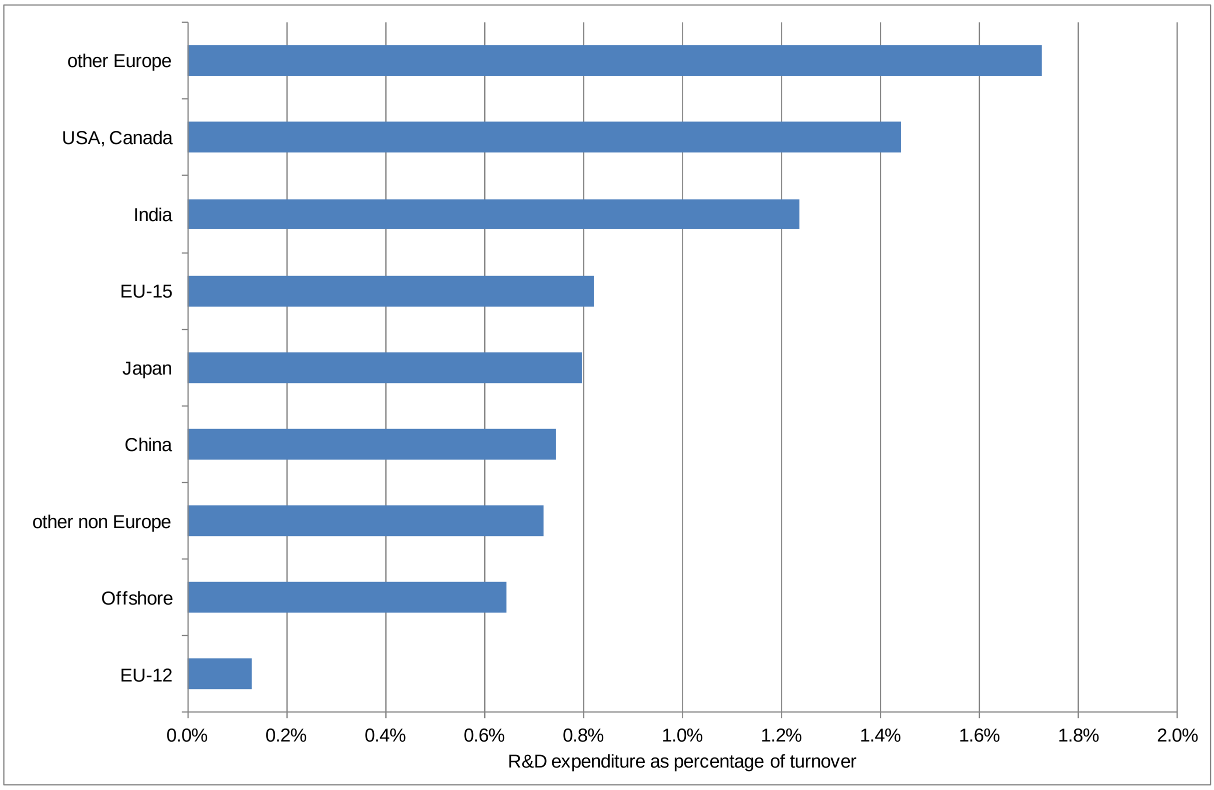
Source: EUROSTAT, CIS 2008

This edge of Chinese firms in innovation activity, however, does not transfer into a higher R&D orientation. The share of Chinese firms with R&D activities (30%) is lower than the share of any other group except firms from offshore financial centres (30%) and EU-12 countries (27%). The share of Japanese firms (34%) is only slightly higher. We find considerably more Indian firms with R&D activities (43%), which is roughly the same level as for firms from the US/Canada.

Figure 59 looks at R&D intensity, which is calculated for each group of firms as the fraction of the mean R&D expenditure[61] and the mean turnover. This method is more robust with respect to outliers, which is important in small sample sizes.

R&D intensities of Chinese and Indian firms are considerably lower than R&D intensities of US and Canadian firms and other European firms, which mainly include foreign-owned firms affiliated to a Swiss and Norwegian group. Indian firms, however, spend more on R&D than Chinese firms in Europe. Readers, however, should keep the small sample sizes for both firm groups in mind.

Figure 59: R&D intensities of various groups of foreign-owned firms in Europe (2008)



Source: EUROSTAT, CIS 2008, own calculations

R&D intensity is lowest among foreign-owned firms affiliated to a group from the EU-12 or from an offshore financial centre. Firms from this country group have already shown a low share of high-technology and medium-high technology firms, so the low R&D intensity may at first be explained by industrial affiliation. Additionally in the case of EU-12 firms, these

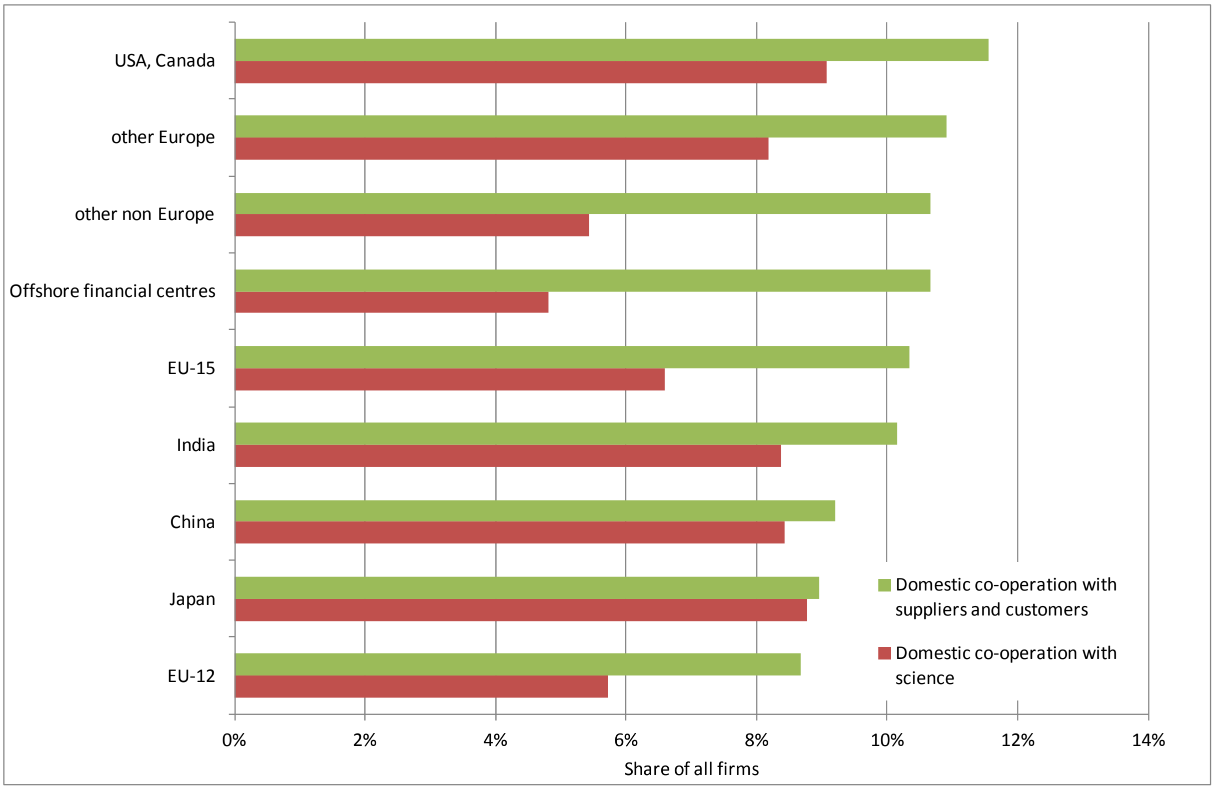
[61] It is important to consider that the Community Innovation Survey is NOT an R&D survey. Although the same definitions of research and development are used, results from the CIS may deviate considerably from figures reported by R&D surveys.

firms have the smallest average size in terms of employment and turnover which may also explain below average innovative performance.

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. In a co-operation between a foreign-owned firm and a domestic organisation knowledge may be transferred between the two partners, and domestic organisations may benefit from this knowledge transfer disproportionally, because multinational firms often possess superior technology. 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 for innovation.

Co-operations can take various forms. The following Figure 60 focuses on two of them, vertical market co-operation (with suppliers and customers) and co-operation with science (universities and research centres). Firms will enter in the first form of co-operation when they are mainly interested in market information to adapt their products to the local market. The motive behind science co-operation, in contrast, is the generation of new knowledge, because universities are the main source of scientific information in the innovation system. However, there is also evidence that science-industry co-operation is a main channel for recruitment of new scientific staff (Schartinger et al. 2002).

Figure 60: Frequency of co-operation in the host country of various groups of foreign-owned firms in Europe (2008)



Source: EUROSTAT, CIS 2008

Figure 60 indicate that 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 above.

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, they 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. This is also supported by the results of the case study in section 5.3. Science-industry co-operation is difficult to maintain over distance, so the establishment of an affiliate in Europe may be the best way for these firms to co-operate with European universities.

To sum up, data from the CIS reveals different attitudes of foreign-owned firms in the ERA towards R&D. In terms of industrial affiliation, R&D intensity and co-operation behaviour, affiliates of an enterprise group from the EU-12 or various offshore financial centres reveal the lowest affinity R&D, while US, Canadian, Japanese and other European firms are most R&D oriented. Chinese and Indian firms have an above-average R&D orientation. The results regarding India and China, however, build on small sub-samples, since there are currently very few Chinese and Indian firms with R&D activities in the ERA, results may therefore be considerably influenced by outliers.

5.4. Motives of non-European firms to do R&D in Europe: a case study of two Indian multinationals in Germany

This case study[62] investigates the motives of two Indian multinational firms to do research and development (R&D) in Europe. In particular, the case study will investigate factors that determine the extent of the R&D undertaken by foreign subsidiaries in a particular country. The aim of the interviews is to get insight into the drivers and motives of firms to do R&D outside their home countries. In particular, we seek to examine which factors the firms regard as locational advantages of the European Union (EU) compared to North America or Asian countries, and how they choose between different locations in regard to their future R&D investments.

We have selected two India multinationals, viz. Defiance Technologies Limited and Suzlon Energy Ltd., for the purpose of this study. Both firms are technology-driven firms and have established R&D capabilities in India as well as overseas in one or more member states of the EU.

5.4.1. Company Information

Defiance Technologies Limited[63]

Defiance Technology Limited ("Defiance Tech") is an India headquartered company offering Engineering, Enterprise Resource Planning (ERP) and Information Technology (IT) services to global customers. It undertakes new product development & design activities on behalf of its customers. Defiance Tech serves "over 60 active global clients including 20 of the Global 500 and Fortune 1000 companies"[64]. The registered corporate office is in Chennai (erstwhile Madras) in Southern India. The company currently employs close to 1200 employees worldwide[65].

Suzlon Energy Limited[66]

Suzlon Energy Limited ("Suzlon") is an Indian company listed at Mumbai Stock Exchange and active in wind energy business. It is headquartered in Pune in Western India. Incorporated in 1995 it has grown impressively capturing nearly 50% of the Indian wind energy market. The Suzlon Group today belongs to top 5 wind turbine makers worldwide with a global market share of approx. 10 % (Bradsher 2006). It employs nearly 13,000 people in 32 countries. The turnover in fiscal year 2010-11 stood at 178.79 billion Indian rupees (approx. 4.01 billion USD). Even though the firm has faced some problems in previous two years, overall the firm has grown 9-fold in previous 7 years.

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62 The case study is, inter alia, based on personal interviews with Mr. Bratin Saha, Practice Head Engineering-Europe at Defiance Tech GmbH in Cologne, Germany, and with one senior level manager at Suzlon's Renewable Energy Technology Centre, responsible for project integration with the headquarters. This person wishes to remain anonymous.

63 Defiance Technologies Limited, Information provided on company website (accessed: 28.11.2011): http://www.defiance-tech.com/

64 See footnote 63

65 See footnote 63

66 Suzlon Energy Limited, Information provided on company website (accessed: 24.11.2011): http://www.suzlon.com/

5.4.2. *Main Geographic Markets*

Main geographical markets of Defiance Tech are India, EU and the USA. Recent turmoil in Middle East has had some negative impact on business there. The company also expects negative developments in the USA in the short run due to recession fears. On the other hand it exudes positive outlook for Asia Pacific, China and India for the coming 5 years. Defiance Tech sees growth opportunities for itself primarily in Western Europe, since the US market is showing signs of saturation. Accordingly, the firm has made Germany a major point of its operations and established a wholly-owned subsidiary Defiance Tech GmbH as part of its global expansion plan. Cologne is set to serve Defiance as its "European Headquarters", whereas the development centre in Walldorf is focused on engineering activities. The firm hopes that its "presence in Germany will help gain better traction with its European customers and make Defiance's presence felt in the European market" (Hinduja Panorama2010).

Key geographical markets for Suzlon are the USA, India, China, Spain, Portugal and Australia[67]. In addition, its subsidiary REpower Systems caters to European markets, especially Germany, Austria, France, Great Britain and Italy (REpower 2011).[68] From company perspective the most important markets are expected to remain principally unchanged. However, the company expects that the relative shares of markets would change over time shifting the balance towards India and China. Recently, Suzlon has re-adjusted its market portfolio. REpower Systems, focused at higher-end products, and announced withdrawal from China citing a ruinous (price-based) competition and the alleged preferential treatment of domestic firms. From now on, Suzlon with a low-cost base in India and local manufacturing facilities in China would serve that market.

5.4.3. *Locations of R&D*

The two companies have established R&D activities in several locations around the world. Suzlon has created R&D capabilities in Germany, the Netherlands, Denmark and India[69]. It's "Technology Group" has a strength of 500 and is headquartered in Hamburg (Germany). R&D locations outside India include Berlin, Hamburg and Rostock in Germany, Århus in Denmark, and Hengelo and The Hague in the Netherlands. Within India, Suzlon has R&D facilities in Pune and Vadodara[70].

Defiance Tech has development centres in Chennai, Bangalore and Pune in India, and at Walldorf in Germany. Furthermore, it has established "state-of-the-art engineering and validation facilities at Troy and Westland" in Michigan (USA). Development capabilities are also located in South Africa

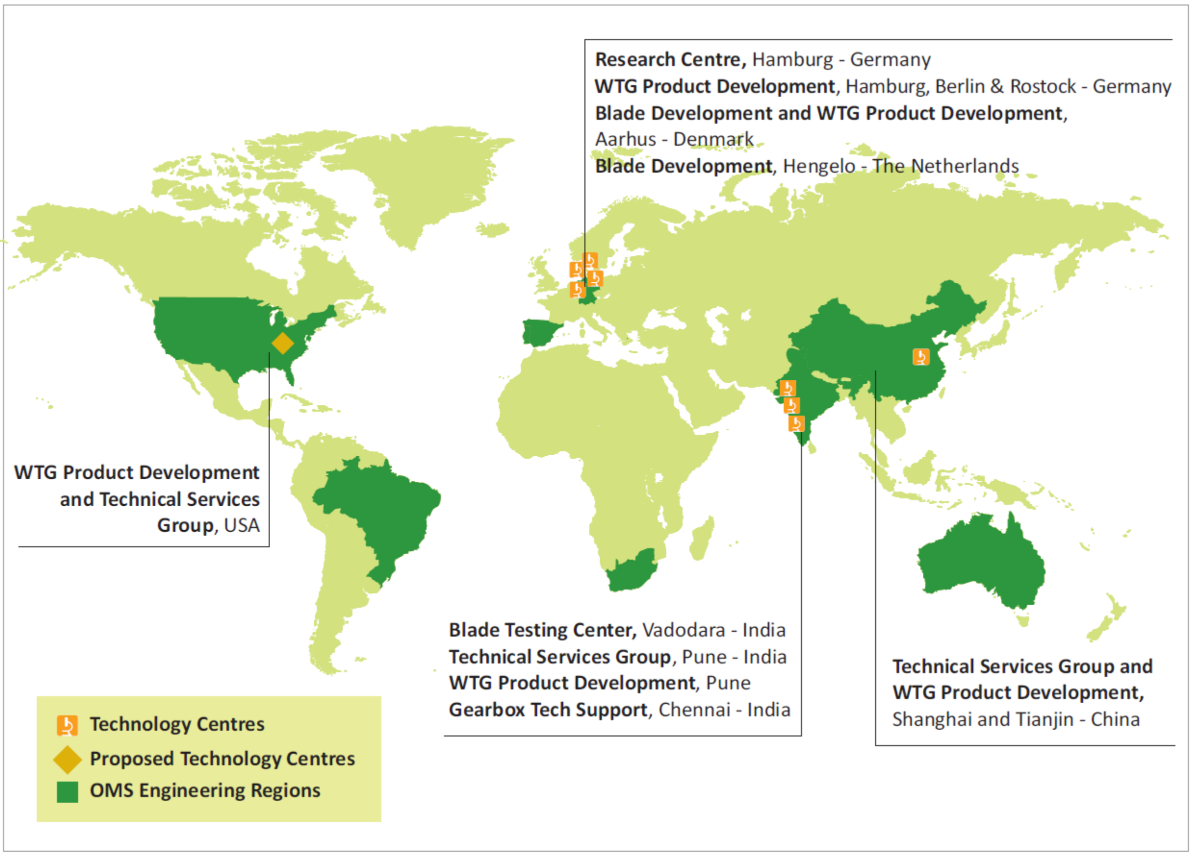
[67] See Suzlon Energie GmbH, Information provided on company website (accessed: 24.11.2011): http://www.suzlo-wind.de/

[68] Suzlon acquired management control of Hamburg-based REpower Systems, a market and technology leader for wind turbines in Germany and Europe, in 2006 for an estimated cost of $ 1.8 billion (Tiwari and Herstatt 2009). In late 2011 Suzlon acquired 100% stake turning REpower into a wholly-owned subsidiary.

[69] See footnote 66

[70] See footnote 66

Figure 61: In-house Technology, Research and Development network of Suzlon



Source: Suzlon Energy Limited Annual Report 2010-11, p. 11.

Role of Mergers & Acquisitions

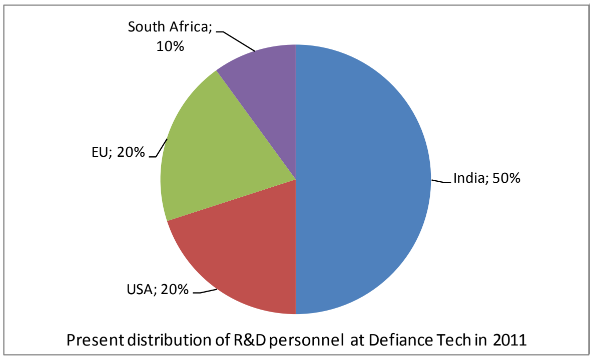
There is considerable difference in the path taken by the two firms for internationalizing their R&D activities. Overseas R&D establishments, for Defiance Tech, have predominantly resulted from mergers & acquisitions (M&A). This preference has been motivated by the desire to acquire established engineering capabilities and reduce the risk associated with greenfield investments in the service sector. Defiance Tech is reportedly looking for further suitable targets in Europe, USA, and Australia (see, e.g., Narasimhan 2011).

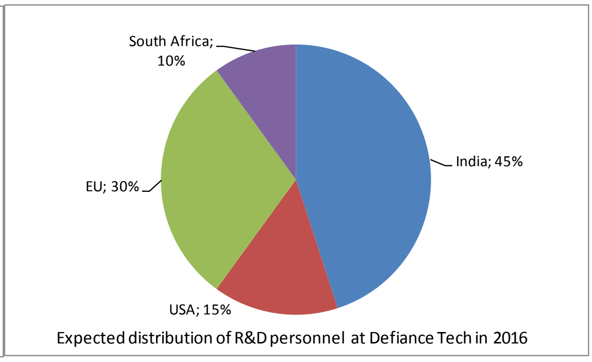
In contrast to Defiance Tech, Suzlon has taken both greenfield and brownfield routes for creating R&D capabilities outside the geographic boundaries of its home base. Its original operations in Germany, initiated under the aegis of Suzlon Windenergie GmbH, were greenfield ventures. Later, it acquired REpower Systems. One of the reasons for this acquisition was its desire to access high-end technology. Later, it created a joint venture (JV) with REpower Systems on parity basis. Under this JV a new entity called Renewable Energy Technology Center (RETC) was established in Hamburg and was entrusted with the task of doing basic research in the field of wind energy. Its mandate also includes trainings and project management.

R&D Distribution between Locations

India plays a dominant role in the present R&D setup of Defiance Tech and is poised to retain a strong position owing to factors such as cost advantages and the abundant availability of skilled labour. The company, however, expects a shift of balance in terms of R&D personnel in the next 5 years with the EU gaining in importance relative to India and the USA, see Figure 62. However, the firm makes it a point to emphasize that it is a growing business so that it expects the overall numbers to increase across all the locations; it is only the relative share that is expected to change.

Figure 62: Present and expected distribution of R&D personnel at Defiance Tech (2011-2016)





Source: information based on interviews with Defiance Tech

The view within the Suzlon Group seems to concur with this scenario. Suzlon intends to further strengthen its R&D engagement in wind energy lead markets, Germany and Denmark, and wishes to leverage the existing technological capacities for cutting-edge research. Capacities in these two countries, especially at locations in Hamburg and Rostock, are expected to be strengthened further. The relative share of Europe in the concern-wide R&D might go down nevertheless, as Suzlon intends to create "dedicated R&D facilities" in countries like China, Singapore, and the USA and has already started setting up engineering facilities related to design and development in several other countries such as Brazil.

R&D Specialization

The two companies in the sample also vary considerably in the assignment of tasks to their various development units. While Defiance Tech has concentrated basic research in India and intends to retain it there at least in the medium run, Suzlon has intentionally created hubs for basic research in Europe and actively shifted such functions away from the home base in India. Product development is carried out at the R&D units, whereas local adaptation is done at several engineering facilities set-up in various key markets including in Brazil and China. Defiance Tech too intends to globalize its applied research and experimental development further. Especially Western Europe, where "a lot of innovation is taking place" is set to gain increasing relevance, as Mr. Bratin Saha (Defiance Tech's Practice Head Engineering – Europe) puts it.

Regional Responsibilities vs. Technology Mandates

Overseas affiliates of Defiance Tech do not have regional mandates as the firm rather prefers to work with product and/or technology mandates. In this scheme Indian units are responsible for matters related to general industrial transportation, the German affiliate is entrusted with the tasks related to aerospace, automotive and SAP, whereas The US unit is responsible for solutions based on Microsoft and Epicor products. Additionally, customer inputs related to the power and energy sector are collected from France and Belgium, for IT sector from the United Kingdom (UK).

Suzlon follows a comparable, though not identical, strategy. Local adaptation and technical support is carried out by engineering facilities in key markets which have a regional focus. On the other hand, R&D units are organized along technology portfolios. Suzlon's German units in Rostock, Berlin and Hamburg working under the aegis of Suzlon Windenergie GmbH concentrate on Systems Simulation, Power Electronics, Design, Drive Systems, Electrical Systems, Software, and Technical Support.[71] The R&D group in Århus is integrated in the local Danish subsidiary Suzlon Energy A/S and focuses on tower design and the Supervisory Control and Data Acquisition (SCADA) System. The R&D division for Blade Technology is based in Hengelo and The Hague in the Netherlands, and at Pune and Baroda (also known as Vadodara) in India, as well as Århus in Denmark (Suzlon 2011). The RETC conducts material and component testing of critical structures in its specialised laboratories and supports its customers along the entire chain of innovation management[72].

5.4.4. Locational advantages of the European Union

One of the most important locational advantages of the EU compared to North America and Asian countries lies in what Mr. Bratin Saha calls is its "centralized location in a happening place". Distance of travel is comfortable and compatible with work process with one overnight flight to US, India and/or South Africa. Furthermore, EU countries are a growing market in terms of engineering services as outsourcing may be considered to be still in a "nascent stage" in many EU countries while there is a growing need for European businesses to outsource. Opportunity-wise the EU is therefore seen as a "young and virgin market" and a "centre of attraction".

For Suzlon it is rather the "lead market" function of Europe, which is the biggest advantage. "Germany and Denmark are together without doubt the headquarters of pioneering engineering knowledge and application for wind technology. Active co-operation of wind energy experts, newest scientific innovations, high-end technology usage and highly qualified human resources for selection of materials and production processes make them the 'destination of choice' for Suzlon's R&D endeavours and accomplishments"[73].

Apart from the desired interaction with the innovation ecosystem in Europe there are also important market related considerations: "Europe's 20 per cent by 2020 renewable targets, alongside developments like Germany's recent decision to shut down its nuclear plants […] have all put in place strong drivers for the wind sector. With Europe's limitations in land area, the opportunity for this growth is clearly offshore. And with REpower's leadership in offshore wind technology, this is again a market we are well positioned in" (Suzlon 2011, p. 2f). Even though India and other emerging markets such as Brazil, China and South Africa are seen as high growth markets and remain a priority for Suzlon, they are not expected to develop into wind energy lead markets in near future. The same holds true for the USA, Suzlon believes.

Challenges faced at EU Locations

Locations within the EU, however, do not offer advantages on a platter. Companies are sometimes also faced with certain challenges that need to be overcome for being successful.

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[71] The integration process of REpower Systems in the Suzlon concern is still on, so that it is too early to speculate what shape the restructuring will take place. Reportedly, a leading management consultancy is currently working on a concept to reorganize the responsibilities between existing Suzlon units and REpower.

[72] The Renewable Energy Technology Center, Information provided on company website (accessed: 21.11.2011): http://www.retc.de/

[73] See footnote 66

Suzlon is worried about the current as well as anticipated shortage of skilled labour in Europe. In some instances, Indian firms in Germany – not well familiar with the management practices and cultural settings of the host country – have struggled to keep attrition rates low (Tiwari and Herstatt 2010) and especially Suzlon has faced some issues retaining the REpower management, post acquisition (Mishra and Surendar 2009; Tiwari and Herstatt 2009). Suzlon has however been optimistic and sees this challenge also as an opportunity. Mr. Tulsi Tanti, Chairman & Managing Director of Suzlon has been quoted by The Economic Times as saying: "Europe doesn't have adequate engineers while we have good human resources but not the knowhow" (Thakur 2007).

Defiance Tech sees EU markets as "tough to crack", especially owing to linguistic and cultural issues. English is not a lingua franca in the most EU states (unlike in the USA and many other Asia Pacific countries). The company is therefore required to customize its products to smaller-sized, culturally diverse markets reducing economies of scale. Moreover, most Fortune-500 companies are concentrated in the USA. In comparison, the EU has a higher share of small and medium-sized enterprises (SMEs) which aggravates the scaling challenge leading to "less volume and magnitude".

Attractiveness of Eastern Europe

Asked to judge the attractiveness of Eastern European countries such as the Czech Republic, Hungary, or Poland, for doing R&D compared to Western European and Asian countries, Defiance Tech, at present, sees less scope for its services in Eastern Europe for want of established major business houses. "Barring one or two major companies there are no big players in our fields of engagement", is the tenor. The company sees some rays of hope in Hungary and Poland, though.

Linguistic issues further complicate the situation in Eastern Europe which has been hit by financial crisis. At the level of technical competencies Eastern Europe is seen at par with India while not offering a similar market advantage. Defiance Tech perceives greater business potential in Asian countries such as Japan and Korea. Owing to these factors Defiance Tech has no immediate plans of establishing direct R&D operations in Eastern Europe and would prefer to consolidate its business in developed economies in Western Europe while adopting a wait-and-watch policy in respect of Eastern Europe. A similar wait-and-watch policy can be observed at Suzlon, which sees great growth potentials in Eastern Europe and has even established a subsidiary in Romania. There are however no immediate plans of setting up R&D facilities in the region.

5.4.5. Drivers of overseas R&D

Both Defiance Tech and Suzlon see market demand as the single most important factor driving the internationalization of R&D in their respective company. For Defiance Tech, a major factor influencing market demand would be the need for cost-cutting by European companies. 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.

For Suzlon, the drivers of overseas R&D are however a bit broader in perspective, which is probably understandable, since it is not a provider of (engineering) services. Rather, it is looking for ways to access and even create knowledge and technologies. For these reasons, it stresses the role of knowledge co-creation partners such as universities and research institutions. Defiance Tech, on the other hand, does not see universities or other knowledge co-creation partners as a major factor for future changes in locations. Similarly, it does not expect initiatives by local managers to play a major role in these future changes, at this stage.

Suzlon, on the other hand, having selected Germany as its R&D headquarters seeks to encourage initiatives by local managers, who are also integrated in the decision-making processes at the group headquarters in Pune. Since one of the primary motives for Suzlon to do R&D in Europe is the desire to participate in the regional and sectoral innovation systems in European wind energy lead markets, it does not see a "unilaterally decisive role" for cost factors in selecting R&D locations.

One interesting factor mentioned by Mr. Saha as a driver for R&D location decisions in the next five years was the expected foreign direct investments (FDI) by emerging market firms. According to Mr. Saha, FDI by low-cost country firms such as India will open new business opportunities for collaboration in engineering and product development in Europe.

5.4.6. Role of public policy

Defiance Tech sees itself confronted with "restrictive immigration policies" in the EU member states, especially Germany. These policies in its opinion affect its ability to hire suitable people from various backgrounds and nationalities. The company is therefore of the opinion that public policy can significantly improve the attractiveness of locations for R&D if it implements regulatory changes to make it easier to recognize academic degrees of immigrated population. The company would highly welcome regulatory initiatives to enable cross-country hiring, advocating that the EU should "follow an open door policy for their own benefit". Citing the example of "much more liberal" immigration policies in the United States and the resultant high numbers of Indian-origin scientists and engineers at NASA and other US firms Mr. Saha emphasizes positive effects of collaboration for all parties involved, terming liberal immigration policies as "key to cooperation and collaboration".

Suzlon expressed its general satisfaction with public policies even while pleading for greater government support for renewable energies. Two areas of policy level encouragement mentioned by the Suzlon representative were: a) need for more liberal visa rules to allow easier and greater exchange with the headquarters, and b) active encouragement of industry-academia collaboration for foreign-owned firms.

5.4.7. Implications for the Home Country

The impact of the two firms' R&D expansion into Europe, from the perspective of India, the home base, can be summarized as follows:

- Creation of R&D capacities in Europe has helped upgrade the technological base (Suzlon) opening up new higher-end markets, or local development capabilities have helped the firm get access to new markets (Defiance Tech).
- Home R&D and European R&D do not compete against each other due to growing business, even though, as in Suzlon's case, basic R&D has been largely shifted from India to Europe.
- R&D capabilities, when measured in *absolute numbers*, continue to grow simultaneously at home and in Europe even as India's *relative share* is expected to go down in the case of both firms. As regards Europe the firms present a mixed picture, while Suzlon expects Europe's relative share to decrease too (since it plans to open

new facilities in places like Singapore, China and the USA), in case of Defiance Tech) Europe's share is set to increase.

- Both firms actively promote internal transfer of tacit knowledge by active cross-country integration of R&D personnel.

5.5. Drivers of offshore R&D investment by Canadian companies

There are many drivers of outward investment of R&D and the literature analysing them is rapidly expanding. However, from what we know of Canadian business the over-riding factor is the business case for the business not R&D. R&D in this sense is a second or third tier issue, the predominant driver of activity is M&As. So with his insight we introduce the case studies with select quotes from various sources that have relevance for discussing the strategy of Canadian businesses in foreign markets.

A number of studies have examined the pattern of Canadian inward and outward investment in R&D. Niosi has summarized the key factors behind Canadian investment aboard, finding that:

> *studies on location factors, emphasizing demand, supply and environmental determinants. Also, geographical and cultural proximity both tend to play a major role in explaining the country location pattern of Canadian R&D abroad. Canadian firms locate their FDI and associated R&D facilities in its two neighbours, English-speaking nations, the United States and the United Kingdom (2004: 155).*

However, he has also noted that at the level of strategy, businesses are not necessarily modelling their decisions on these factors.

> *… almost invariably, the new R&D activities were incorporated through the acquisition of foreign productive facilities. The new foreign laboratories were either already existent in the acquired facility, or were added to the new plant in order to support manufacturing and marketing. In a few cases, particularly in new science-based industries such as telecommunication equipment, new greenfield plants and related R&D laboratories were created. In this sense, the internationalization patterns of Canadian multinational corporations look more similar to the Swedish than to the Japanese postwar experience (Florida & Kenney, 1994; Hakanson, 1990; Solocha et al., 1994). We know that there are over a hundred laboratories of Canadian-owned-and-controlled firms, mostly in the United States and Western Europe, and that they span over a large spectrum of industries. Also, these laboratories tend to support local and global production and marketing activities of the foreign subsidiaries of the Canadian corporations (p145).*

In contrast to this perspective we can want to highlight the observation that the literature on this topic of foreign R&D sometimes uses inappropriate words. Hall, for example, states: 'the raw data in Harhoff and Thoma (2010) shows that Canadian firms have been ***shifting*** some R&D abroad between the 1986-1990 period and the post-2000 period, mostly to Germany, the US, and to developing countries including China and India' (2011: 7).

If it were possible to calculate Canadian Gross National R&D which like GNP would be equal to Canadian domestic R&D – foreign R&D in Canada + Canadian controlled R&D abroad, it would almost certainly show that Canadian home R&D has been fairly static while there has been some growth in R&D abroad.

Nortel (now bankrupt) and RIM, both very large R&D players on the corporate scene in Canada, have been organisations that have operated very close to home. There is only one reference to RIM investing any R&D abroad[74] and that is in Bochum Germany. In contrast to this scenario, two large Canadian transport industry companies (Bombardier and Magna

[74] http://www.canadainternational.gc.ca/germany-allemagne/highlights-faits/BlackberryBold9700-Nov09.aspx?lang=en

International) have substantial investments in Europe. In particular, Bombardier, through significant acquisitions has become a major rail industry player in Europe. But in all this the R&D is a secondary feature of the business strategy to grow the company.

So to say that Canadian firms have been ***'shifting'*** R&D may be very misleading. There does not appear to be any decline in Canadian R&D as a result of these acquisitions so there is no apparent shift – just acquiring existing R&D gets it rebranded as 'Canadian'. The revenues to fund the new R&D flow from the expansion itself. It is thus important to be aware of the two levels of analysis that are at play. The first is interviews will emphasise the role of strategic decision making while there may be larger economic geography forces that influence the parameters for those decisions.

5.5.1. A wireless company

Canada has a series of largely independent electronics/ICT related clusters spread across the major economic zones of the country. Two clusters in central Canada have been anchored by large firms. Ottawa, until recently had the key firm of Nortel and Waterloo has grown around RIM. Although these clusters have many small and medium sized firms their economic landscape for some time has been dominated by the large international players.

Two western province clusters have been markedly different in their histories. The Calgary based cluster emerged with a single leading edge firm (see Wixted 2012), while the Vancouver cluster emerged after World War II with several firms that were in different fields such as wireless communications and electronics (Wixted and Holbrook 2011 and Wixted and Holbrook forthcoming). In both cities there has been a history of company failures, buyouts and mergers but importantly, growth has been maintained through a sticky labour market, a sticky investment market due to the attractiveness of both cities and in Calgary's case – the oil and gas industry acting as an economic anchor cluster while in Vancouver it appears to be the diversity of human capital intensive activities, the climate and physical attractiveness.

Vancouver's is a particularly 'west coast' place to do business. It is the home of Hollywood North – which needs no explanation, a new media cluster and wireless industry cluster which though initially separate increasing appear to have strong combinatorial advantages. Being in the same time zone as Seattle and California is important for these clusters. However, though the clusters appear solid many of the firms within them appear to be often marginal operations that survive for a while then collapse with the entrepreneurs re-emerging with a new entity. There are very few businesses of any scale in these Vancouver human capital clusters.

Box 3

The wireless cluster started in British Columbia prior to the Second World War with the work of Donald Hings, one of several separate inventors of the class of portable communications devices known commonly as the 'walkie-talkie' (Hayter *et.al* 2005, Hanson 2001). Since then the cluster has been through many ups and downs, with expansionary periods leading to the creation of major firms (MPR Technologies, Glenayre), their subsequent takeover by multinational firms such as Motorola, followed by absorption and ultimate disappearance (see also Langford and Wood 2005). Today Nokia maintains a significant R&D presence in the region, although this facility was down-sized during the global financial crisis.

In many ways the Vancouver cluster is representative of the emerging inheritance model of cluster formation (Klepper 2001). Two early wireless organisations, Glenayre Electronics Ltd and Mobile Data International (MDI) Inc., played a role in schooling engineers and entrepreneurs. Glenayre sold radio-telephone equipment for vehicles (Globe and Mail 1980a) as well as for use as an early form of GPS, deployed by BC Rail (Globe and Mail 1980b)[75].

One exemplar story might be useful. MDI was a spin-off from another BC company MacDonald Dettwiler and Associates, an aerospace communications company, which has received significant government funds for technology programmes. MDI won a significant contract with Fed Express in competition with Motorola[76], shortly afterwards it was taken over by Motorola. Although Motorola did not continue its investment in the metro Vancouver region, the people and money stayed.

As Figure 63 shows, over the past decade, both in employment and exports have been relatively static in Vancouver. However, R&D shows strong growth reflecting confidence in the future. In 2009 there was significant economic turbulence in the ICT industry globally (OECD 2009b) which was also reflected in the local Vancouver cluster. In 2009 Nokia reduced staff at its R&D centre which crosses over wireless and new media.[77,78] Despite this there seems to be optimism that Vancouver will retain its talent base as it has done so in previous global crises.

Today's cluster has close ties to the new media cluster. This closeness is highlighted by the very recent amalgamation of the two industry associations WinBC (for Wireless) and New Media BC into DigiBC, an organisation representing approximately 22,000 employees and 1300 companies. Nevertheless, there is also anecdotal evidence that there is considerable labour market turbulence in the Vancouver over a long period of time. The innovation system appears to be unstable, which for a cluster in the transforming phase of its existence could lead to either greater success or, equally, a major decline.

Knowledge flows appears to have been intra-cluster and cumulative for many years, with organisations being birthed and dying but the entrepreneurs (serial entrepreneurs) staying in the region. In recent years, the wireless cluster seems at the very least interdependent with knowledge spillovers associated with the new media cluster. Capital from outside the region but which has been captured by the region has been an important factor for many years. (Wixted and Holbrook (forthcoming))

Vancouver's special conditions are exemplified by Figure 63 which shows strong R&D growth with unimpressive employment and export performance.

Our first case is of a Vancouver based company in the wireless industry that markets its products mostly to telecommunications companies around the world who re-sell them to end consumers. Its R&D is almost entirely applied. The company has made two significant acquisitions. The first was a California based operation that came with R&D facilities in the Bay area and San Diego. A second acquisition was a French company that had R&D in Toulouse, Paris and Hong Kong. The original Canadian company has only established one non M&A off-shore R&D facility and that is in Shenzhen, China. Both acquisitions were for strategic reasons as they were available for the right price and had good strategic alignment

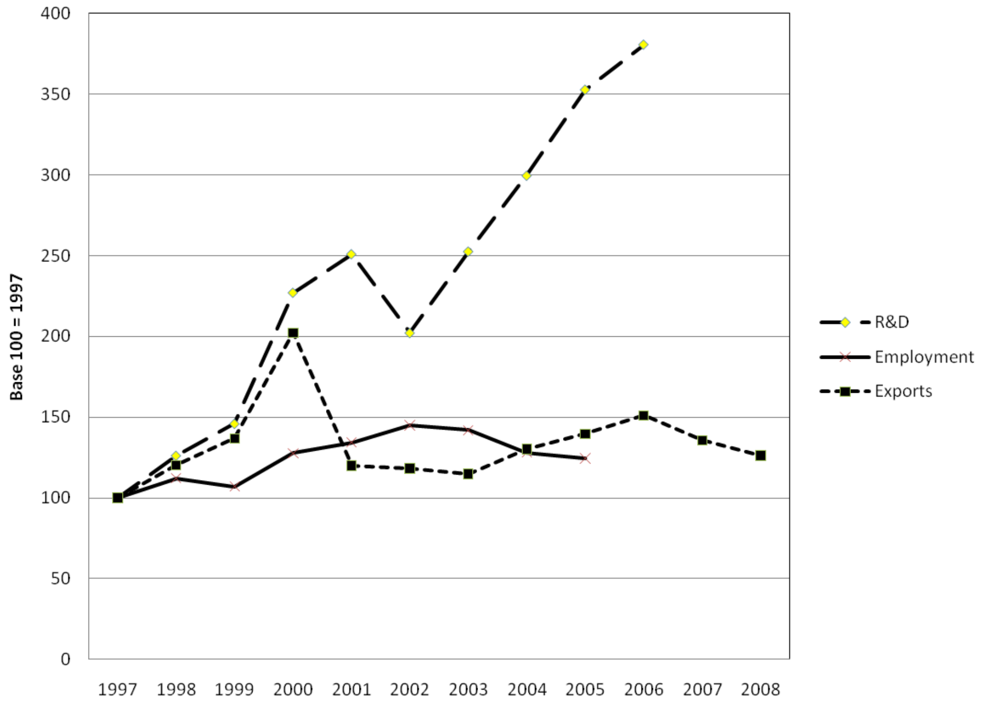
[75] Glenayre was eventually bought and sold by several companies with its corporate history becoming hard to trace.

[76] http://www.derekspratt.com/HTML/Business/Other/Motorola%20Overview.html accessed 24 September 2009

[77] Nokia in BC has during the 2008-2009 year laid off half the work force http://www.vancouversun.com/business/Nokia+cuts+jobs/1790820/story.html accessed 24 November 2009.

[78] http://www.techvibes.com/blog/july-17-weekly-vancouver-game-industry-news accessed 22 July 2010

Figure 63: Growth in the ICT sector in Vancouver (normalized to 1997)



Notes: Base year 1997.

Source: Industry Canada 2007 and Industry Canada 2009a and 2009b.

R&D	$199M
Employment	5,526
Exports	$844M

Although, R&D locations came with the purchases there have been choices regarding geography. Both of the California R&D locations are prime places to take advantage of the electronics mega-cluster in that region. Curiously, although Toulouse is not a particularly strong cluster for wireless, having a lab there has been advantageous because of the diversity of activity in that region (the home of the Airbus assembly facility and associated clusters). One of the acquired companies had activities in the research triangle region of the USA. As these activities were geographically misaligned (not West Coast North America, Europe or China) the site was closed.

The Canadian, European, and US locations are utilised for more strategic R&D while the Asia locations are used for more basic engineering. France is seen as having good R&D tax structures but the entire package – particularly labour laws - are seen as problematic. There is therefore no powerful logic for moving more projects to France, as the total policy mix is seen as neutral.

There was no immediate interest in creating further stand-alone R&D sites anywhere. More particularly there was no appetite for doing R&D or purchasing businesses Eastern Europe as the business environment is seen as unfavourable. The company obviously does not rule out further business purchases or mergers if the business case is 'right'.

The business case therefore trumps any idea of internationalisation of R&D.

5.5.2. Auto industry company

A history of the Canadian Auto and Auto Parts Industry

Automobile manufacturing began in Canada in the early years of the twentieth century when Canadian automobile manufacturers started as partners of established US companies, assembling and selling their partner's cars in Canada. These companies were concentrated mainly in southern Ontario. By the 1920s Canadian control of the industry was lost as the US automakers established control of their Canadian partners.

The Second World War gave the industry a huge boost, as Canada became one of the main suppliers of military vehicles for the Allied forces, and the industry came out of the war with a vastly increased capacity. But, by the end of the 1950s the industry had lost its Imperial-preference export market, and even some of its domestic market, to smaller, cheaper, cars made outside North America. The Canadian government took action, resulting in an agreement between Canada and the US which permitted the major automakers to integrate their operations on a continental scale.

The Canada—United States Automotive Products Agreement, commonly known as the Auto Pact, was signed in early 1965, removed tariffs on cars, trucks, buses, tires, and automotive parts between the two countries, greatly benefiting the large American car makers. In exchange, the big three car makers, General Motors, Ford, and Chrysler, (and later Volvo) agreed that automobile production in Canada would not fall below 1964 levels and that they would ensure the same production-to -sales ratio in Canada.

Before the Auto Pact only three percent of vehicles sold in Canada were assembled in the United States, but most of the parts were manufactured in the US and there was a large overall trade deficit[79]. The Pact caused immediate changes; Canada began to assemble far fewer different models of cars. Instead, much larger branch plants producing only one model for all of North America were constructed. In 1964, only seven percent of vehicles made in Canada were sent to the US, but by 1968, the figure was sixty percent. By the same date, forty percent of cars purchased in Canada were made in the United States. Automobile and parts production quickly surpassed pulp and paper to become Canada's most important industry. When Japanese car makers established Canadian plants in the 1970s they also began to export their Canadian-made cars to the US.

The objective of the pact was to reduce costs in Canada by more efficient production of a smaller range of vehicles and components. The agreement is also said to have benefitted Canadian workers and consumers through lower prices and increased production creating thousands of jobs and increasing wages. These newly-created jobs were highly localised in southern Ontario, with little employment benefit to the rest of Canada. The jobs created by the new market conditions under the pact were almost exclusively blue collar; administration and R&D remained in the US. Canadian subsidiaries had (and still have) little control with respect to vehicle and component specification, design, and sourcing; manufacturing and production, branding and marketing, etc. US automakers also benefitted from both the favourable (to them) exchange rate between the US and Canadian dollar, and labour cost savings resulting from Canada's state-supported health care and universal pension system, which is funded mainly by personal income taxes. The Auto Pact was abolished in 2001 after a World Trade Organization ruling declared it illegal, though by that time the North American Free Trade Agreement (NAFTA) had effectively superseded it.

[79]For more details please see "The continental integration of the North American automobile industry, from the Auto Pact to the FTA and beyond", John Holmes, "*Environment and Planning A*", Vol. 24, pp 95 – 119, 1991

The Auto and Auto Parts cluster today[80]

*"Despite being a mature industry, the automotive parts industry in Ontario has experienced very significant technological changes, innovation and entrepreneurship over the last decade" (*Fitzgibbon *et.al.* 2004).

The automobile industry in Canada is an almost perfect model of an industrial cluster. The industry is vertically integrated and geographically concentrated[81]. Since the end of the auto pact parts suppliers have heavily been squeezed by the large car assemblers on price and performance, with among other things, the threat to procure parts overseas (and not just from Mexico, which is part of NAFTA). This has led to significant agglomeration and concentration with smaller firms being taken over by larger firms. The largest, and by far the most successful, is Magna International. Magna has grown over the years through both domestic and international acquisitions, to become, effectively the fourth largest car maker in Canada, even though it sells no cars under its own marque. At the same time the Canadian automotive cluster has lost much of its competitive advantage due to the strengthening of the Canadian dollar against the US dollar over the past few years[82] and the entry of Mexican subsidiaries into the continental market through NAFTA. Since the economic crisis of 2008 the cluster has contracted due to the troubles of the US automakers.

The Company

The company was founded in 1957 by an Austrian-born immigrant. By 1973, it was a major parts supplier; the company has benefitted greatly from the Auto Pact as a contract parts supplier to American and Japanese manufacturers. Its headquarters are in southern Ontario. Its major product lines are all related to supplying auto parts under contract to primary auto manufacturers (and designed by them). Recent financial figures (2010) show revenue of $25B (approx), with $1B (approx), after tax profit. Its R&D policy is that 7% of after-tax profit be devoted to R&D – approx $ 70m/yr.

It has approximately 104,000 employees in over 2200 divisions in 6 groups, in 26 countries. It is difficult to estimate the number of R&D employees, since there are many "part-timers" – people who do R&D but who do this as part of their normal production duties.

The company has expanded mainly through mergers and acquisitions. In general it has kept the research operations of the acquired companies: its policy is to carry out its research near its customers. Its R&D operations are located in North America (approx 55-60 %), Europe (30%), with less than 15% elsewhere (mainly China, to a lesser extent Mexico). There are other manufacturing locations (e.g. in Brazil) but which have no R&D activities.

As a consequence of its international expansion, the company today has a major EU R&D operation at Graz and other places in Austria. This capacity was the result of the take-over of a Austrian automobile company with considerable vehicle testing facilities, such as a test track. This acquisition was a major step to global market presence and international R&D capacity.

[80]A more detailed description can be found in Fitzgibbon et. al. (2004) and Rutherford and Holmes (2008)

[81]See Michael Porter and Claas van der Linde, Cluster Meta Study at www.isc.hbs.edu, 2004

[82]Due mainly to the rise in oil prices and resources – Canada is a major exporter of oil and other forms of energy to the US, and resources to the rising economies of Asia.

The Canadian company also established the Frank Stronach Institute at the Graz University of Technology (Technische Universitat Graz or TU Graz) in 2006. There are also R&D operations in Germany, primarily near major customers in Munich and Stuttgart

Corporate R&D Strategy

Each R&D project is evaluated on a business case basis. Much R&D consists of product development for existing products. Local and national incentives for R&D are important in determining the location of projects (such as the federal and provincial Scientific Research and Experiment development tax credits in Canada for work in Canada, and state level subsidies in the US, such as those for E-car testing in Michigan, which enjoys specific support by the state of Michigan).

R&D projects are very much development related, and are directed at meeting specific customer needs. Thus, their R&D facilities are located near major customer headquarters in Germany and Detroit. An exception is Austria: Magna-Steyr and FS Institute at T U Graz are located there because of the founder's ties to his former homeland.

The company has no ambition to expand its R&D activities to Eastern Europe since few major auto manufacturers have their headquarters in former Eastern Europe, but now EU, countries. R&D activities in Asia are small because Japanese and Korean manufacturers are heavily vertically integrated (keiretsu), and their parts suppliers do their R&D within the conglomerate.

R&D management comments on government policies

EU nations have better R&D tax credit schemes – not so much in terms of amounts but in terms of consistent application. Interestingly the interviewee felt that <u>his</u> definition of R&D was more restrictive than that used by Revenue Canada – the company's financial people actively work the tax system and usually have a wider definition than that of the R&D division. Canada's SRED system is widely criticized (see the recent Jenkins 2011): while it is designed to stimulate R&D, tax administrators are evaluated on the basis of how much they can claw back from tax credit claims.

The company would put in more money if there were project "pull" e.g. projects directed at the company's needs, not projects looking for a customer. The company is willing to put money into university projects for early stage research that it believes in, but not much of interest shows up.

5.5.3. Discussion and Conclusions

This section presented two case studies on outward BERD of Canadian companies. In these two cases the expansion into new locations was organised through major acquisitions. Once established in these locations the companies may move funds around between them but this is insignificant in comparison to the individual mandates of the centres and the origins of the research centres. The specific location of the auto case was pushed towards Austria for particular reasons but the decision still could be explained by the market expansion motive. R&D was seen as a necessary complementary asset of the target firm but the whole picture of location, strategic technologies and markets were critical.

Policy issues, particularly R&D subsidies were seen as a useful complementary benefit when they were advantageous but insufficient for making a decision. The electronics company thought the French R&D policies were useful but the overall policy-mix (labour laws etc) were a negative, so on balance they cancelled each other out. Neither organisation saw a strategic reason for moving to, acquiring or establishing operations in Eastern Europe.

While large dataset analysis can reveal the hidden preferences of companies, the casual and sometimes inaccurate use of language in the existing literature carries with it the risk of poor policy decisions. From our work on a limited number of cases but with experience that includes 10 years of research on Canadian clusters and city innovation systems, one conclusion is that more emphasis needs to be placed on being very careful of what is being described as foreign controlled and on the circumstances of the evolution of control.

Our two in-depth studies completed combined with our clusters research and built upon with some awareness of particular corporate strategies provides us with a number of stories.

Growth and Scale in the geography of R&D

We can illustrate our finding with six stories, two cases studies for the current project and four that became evident from other sources in preparing this report.

Table 21: Stories of Canadian outward 'foreign' R&D

Case	**Comments**
• Exhibit 1 Vancouver Bio-Pharma cluster firms.	From interviewing a number of small firms in the Vancouver bio-pharma cluster we are aware that many conducted the strategic outsourcing of research across the North American continent or internationally. This outsourcing of research was not aimed at being nearer to customers but building IP through using cost effective contracted partners in a distributed system that enhanced secrecy.
• Exhibit 2 Bombardier Aerospace (2a) and Transport (2b)	From web research[83] and other published material, it appears that Bombardier aerospace has grown through acquisition but now the company is global player it does choose strategically where to do research because: • Competitiveness in aerospace increasingly demands breakthroughs in science; • Bombardier has achieved critical mass; and • Aerospace production is a political issue. • Bombardier Transport has rapidly expanded in Europe through acquisitions in the rail sector with started in the 1970s and accelerated in the 1990s: *In 1990, it enters the U.K. market for the first time, acquiring Procor Engineering Limited, a manufacturer of*

[83] See for example – collaboration with NRC http://www.nrc-cnrc.gc.ca/eng/news/nrc/2010/07/26/bombardier.html , submission to recent federal inquiry into research http://rd-review.ca/eic/site/033.nsf/vwapj/sub023.pdf/$file/sub023.pdf Bombardier invested in a composities research facility in Northern Ireland http://www.ukti.gov.uk/export/countries/asiapacific/middleeast/yemen/item/125671.html

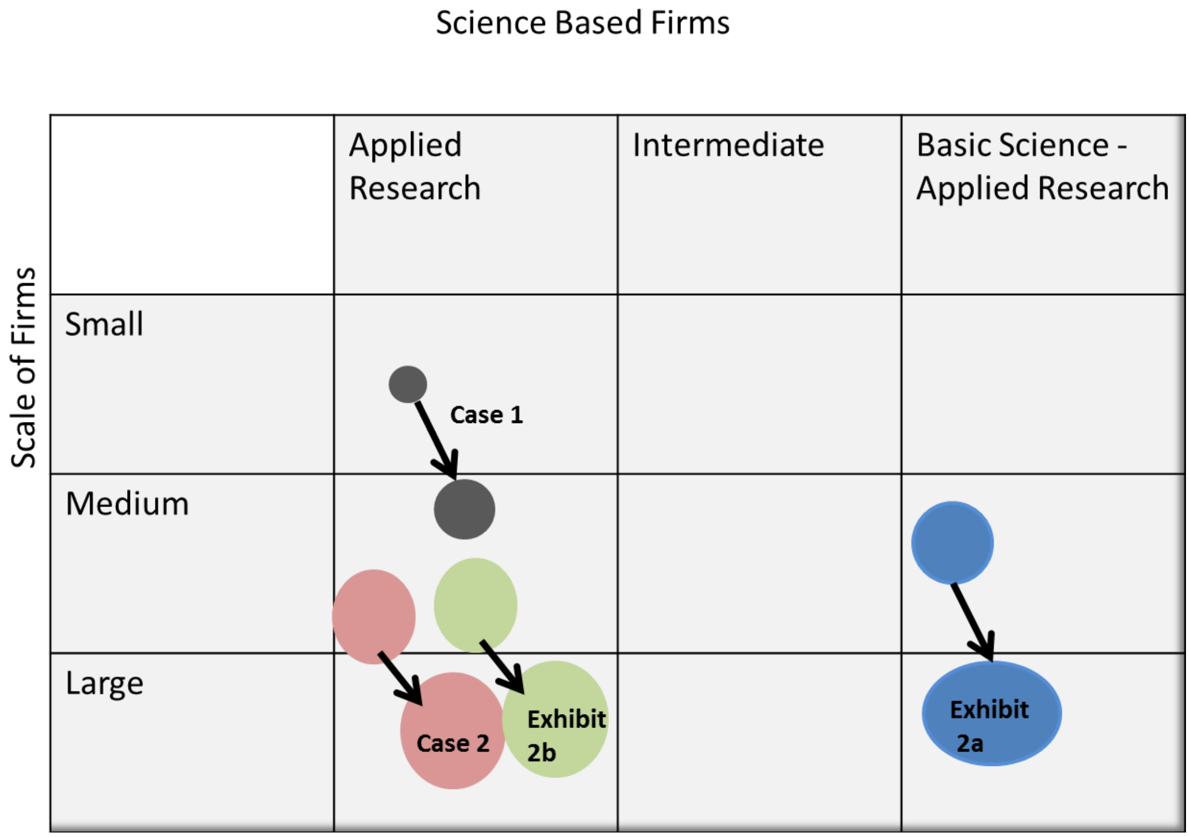
	body shells for locomotives and rail passenger cars. In 1992, it ventures into Mexico, acquiring rail rolling stock manufacturer Constructura Nacional de Carros de Ferrocarril. In 1995 and 1998 respectively, it acquires Waggonfabrik Talbot GmbH & Co. and Deutsche Waggonbau AG (DWA) , rail transportation equipment manufacturers in Germany. These acquisitions expand Bombardier's foothold in Europe, the world's largest rail market (Bombardier [84]). • This pattern of expansion continued in the 2000s: *2001 Bombardier acquires Germany-based DaimlerChrysler AG's subsidiary DaimlerChrysler Rail Systems GmbH (Adtranz). The Adtranz acquisition gives Bombardier global leadership in the rail equipment manufacturing and servicing industry. A year later, Bombardier relocates its Transportation headquarters from Montréal, Canada, to Berlin, Germany. This move strengthens its ability to serve Europe, the world's largest rail market. (Bombardier[85])*
• Exhibit 3 Global Chemicals company	In a presentation recently to the Canadian Science Policy Conference, a representative of Dupont – the global diversified chemicals company emphasised that it did strategically choose the location of its R&D. The company already has a global network of R&D centres so the strategic choice is what projects go where. The prime factors were being close to customers (the business case) and the capability of local centres. Policy and incentives were considered but were not determining factors
• Case 1: Wireless communications	Pursued a growth through strategic acquisition acquiring research facilities in the journey. Complementary research both technically and geographically were kept with non-complementary assets being culled. The company opened one standalone R&D facility and that was Asia.
• Case 2: Auto Transportation	New assets acquired through M&As. But, new locality based arrangements are entered into.

This analysis begins to suggest a framework that might be helpful in relation to ***developed to developed country relationships*** Figure 64 and Figure 65.

[84]http://www.bombardier.com/en/corporate/about-us/history?docID=0901260d8001dffa accessed 14 November 2011

[85]http://www.bombardier.com/en/corporate/about-us/history?docID=0901260d8001dffa accessed 14 November 2011

Figure 64: Speculative pilot framework of foreign R&D growth

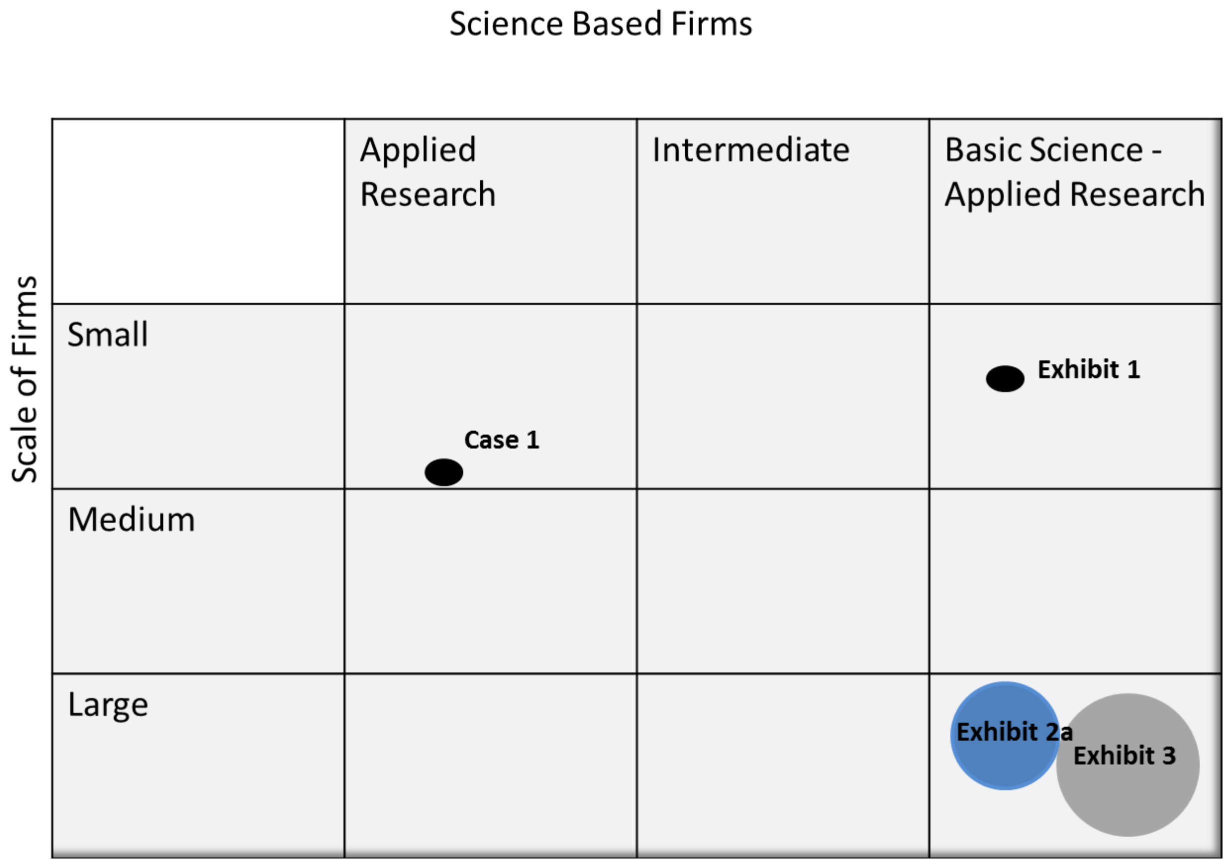


Of the six organisations outlined in table 3 we have evidence of 4 of them growing their foreign R&D. In all cases the growth was mostly achieved through acquisition of local firms. In three of our four examples these were companies that were and are primarily engaged in applied science to support their activities. In three of the four examples they were companies moving from a significant continental to an international or global presence.

Our wireless study reveals that the company looked for opportunities of close alignment. The value framework of the industry being global this makes sense. Our transport case revealed that there was a need to be close to European customers with the particular influence of the CEO colouring the decision making process.

Figure 65summarises the evidence we have on the choices firms exercise in specifically choosing R&D locations.

Figure 65: Speculative plot – strategic R&D choice



From our (albeit limited) sample of corporate examples it could be hypothesised that only a limited number of firms appear to truly choose strategically where to conduct research and development. In our examples small firms engaged in pure science (such as the bio-pharma sector) needed to outsource IP development. At the other end of the scale, 'global' science based firms have the scale but also the need to choose where to locate their R&D, to align these choices with specific strategic factors such as customer locations. In applied research we have just one example of the establishment of standalone research (actually both the parent company did it and one of the acquired firms has done almost exactly the same experiment).

It thus appears that scale and the nature of the research / science have a bearing on standalone research centre establishment, whether research is strategically outsourced or indeed once a global network is established the matching of research with capability.

R&D positioning - developed to developing or transitioning economies

It is worth noting that we only came across one example of a company establishing a lab in an economy that was not a traditional OECD member. In that particular case there was a choice to establish research in Asia. The wireless company had already established a Shenzhen location for cost reasons to tap into local human capital and to assist with commercialisation. When it acquired a French company that had also established a location in Hong Kong the company decided to maintain both at present.

The European policy dimension

As has been already highlighted most investments in our cases were for strategic business reasons and therefore the policy environment did not play a significant role. However, several comments were made.

First, the wireless company noted that the R&D investment regime in France was very good for them. This was however, offset by the labour laws that are more restrictive and cumbersome that North American rules and therefore form a disincentive to invest there (and require a high-level human resources executive to manage the labour issues).

Our auto company also commented favourably on the R&D regime in Europe, noting that a big advantage over the Canadian situation was the predictability of the schemes in Austria and Germany.

Neither country has expressed an interest in Eastern Europe because of the lack of business case to be there. Customers and are important dimension and Eastern Europe lacks the key customers on the human capital. Also, though it was not said as most diversification happens through M&As the lack of suitable existing enterprises would be a deterrent.

6. IMPACTS OF R&D INTERNATIONALISATION ON THE HOST AND HOME COUNTRY – A QUANTITATIVE APPROACH

As discussed in the literature survey of Deliverable 1, host countries can profit considerably from the presence of R&D intensive foreign-owned firms. Hence, attracting these firms has been high on the political agenda. Firstly, higher inward R&D expenditure can increase aggregate domestic R&D and innovation expenditure, essential inputs in the highly risky and resource intensive innovative processes. On the one hand, foreign affiliates may have substantial financial means as they can access funds of their parent companies abroad. On the other hand, domestic firms feel threatened by the growing market entry of foreign firms and see the need to intensify their own R&D activities to keep pace with and resist growing competition from abroad (Aghion et al. 2009).

Secondly, inward R&D expenditure may also give rise to substantial knowledge spillovers (Blomström and Kokko 2003). As a consequence, host countries can upgrade their domestic innovative and technological capacities, provided they possess the necessary absorptive capacity to benefit from these spillovers. Such an upgrading may have a considerable impact on the competitiveness of domestic firms.

Thirdly, inward R&D expenditure may also boost the demand for skilled personnel by creating jobs for researchers or other R&D staff which in turn enhances the level and quality of human resources in the host country and improves its absorptive capacity.

Finally, inward R&D and the presence of foreign firms may lead to structural change and agglomeration effects (Young et al. 1994). On the one hand, since foreign firms predominantly operate in technology-intensive industries, enhanced market entry of foreign firms moves the host country's industrial structure towards technology intensity (Driffield and Taylor 2000). On the other hand, foreign affiliates may give rise to the emergence of clusters of other agglomerations in host countries as their increased demand for technology-intensive inputs can spur the development of regionally concentrated technology-intensive supply chains.

On the contrary, however, inward R&D may also entail negative effects for the host country. Firstly, host countries may lose the control over their indigenous innovation capacity if foreign affiliates predominantly pursue adaptive research and less basic, strategic research, leading to fewer radical innovations.

Secondly, a potential separation of research and production may only yield a few jobs and only provide a weak growth stimulus to the host country when foreign affiliates pursue research in the host country, but transfer production abroad due to more favourable production conditions like cheaper and/or more abundant inputs, less stringent labour protection or proximity to the final consumer (Pearce and Papanastassiou 2009).

Finally, increased presence of foreign firms may also increase competition with domestic firms for essential resources like skilled personnel. Specifically, due to higher wages paid by foreign firms, scientists, engineers and technicians may end up working for foreign firms, leaving domestic firms without vital personnel to successfully pursue research (Driffield and Taylor 2000).

Against that backdrop, the ensuing analysis attempts to identify impacts and consequences the internationalisation of R&D has on the host country. Since the overall country-sample is rather heterogeneous, comprising economies at different stages of economic development and with partly strongly diverging human capital endowments or technological capabilities, more homogenous sub-samples are formed to reveal whether different mechanisms or dynamics are at work for different country sub-samples. In particular, the overall sample was split up into an EU-sample (excluding Japan, Norway and the US), an EU-15 sample (comprising EU-15 member states only) as well as an EU-12 sample (comprising EU-12 member countries only).

6.1. Impact on the scale of domestic R&D expenditure

As a first step, the analysis throws light on whether R&D activities of foreign affiliates crowd-in (complement) or crowd-out (substitute) domestic R&D spending. Particularly, the analysis identifies if foreign and domestic R&D expenditure are positively or negatively associated, without shedding light on the underlying causality. For that purpose, the following specification is analysed:

$$\ln DOMRD_{ikt} = \alpha_0 + \beta_1 \ln FORRD_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt} , \qquad (10)$$

where $\ln DOMRD_{ikt}$ is the log of domestic R&D expenditure in sector k of country i in time t, while $\ln FORRD_{ikt}$ is the corresponding log of R&D expenditure of foreign affiliates in sector k of country i in time t.

Moreover X_{zikt} is a matrix of z additional variables that capture both sector and country level characteristics of host countries only. At the sectoral level, the size of a host country's sector as the share of a sector's employment in total labour force is included to account for potential size effects. In particular, large sectors not only act as major employers but may also be very dynamic and innovative sectors characterised by non-negligible R&D efforts and sizeable R&D expenditure.

Related to that, sectors which host successful and thriving firms also grow rapidly and expand employment very quickly. And in order to stay competitive and profitable, firms in rapidly expanding sectors may have to increase their R&D efforts and R&D expenditure. Hence, sectoral growth, captured by the annual sectoral employment growth rate is included to capture whether R&D expenditure are higher in fast growing sectors.

Moreover, a sector's openness to international trade may affect the scale of domestic R&D expenditure. Basically, innovative activities are inherently risky, uncertain and resource-intensive but if successful, give rise to temporary monopoly positions characterised by above-normal rents which help guarantee firm survival and growth. However, faced with intense competition, firms may have to intensify their R&D efforts to keep pace with competition and their competitors' efforts. Hence, sectors that are more open and exposed to international trade, both in terms of imports and exports, tend to face fiercer competition and, as a consequence, also tend to be characterised by stronger R&D efforts and higher R&D expenditure. Openness is included as the share of the sum of a sector's exports and imports in total sectoral output.

Additionally, the analysis also accounts for country level characteristics of host countries. Specifically, the annual growth rate of a host country's real GDP per capita is included to account for improvements in host countries' standard of living. In particular, extensive R&D efforts in the past may have improved a country's standard of living, a trend that is however sustainable only if additional resources are allotted to R&D activities and the development of new product and/or process technologies.

Moreover, the scale of domestic R&D activities may also crucially depend on the host country's specialisation in high-intensive technology products and exports, captured in terms of the contribution of medium-high-technology industries to the manufacturing trade balance.[86] Generally, since medium-high-technology products are technically more sophisticated, they also tend to be more R&D intensive in their development. Hence, countries which specialise in the production and export of medium-high-technology products are also characterised by, on average, higher R&D efforts and R&D expenditure.[87]

Finally, public STI policies may be pivotal to the level of R&D expenditure of domestic firms - potentially facilitating access to funding or fostering R&D cooperation - encouraging resource-intensive and risky innovative activities of firms. 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 for R&D expenditure of domestic firms (GBAORD_GDP).

The data for the analysis are drawn from various different sources. The dependent variable is calculated as the difference between total R&D expenditure of a country i in sector k and inward R&D expenditure in country i and sector k. Both, data on total and inward R&D expenditure were collected by both AIT and wiiw in the course of the project. Furthermore all sector level control variables (size, growth rate of size and openness) originate from the *OECD Structural Analysis Database* (OECD STAN).[88]The growth rate of real GDP per capita is calculated from official OECD data on real GDP per capita. The contribution of medium-high-technology industries (to the manufacturing trade balance) is calculated from data stemming from the *OECD STAN Bilateral Trade Database* while information on government

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86 In accordance with the OECD, the contribution of medium-high-technology industries (i.e. Electrical machinery and apparatus, n.e.c., motor vehicles, trailers and semi-trailers, chemicals excluding pharmaceuticals, railroad equipment and transport equipment, n.e.c, and machinery and equipment, n.e.c. (see Hatzichronoglou 1997)) to the manufacturing trade balance is calculated as follows:

$$\frac{(X_i - M_i) - (X - M) * \left[\frac{(X_i + M_i)}{(X + M)} \right]}{(X + M)} * 100$$, where $(X_i - M_i)$ is the trade balance of sector i and

$(X - M_i) * \left[\frac{(X_i + M_i)}{(X + M)} \right]$ is the theoretical trade balance or weighted manufacturing sector trade balance.

87 To identify the potential crowding-in or crowding-out effect of inward R&D expenditure, a series of different control variables was tested in the course of the analysis. However, due to partly strong multicollinearities between variables, these variables had to be excluded from the analysis. At the country level, these variables captured the log of real GDP, the log of real GDP per capita, the log of population, the real GDP growth rate, government R&D expenditure as share of real GDP, the log of value added, the log of government R&D expenditure, the tertiary school enrolment rate, public spending on education (both as share in government expenditure and in total GDP), the share of people with tertiary education in total labour force, the number of patent applications by residents per 1000 people or per 1000 researchers as well as their share in total patent applications. At the sector level, excluded control variables comprised the investment rate and inward FDI intensity.
Moreover, due to the lack of appropriate instruments, several other variables had to be excluded from the analysis to avoid biased results from endogeneity. These variables comprised the share of researchers in total labour force, the share of R&D personnel in total labour force and labour productivity.

88 The analysis also intended to use data from EU KLEMS but given either strong multicollinearities between variables or issues of endogeneity, sectoral data were exclusively taken from the OECD Structural Analysis Database.

budgetary appropriations or outlays for R&D stem from the *OECD Main Science and Technology Indicators*.[89]

Generally, given data quality and availability, the ensuing econometric analysis focuses on the short unbalanced panel from 2004 to 2007. Moreover, due to scarce or altogether lacking data for the service sector, the analysis focuses on the manufacturing sector only. Additionally, given the panel nature of the data, both random and fixed effects models were estimated to account for unobserved country-sector heterogeneity. However, since the Hausman test rejected the null hypothesis that the difference in coefficients is not systematic, a fixed effects approach was taken with time fixed effects to account for common time effects. Finally, in accord with above analysis on drivers of inward R&D expenditure, analyses are conducted for the overall sample comprising a set of OECD and non-OECD countries on the one hand[90] as well as three sub-samples on the other. The three sub-samples consist of 21 EU member countries, 12 EU-15 member countries (Austria (AUT), Belgium (BEL), Denmark (DNK), Finland (FIN), France (FRA), Germany (GER), Ireland (IRL), Italy (ITA), the Netherlands (NLD), Spain (ESP), Sweden (SWE) and the UK (GBR)) and 9 EU-12 member countries (Bulgaria (BUL), the Czech Republic (CZE), Estonia (EST), Hungary (HUN), Latvia (LVA), Poland (POL), Romania (ROM), Slovakia (SVK) and Slovenia (SVN)).

Results are presented in Table 22 which demonstrates that except for the overall sample considered the level of foreign R&D expenditure is not significantly associated with the level of R&D expenditure of domestic firms. Hence, there is hardly evidence that R&D expenditure of foreign affiliates complement or substitute (crowd-in or crowd-out, respectively) domestic R&D expenditure.

Generally, significant positive effects are found for four variables only, for different sub-samples though. The level of domestic R&D expenditure tends to be higher in larger sectors in the overall sample and the EU sample only. For the group of EU-12 countries only, a sector’s openness to international trade is associated with higher domestic R&D expenditure which indicates that probably due to keep pace with intense international competition, domestic firms in very open and internationally closely interweaved sectors tend to spend significantly higher resources on research. For the group of EU-15 countries only, R&D expenditure of domestic firms is also found to be significantly higher in countries whose standard of living has been improving. Finally, as expected, the contribution of medium-high-technology sectors to the manufacturing trade balance is positively associated with the level of domestic R&D expenditure.[91] Hence, irrespective of sample considered, domestic R&D expenditure is significantly higher in countries which specialise in the production and export of medium-high-technology products.

In contrast, no effects emerge for sector size growth or the share of government budgetary appropriations or outlays for R&D (GBAORD).

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[89] Descriptive statistics of all variables used in the estimations are provided in Table 68 to Table 71 in Appendix 6. Across all samples considered, between 2004 and 2007, domestic R&D expenditure was on average higher than business R&D expenditure of foreign affiliates. In contrast to the EU-15 sample, however, the difference between domestic and foreign R&D expenditure was smallest in the EU-15 sample. Furthermore, by comparison, the majority of remaining control variables was higher for the EU-12 sample.

[90] The overall sample comprises the following 27 countries: Austria (AUT), Belgium (BEL), Bulgaria (BUL), Canada (CAN), the Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (GER), Hungary (HUN), Ireland (IRL), Israel (ISR), Italy (ITA), Japan (JPN), Latvia (LVA), the Netherlands (NLD), Norway (NOR), Poland (POL), Portugal (PRT), Romania (ROM), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), the UK (GBR) and the US (USA).

[91] In contrast, no significant effects emerge if the contribution of high-tech and medium-high-technology sectors to the manufacturing trade balance is used instead.

Table 22: Impact of R&D internationalisation on the host country (2004-2007) – the scale of domestic R&D expenditure

Dep.Var.: log domestic R&D expenditure	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	3.197***	2.747***	3.794***	-0.937
	(8.01)	(6.19)	(5.58)	(0.75)
Sector level				
Log R&D expenditure of foreign affiliates	-0.067*	-0.073	-0.072	-0.044
	(1.74)	(1.58)	(1.42)	(0.41)
Size	0.548**	0.566**	0.438	0.583
	(2.08)	(1.97)	(0.77)	(1.47)
Size growth rate	-0.004	-0.004	-0.002	-0.005
	(0.79)	(0.74)	(0.37)	(0.56)
Openness	0.000	0.000	0.000	0.004**
	(0.62)	(0.58)	(0.01)	(2.59)
Country level				
Real GDP per capita growth rate	0.010	0.008	0.111***	-0.008
	(1.53)	(0.96)	(3.20)	(-0.63)
Contribution of MHT sectors to manufacturing trade balance	0.159***	0.162***	0.115**	0.207**
	(4.05)	(3.78)	(2.22)	(2.14)
Share of GBAORD in real GDP	0.020	0.028	0.063	0.631
	(0.07)	(0.09)	(0.21)	(0.48)
No of observations	614	523	368	155
R^2	0.0318	0.0087	0.0352	0.0900
Number of i	274	231	170	61

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

All regressions are based on FE estimation procedures and include time fixed 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.

The analysis also experimented with potential lagged effects of foreign R&D expenditure as both crowding-in and crowding-out effects may need time to materialise in the host country. Specifically, domestic firms may need time to adjust their R&D expenditure to higher R&D expenditure of foreign affiliates or to a stronger presence of foreign affiliates. Given the short panel nature of the data (from 2004 to 2007), a one-year lag of the log of R&D expenditure of foreign affiliates was used to shed light on the potential crowding-in or crowding-out effect of foreign R&D expenditure. This analysis leaves all basic conclusions unaltered, however.[92]

[92] To conserve space, the results are not reported here. The results are, however, available upon request from the authors.

6.2. Impact on domestic R&D intensity

Alternatively, the analysis looks at R&D intensities instead and identifies whether sectoral domestic and foreign R&D intensities represent complements or substitutes. It analyses the following specification:

$$DOMRD\mathrm{int}_{ikt} = \alpha_i + \beta_1 FORRD\mathrm{int}_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt}\,, \qquad (11)$$

where $DOMRD\mathrm{int}_{ikt}$ is the share of domestic R&D expenditure in value added in sector k of country i in time t, while $FORRD\mathrm{int}_{ikt}$ is the corresponding share of R&D expenditure in value added of foreign affiliates in sector k of country i in time t.

Again, X_{zikt} is a matrix of z additional variables that capture both sector and country level characteristics of host countries only. Like before, the size of a host country's sector, the growth rate of the sector and the sector's openness are included at the sectoral level. In contrast to above analysis, the log of real GDP as a proxy for the size of the economy or market and the contribution of medium-high-technology sectors (to the manufacturing trade balance)[93] are included at the country level.[94]

Again, both random and fixed effects models were estimated to account for unobserved country-sector heterogeneity. However, the Hausman test did not reject the null hypothesis that the difference in coefficients is not systematic while the Breusch-Pagan Lagrange multiplier test rejected the presence of any random effects so that a pooled OLS approach was chosen with both time and country fixed effects to account for both common time effects and unobservable time-invariant country characteristics. Analyses are again conducted for various samples.

Results are presented in Table 23 below which highlights that with the exception of the overall OECD sample (column (1)), significant complementarities prevail between R&D intensities of foreign and domestic firms. Specifically, for the EU as a whole as well as for the group of EU-15 and of EU-12 countries, R&D intensities of domestic firms are high if R&D intensities of foreign affiliates are high too. This is consistent with findings of the graphical analysis of R&D intensities (see section 3.1.2 above) which highlight that apart from a couple of outliers, R&D intensities of both domestic and foreign firms are pretty similar and align closely along the 45 degree line. Moreover, Table 23 also highlights that complementarities between domestic and foreign R&D intensities are stronger in the EU-15 sample (column (3)). However, the underlying causality is still an open issue: did domestic firms increase their R&D intensities to match higher R&D intensities of foreign firms (as a measure to keep pace with foreign affiliates' R&D efforts) or did foreign affiliates increase their R&D intensities to match inherently higher R&D intensities of domestic firms in a sector (as a measure to keep pace with R&D efforts of domestic firms)? A test of the direction of this causality would require a longer time series on both inward and domestic R&D expenditure.

Furthermore, the analysis shows that larger sectors tend to be characterized by significantly lower R&D intensities of domestic firms. This effect is stronger in the sample of EU-15 countries (column (3)) (compared to the group of EU-12 countries (column (4)).

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93 See footnote 86 for the definition.

94 Table 76 to Table 79 in Appendix 6 provide descriptive statistics of all variables used in the analysis. Across all samples considered, between 2004 and 2007, R&D intensities of domestic firms were, on average, higher than R&D intensities of foreign affiliates. This discrepancy was most pronounced for the group of EU-15 countries. Moreover, with one exception only (i.e. log of real GDP), all remaining control variables were higher for the group of EU-12 countries.

In contrast, no effect is found for either sectoral growth or openness to international trade and competition. Finally, none of the country level control variables exhibits any significant effect on sectoral R&D intensities of domestic firms.[95] These effects are entirely absorbed by the country fixed effects.

Table 23: Impact of R&D internationalisation on the host country (2004-2007) – domestic R&D intensity

Dep.Var.: domestic R&D intensity	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	30.538	10.270	33.984	9.406**
	(0.29)	(1.13)	(1.42)	(2.12)
Sector level				
R&D intensity of foreign affiliates	0.010	0.726***	0.765***	0.267**
	(0.04)	(9.56)	(8.07)	(1.99)
Size	-5.770**	-1.593***	-2.113**	-1.409***
	(2.45)	(3.12)	(2.55)	(3.14)
Size growth rate	-0.117	0.097	0.178	0.073
	(0.33)	(1.24)	(0.96)	(1.38)
Openness	0.019	0.007	0.007	0.003
	(1.00)	(1.56)	(1.30)	(0.46)
Country level				
Log real GDP	-1.444	-0.047	-0.210	-0.294
	(0.52)	(0.08)	(0.08)	(0.68)
Contribution of MHT sectors to manufacturing trade balance	1.227	0.767	4.925	-0.753
	(0.17)	(0.51)	(1.37)	(0.68)
No of observations	429	346	221	125
Adj. R^2	0.0708	0.482	0.486	0.168

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

All regressions are based on pooled OLS estimation procedures and include time fixed effects and country fixed 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.

To sum up, the analysis of absolute R&D expenditure of foreign and domestic firms reveals (almost) no significant relationship between inward and domestic R&D expenditure. In contrast, however, a significant positive relationship emerges between R&D intensities of domestic and foreign firms which highlights that foreign firms do not crowd out domestic R&D activities. Rather, it supports the hypothesis that both, R&D expenditure of domestic and foreign firms complement each other. Both, foreign and domestic firms may react to the same incentives in their planning of R&D and may benefit from the same framework conditions. There may be cross-fertilisation by transfers of knowledge between the two groups. In addition, there may also be competitive pressures from one group that forces the other group to modify R&D efforts in order to remain competitive. In this respect, foreign R&D activities in a country contribute to the competitiveness of domestic firms and of the host country.

[95] This finding is unaltered if the contribution of high-tech and medium-high-technology sectors to the manufacturing trade balance is used instead.

6.3. Impact on domestic labour productivity

The analysis also looks at labour productivity as another source of firm competitiveness. It is generally acknowledged that innovation and technology are important sources of labour productivity growth (Pianta 2005, Harrison et al. 2008). Specifically, product and process innovations may increase labour productivity such that new products increase the overall output of a firm or that new processes lessen input-requirements necessary to produce a specific volume of output. Generally, there is ample empirical evidence that productivity levels of foreign affiliates are higher compared to their domestic competitors which is typically traced back to superior assets like superior production technologies of foreign firms (see e.g. Girma et al. 2001 or Driffield 2001). And even though foreign affiliates are interested in and take measures to protect their knowledge and technologies, protection may not be perfect and some technological knowledge may still spill over to domestic firms, improving their productivity levels and amplifying their performance and growth. Such leakages exist in the form of i) systematic imitation by domestic firms, ii) labour mobility of skilled employees from foreign firms to local firms, or iii) as a result of competitive forces which encourage domestic firms to become more efficient.

Against that backdrop, the ensuing analysis takes a two-pronged approach. In a first step, the analysis seeks to shed light on the effects R&D efforts of foreign affiliates have on domestic firms' labour productivity, implicitly assuming that intense R&D efforts of foreign affiliates translate into marketable new or modified products or processes which, in turn, improve their labour productivity and, due to the existence of spillovers, also affect the labour productivity of domestic firms. However, innovative processes are inherently complex, resource intensive, selective and uncertain so that there is no guarantee that intense R&D efforts result in new (or modified) products and/or processes at all. Hence, the effect on labour productivity of domestic firms may be rather limited or absent altogether. Therefore, a second, complementary approach is pursued which more directly tests for the existence of spillovers by examining whether the presence of more productive foreign affiliates (i.e. foreign firms whose labour productivity improved due to successful R&D activities) in a sector renders domestic firms more productive also.

With respect to the effects of R&D expenditure of foreign affiliates on labour productivity of domestic firms, the following specification is analysed:

$$\ln DOMLP_{ikt} = \alpha_i + \beta_1 \ln RDf_{jkt} + \delta_z X_{zikt} + \varepsilon_{ikt}\,, \tag{12}$$

where $\ln DOMLP_{ikt}$ is the log of domestic labour productivity (defined as the ratio of gross output to total employment) in sector k of country i in time t, while $\ln RDf_{jkt}$ is the log of R&D expenditure of foreign affiliates in sector k of country i in time t.

Again, 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, the annual growth rate of a sector's size (in terms of employment) is included to capture the potential disruptive effect sizeable employment expansion may have on labour productivity. Specifically, it takes time to adapt the overall production process to newly hired employees and before newly hired employees are able to operate at their highest possible productivity levels.

Furthermore, the scale of domestic labour productivity may also be affected by a sector's openness and exposure to international trade. Specifically, faced with fierce international competition domestic firms may see the need to improve their ability to compete by raising productivity, for example by implementing new technologies or more efficient ways of organisation and management. Hence, sectors that are more open to international trade may be characterised by higher labour productivity. Openness is included as the share of the sum of a sector's exports and imports in total sectoral output.

Moreover, sectoral investment rates defined as the share of gross fixed capital formation in total gross output may be key to domestic labour productivity. In particular, from a vintage-model point of view, new capital goods like new machinery and equipment which embody leading-edge technology and knowledge result in non-negligible productivity improvements. However, Nickell (1978) stresses that the implementation of capital goods incurs costs over and above their price. Specifically, Hamermesh and Pfann (1996) point out that costs of adjusting the level of capital goods are associated with temporary disruptions of routines, reassignment and restructuring of tasks and consequently, temporary productivity (and output) losses. Hence, higher investment rates are expected to - at least temporarily - be associated with productivity losses.

The analysis also accounts for country level characteristics of host countries. Specifically, the log of a host country's real GDP per capita is included to account for the potential standard-of-living effects on labour productivity.

Finally, human capital is considered to be essential for productivity improvements and growth. Hence, the share of tertiary graduates in the fields of science, mathematics, computing, engineering, manufacturing and construction in the total labour force is included and expected to positively affect labour productivity.

The data stem from various sources. The dependent variable is calculated from data taken from *OECD Structural Analysis Database* as well as the *OECD Activities of Foreign Affiliates statistic* (OECD AFA)[96]. Moreover, all sector level control variables (size growth, openness and the investment rate) originate from the *OECD Structural Analysis Database* (OECD STAN). The log of real GDP per capita is taken from official OECD data on real GDP per capita while the share of tertiary graduates is calculated from official data on OECD school attainment levels.[97]

Both random and fixed effects models were estimated to account for unobserved country-sector heterogeneity. However, the Hausman test did not reject the null hypothesis that the difference in coefficients is not systematic while the Breusch-Pagan Lagrange multiplier test rejected the presence of any random effects. Hence, a pooled OLS approach was taken with both time and country fixed effects to account for common time effects as well as systematic but unobservable time-invariant differences across countries.

Results are presented in Table 24 which highlight that except for the group of EU-12 countries, innovative efforts of foreign affiliates are positively associated with labour productivity of domestic firms. Hence, there is evidence that, except for the group of EU-12 countries, higher R&D expenditure of foreign affiliates in a sector renders domestic firms significantly more productive, though the effect is rather small. Specifically, a 1% increase in R&D expenditure of foreign affiliates is associated with a 0.05% increase in labour productivity of domestic firms.

[96] The analysis also attempted to use data from EU KLEMS but given either strong multicollinearities between variables or issues of endogeneity, sectoral data were exclusively taken from OECD Structural Analysis Database.

[97] Descriptive statistics of all variables are provided in Table 84 to Table 87 in Appendix 6.

Table 24: Impact of R&D internationalisation on the host country (2004-2007) – domestic labour productivity

Dep.Var.: Log domestic labour productivity	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	3.892	4.210	-3.304	12.836
	(0.36)	(0.33)	(0.03)	(0.94)
Sector level				
Log inward R&D expenditure	0.054***	0.054***	0.056**	0.043
	(3.00)	(2.95)	(2.30)	(1.48)
Size growth	0.018***	0.020***	0.034***	0.019**
	(2.84)	(2.94)	(2.72)	(2.29)
Openness	0.000	0.000	0.000	0.001*
	(0.31)	(0.29)	(0.99)	(1.77)
Investment rate	0.002	0.002	0.011	-0.003
	(0.21)	(0.13)	(0.60)	(0.21)
Country level				
Log real GDP per capita	0.798	0.798	1.650	-0.338
	(0.63)	(0.62)	(0.16)	(0.21)
Share of tertiary graduates	-4.035	-4.067	-10.156	8.736
	(0.86)	(0.85)	(0.71)	(0.74)
Dummy: MT sector	-0.017	-0.027	0.038	-0.158
	(0.24)	(0.38)	(0.42)	(1.36)
Dummy: HT sector	0.016	0.014	0.139	-0.215
	(0.15)	(0.12)	(0.85)	(1.31)
No of observations	303	290	167	123
Adj. R^2	0.576	0.553	0.251	0.126

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

All regressions are based on pooled OLS estimation procedures and include time and country fixed effects. Column (1) is based on the overall EU sample; column (2) uses the EU-15 sub-sample only, while column (3) uses the EU-12 sub-sample only.

Furthermore, Table 24 also reveals that labour productivity of domestic firms which operate in rapidly expanding sectors is significantly and consistently higher.

In contrast, no significant effects are found for either sectoral openness or sector level investment rates as well as for both the standard of living and the share of graduates in total labour force.

Next, the analysis determines whether higher labour productivity of foreign affiliates also translates into higher labour productivity of domestic firms. This is analysed by the following specification:

$$\ln DOMLP_{ikt} = \alpha_i + \beta_1 \ln FORLP_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt} \,, \qquad (13)$$

where $\ln DOMLP_{ikt}$ is the log of domestic labour productivity (defined as the ratio of gross output to total employment) in sector k of country i in time t, while $\ln FORLP_{ikt}$ is the corresponding log of labour productivity of foreign affiliates in sector k of country i in time t.

Again, X_{zikt} is a matrix of z additional variables that captures both sector and country level characteristics of host countries only.

Results are presented in Table 25 below which highlight that irrespective of sample considered, labour productivity of foreign affiliates is positively associated with labour productivity of domestic firms. Hence, there is consistent evidence that the presence of more productive foreign affiliates in a sector also renders domestic firms significantly more productive. Specifically, a 1% increase in labour productivity of foreign affiliates is associated with a 0.4% increase in labour productivity of domestic firms. By comparison, this relationship is strongest for the sample of EU-15 countries (column (2)).

Table 25: Impact of R&D internationalisation on the host country (2004-2007) – domestic and foreign labour productivity

Dep.Var.: Log domestic labour productivity	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	-3.066	-2.606	-38.516	13.699
	(0.26)	(0.21)	(1.12)	(0.63)
Sector level				
Log foreign labour productivity	0.405***	0.404***	0.444***	0.368***
	(6.84)	(6.61)	(6.83)	(2.87)
Size growth	-0.011**	-0.011*	0.004	-0.018*
	(2.00)	(1.87)	(0.48)	(1.96)
Openness	0.000	0.000	-0.001	0.000
	(1.23)	(1.24)	(1.64)	(0.36)
Investment rate	-0.009	-0.010	0.012	-0.016
	(0.88)	(0.90)	(0.78)	(0.94)
Country level				
Log real GDP	0.906	0.863	3.740	-0.877
	(0.79)	(0.72)	(1.30)	(0.39)
Share of tertiary graduates	-2.420	-2.376	1.918	13.157
	(0.70)	(0.67)	(0.39)	(0.77)
Dummy: MT sector	0.225***	0.230***	0.255***	0.146
	(3.43)	(3.37)	(3.60)	(0.98)
Dummy: HT sector	0.507***	0.527***	0.412***	0.691***
	(5.20)	(5.17)	(3.71)	(3.34)
No of observations	457	435	288	147
Adj. R^2	0.479	0.460	0.351	0.140

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

All regressions are based on pooled OLS estimation procedures and include time and country fixed effects. Column (1) is based on the overall EU sample; column (2) uses the EU-15 sub-sample only, while column (3) uses the EU-12 sub-sample only.

Furthermore, Table 25 reveals that labour productivity of domestic firms which operate in rapidly expanding sectors is significantly lower. This is found for the overall EU sample (column (1)) as well as the EU-12 sub-sample (column (3)), but not in the EU-15 sub-sample of column (3). This finding is indicative of the disruptive effect sizeable employment expansion has on labour productivity in the EU-12 as production processes need to be adapted to larger workforces, temporarily disrupting smooth and routinised processes, and newly hired employees are less routinised and productive than incumbent employees.

In contrast, no effect whatsoever is found for either sectoral openness or sector level investment rates as well as for both the size of the economy (as proxied by the log of real GDP) and the share of graduates in total labour force.

Finally, evidence is found that labour productivities of domestic firms differ across sectors with different R&D intensities. In particular, relative to low-technology sectors, characterised by low R&D intensities, medium and high-technology sectors host domestic firms with significantly higher labour productivities. And by comparison, high-technology sectors host the most productive domestic firms.

6.4. Impact on domestic employment

In addition, the analysis attempts to determine the impact or effects R&D efforts of foreign affiliates have on host country employment levels. Again, a two-pronged approach is taken. The first approach examines whether more intense research efforts of foreign affiliates stimulate or deter employment in domestic firms. Generally, there is a rich strand of firm-level based literature on the employment-effects of innovations which highlights that product innovations tend to have a positive effect on employment while employment responses to process innovations are less clear-cut and rather mixed.[98] Hence, the first approach implicitly assumes that, in the face of highly resource intensive and uncertain innovative processes, intense R&D efforts of foreign affiliates result in successful innovations which, in turn, spur growth (in terms of employment), and, through spillover effects, also render domestic firms more successful and stimulate employment expansion. In contrast, the second approach takes a more direct approach and focuses on the existence of any spillover effects by analysing whether, in response to higher employment in foreign firms, domestic firms also tend to employ more workers.

With respect to the first approach, following specification is analysed:

$$\ln DOMEMPL_{ikt} = \alpha_i + \beta_1 \ln RDf_{jkt} + \delta_z X_{zikt} + \varepsilon_{ikt} , \qquad (14)$$

where $\ln DOMEMPL_{ikt}$ is the log of employment of domestic firms in sector k of country i in time t, while $\ln RDf_{jkt}$ is the corresponding log of R&D expenditure of foreign affiliates in sector k of country i in time t.

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 openness to international trade as the share of the sum of exports and imports in total gross output is included to account for the potential effect exposure to fiercer international competition has on employment at home. Specifically, exposure to international competition may force firms to be cost-efficient and productive in order to remain competitive and to survive and thrive. Hence, cost considerations may force firms to scale down their workforce.

Moreover, a sector's investment rate as the share of gross fixed capital formation (GFCF) in total gross output may affect the scale of domestic employment. Specifically, Bartel and Lichtenberg (1987) point at the existence of non-negligible capital-labour complementarities such that employment expands should firms decide to upgrade their machinery and equipment with leading-edge technologies embodied in new machinery and equipment. In contrast, however, these complementarities vanish if investment activities are driven by cost and rationalisation considerations intended to increase the degree of mechanisation.

Additionally, the analysis also accounts for specific characteristics of host countries. In particular, host countries' real GDP growth rates are included to capture the role growing income or, equivalently, a growing market has on sector level domestic employment. To some

[98] For product innovations, see e.g. Van Reenen (1997), Smolny (1998), Rottmann and Ruschinski (1998), Lachenmaier and Rottmann (2006), Becker and Ecker (2007), Garcia et al. (2002), Hall et al. (2007) or Benavente and Lauterbach (2008). For process innovations see e.g. Smolny (1998), Lachenmaier and Rottmann (2006) and Becker and Egger (2007) or Garcia et al. (2002) for positive effects, Ross and Zimmermann (1993) for negative employment effects or Van Reenen (1997), Rottmann and Ruschinski (1998), Hall et al. (2007) and Benavente and Lauterbach where no significant effect of process innovations is detected.

extent, this indicator captures the potential presence of jobless growth observed in Europe during the last decade.

Finally, host countries' contribution of medium-high-technology industries to the manufacturing trade balance [99] are included since a country's industry specialisation towards medium-high-technology products and medium-high-technology exports may be key to domestic employment levels. Specifically, due to cost and productivity considerations, firms located in countries which strongly specialise in medium-high-technology products may be forced into reducing employment to successfully compete with their products on the international arena.

The data come from various different sources. The dependent variable is calculated as the difference between total employment of a country *i* in sector *k* (as provided by the *OECD Structural Analysis Database*) and employment at foreign affiliates in country *i* and sector *k* (as provided by the official *OECD Activities of Foreign Affiliates statistic*). Furthermore all sector level control variables (openness, investment rate and R&D intensity) originate from the *OECD Structural Analysis Database* (OECD STAN), the *OECD Analytical Business Enterprise Research and Development Database* (OECD ANBERD) as well as the *EU Business Expenditure on R&D Database* (EU BERD).[100] The growth rate of real GDP per capita is calculated from official OECD data on real GDP per capita while the contribution of medium-high-technology industries (to the manufacturing trade balance) is calculated from data stemming from the *OECD STAN Bilateral Trade Data*.[101]

To account for unobserved country-sector heterogeneity, both random and fixed effects models were estimated. However, the Hausman test rejected the null hypothesis that the difference in coefficients is not systematic. Consequently, a fixed effects approach was chosen with time effects to account for both common time effects. Analyses are conducted for the overall sample comprising a set of OECD countries on the one hand as well as an overall sample of EU countries and two EU sub-samples on the other comprising EU-15 and EU-12 countries, respectively.

Results consistently demonstrate that irrespective of sample considered employment in domestic firms and the level of inward R&D expenditure are unrelated (Table 26).

Moreover, there is some indication that domestic employment is significantly lower in sectors with stronger openness and exposure to international trade. This negative openness-employment nexus emerges for the group of EU-15 countries only (column (3)).

In contrast, no effect emerges for either the investment rate or the real GDP growth rate.

Finally, except for the group of EU-15 countries, the host country's specialisation in medium-high-technology products and exports turns out to be irrelevant for domestic employment levels.[102]

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[99] See footnote 86 for the definition.

[100] The analysis also attempted to use data from EU KLEMS but given either strong multicollinearities between variables or issues of endogeneity, sectoral data were exclusively taken from OECD Structural Analysis Database.

[101] Descriptive statistics of all variables are provided in Table 100 to Table 103 in Appendix 6.

[102] This remains unaltered if the contribution of high-tech and medium-high-technology sectors to the manufacturing trade balance is used instead.

Table 26: Impact of R&D internationalisation on the host country (2004-2007) – domestic employment levels

Dep.Var.: log domestic employment	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	11.492***	11.314***	12.083***	10.588***
	(111.05)	(102.61)	(122.88)	(48.69)
Sector level				
Log inward R&D expenditure	-0.010	-0.008	-0.002	0.024
	(0.71)	(0.55)	(0.21)	(0.55)
Openness	0.001	0.001	-0.006***	0.003
	(0.81)	(0.83)	(5.60)	(1.60)
Investment rate	0.004	0.004	-0.003	0.004
	(0.74)	(0.76)	(0.36)	(0.52)
Country level				
Real GDP growth rate	-0.001	-0.001	0.001	-0.002
	(0.50)	(0.60)	(0.63)	(0.84)
Contribution of MHT sectors to manufacturing trade balance	0.015	0.018	0.060***	0.014
	(0.85)	(0.91)	(3.20)	(0.40)
No of observations	288	267	175	92
R^2	0.101	0.073	0.229	0.194

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

All regressions 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.

Next, the analysis pursues to analyse the direct effect of employment in foreign affiliates on employment in domestic firms. In that respect, it analyses the following specification:

$$\ln DOMEMPL_{ikt} = \alpha_i + \beta_1 \ln FOREMPL_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt}, \qquad (15)$$

where $\ln DOMEMPL_{ikt}$ is the log of employment of domestic firms in sector k of country i in time t, while $\ln FOREMPL_{ikt}$ is the corresponding log of employment of foreign affiliates in sector k of country i in time t.

X_{zikt} is a matrix of z additional variables that captures both sector and country level characteristics of host countries only.

Results are presented in Table 27 below which consistently demonstrates that irrespective of sample considered, employment in foreign affiliates and domestic firms are positively associated. Specifically, a 1% increase in employment of foreign affiliates is associated with a 0.4% increase in employment of domestic firms. By comparison, this relationship is slightly stronger for the sample of EU-12 countries however (column (4)).

Moreover, there is consistent evidence that domestic employment is significantly lower in sectors with stronger openness and exposure to international trade.

In the same vein, a negative relationship emerges between the level of domestic employment and the R&D intensity of a sector.

Table 27: Impact of R&D internationalisation on the host country (2004-2007) – domestic and foreign employment levels

Dep.Var.: log domestic employment	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	2.510***	3.426***	4.280***	2.387*
	(2.93)	(4.64)	(4.85)	(1.74)
Sector level				
Log foreign employment	0.468***	0.443***	0.403***	0.514***
	(12.52)	(11.24)	(8.37)	(7.57)
Openness	-0.001***	-0.003***	-0.002***	-0.003***
	(5.39)	(6.90)	(5.62)	(3.01)
R&D intensity	-0.029***	-0.027***	-0.026***	-0.087***
	(7.03)	(5.56)	(5.19)	(3.23)
Investment rate	0.017*	0.030***	0.010	0.072***
	(1.68)	(2.80)	(0.78)	(3.46)
Country level				
Contribution of MHT sectors to manufacturing trade balance	-0.025	-0.028	0.013	-0.157
	(0.29)	(0.33)	(0.13)	(0.73)
No of observations	637	568	406	162
Adj. R^2	0.735	0.694	0.711	0.609

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

All regressions are based on pooled OLS estimation procedures with time and country fixed 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.

By comparison, for all but the EU-15 sub-sample only (column (3)), domestic employment is significantly higher in sectors characterised by high investment rates, pointing at capital-labour complementarities as emphasised by Bartel and Lichtenberg (1987).

Finally, the host country’s specialisation in medium-high-technology products and exports turns out to be irrelevant for domestic employment levels.[103]

[103] This finding remains unaltered if the contribution of high-tech and medium-high-technology sectors to the manufacturing trade balance is used instead.

6.5. Impact on domestic patenting activity

Finally, the analysis also sheds light on the effects R&D activities of foreign affiliates have on host country patenting activities. In particular, it analyses whether higher R&D efforts of foreign affiliates spurs domestic patent activities by increasing domestic firms' inventiveness and innovativeness: either through knowledge spillovers which help domestic firms develop technological capabilities essential for any successful R&D activities or through 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 analysed:

$$\ln DOMPATENTS_{ikt} = \alpha_i + \beta_1 FORRDintensity_{ikt} + \beta_2 DOMRDintensity_{ikt} + \delta_z X_{zikt} + \varepsilon_{ikt}, \qquad (16)$$

where $\ln DOMPATENTS_{ikt}$ is the log of patent applications to the European Patent Office (EPO) of domestic firms in sector k of country i in time t while $FORRDintensity_{ikt}$ and $DOMRDintensity_{ikt}$ are the R&D intensities of foreign affiliates and domestic firms, respectively, (as the share of R&D expenditure in value added) in sector k of country i in time t.[104]

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), its growth rate as well as its degree of openness to international trade are included as potential determinants of domestic firms' patenting activities. In particular, larger sectors may also 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 at the patent office. Furthermore, R&D efforts (and success) may be higher in quickly expanding sectors, resulting in higher patent applications.

A sector's 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.

Furthermore, some host country characteristics are included. In particular, 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 such, innovative and patenting activities may be higher in economies characterised by swiftly improving standards of living, as consumers' 'love of variety' induces firms to continuously invest in R&D activities so as to develop new products and/or processes that match consumers' tastes and preferences and help firms expand profits and defend or expand market shares.

Account is also taken of the share of government R&D expenditure (for R&D activities conducted in the tertiary education sector) in total GDP as a proxy for public science, technology and innovation policies. In particular, countries with governments that are committed to funding tertiary sector research activities may also be more innovative, as crucial resources are provided for the highly resource-intensive but risky innovative activities, rendering successful innovations potentially more likely.

[104] Due to strong underlying multicollinearities between the level of both inward and domestic R&D expenditure, the analysis focuses on the role of R&D intensities instead.

Finally, account is also taken of the contribution of medium-high-technology industries to the manufacturing trade balance[105] since a country's industry specialisation towards medium-high-technology products and medium-high-technology exports may be pivotal to the quality and effectiveness of domestic technological capabilities. Specifically, firms located in countries which strongly specialise in medium-high-technology products may possess superior technological capabilities to continuously develop technological novelties which, for protective reasons, may be patented.

The analysis uses different data sources. The dependent variable stems from the *OECD Patent Database*, R&D expenditure of foreign 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 affiliates. Furthermore, information on value added of foreign affiliates is taken from the *OECD Activities of Foreign Affiliates statistic* (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 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*.[106]

Methodologically, both random and fixed effects models were estimated to account for the presence of unobserved country-sector heterogeneity. However, the Hausman test rejected the null hypothesis that the difference in coefficients is not systematic. Hence, a fixed-effects approach was chosen without time fixed effects. In line with above analyses, results are presented and discussed for various samples: the overall sample comprising a set of OECD countries, an overall sample of EU countries and two EU sub-samples comprising EU-15 and EU-12 countries, respectively.[107]

Results are presented in Table 28 which stresses that host country patenting activities appear unrelated to both foreign 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). Likewise, empirical evidence also stresses that host country patenting activities are unrelated to domestic firms' R&D intensities. The only exception is the group of EU-15 countries for which a positive and significant relationship emerges: hence, only for the group of EU-15 countries are higher R&D intensities of domestic firms associated with higher EPO patent applications. Generally, however, the absence of a significant relationship between (foreign 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. For one, patents represent imperfect proxies for

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[105] See footnote 86 for the definition

[106] The analysis also attempted to use data from EU KLEMS but given either strong multicollinearities between variables or issues of endogeneity, sectoral data were exclusively taken from OECD Structural Analysis Database.

[107] Descriptive statistics of all variables used in the analysis are provided in Table 116 to Table 119 in Appendix 6. The descriptive statistics show that between 2004 and 2007, the sample of EU-15 countries reported, on average, more EPO patent applications. Moreover, as for the remaining control variables, both foreign and domestic R&D intensities are, on average, two to three times higher in the EU-15 than in the EU-12 sample. Furthermore, in the EU-15 sample, both R&D intensities also show broader variation. Finally, for all remaining variables, the sample of EU-12 countries outperforms the sample of EU-15 countries.

the output of any research activities: Firstly, 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. And secondly, patents do not capture innovations of imitators. Hence, official patent statistics strongly underestimate a country's true innovativeness. Moreover, 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. Finally, there is a tendency that complex relationships vanish or become obstructed once higher levels of aggregation are analysed.

Table 28: Impact of R&D internationalisation on the host country (2004-2007) – domestic patenting activity

	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	2.361***	1.794***	4.910***	-0.760
	(7.58)	(5.08)	(27.86)	(1.20)
Sector level				
R&D intensity of foreign affiliates	0.005	0.006	0.003	0.009
	(0.76)	(0.83)	(1.09)	(0.60)
R&D intensity of domestic firms	-0.001	-0.001	0.003**	-0.003
	(0.23)	(0.19)	(2.20)	(0.38)
Size	1.298***	1.325***	0.199	1.649***
	(5.76)	(5.41)	(1.47)	(4.19)
Size growth	0.003	0.003	0.003	0.002
	(0.98)	(0.95)	(1.04)	(0.53)
Inward FDI intensity	0.003	0.003	-0.001	0.004
	(1.07)	(0.99)	(0.41)	(0.67)
Openness	0.000	0.000	0.000	0.000
	(0.01)	(0.04)	(0.95)	(0.11)
Country level				
Real GDP per capita growth	-0.002	-0.005	-0.008	-0.006
	(0.49)	(0.77)	(1.08)	(0.63)
Contribution of MHT sectors to manufacturing trade balance	0.030	0.027	0.054**	0.004
	(0.88)	(0.73)	(2.44)	(0.07)
No of observations	251	208	116	92
R^2	0.0395	0.0274	0.0409	0.00654
Number of i	107	84	54	30

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

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.

As for the remaining sector level control variables, only the size of the sector appears to matter. In particular, empirical findings suggest that for all but the group of EU-12 countries, patenting activities are significantly higher in larger sectors.

Furthermore, no evidence is found that patenting activities are significantly higher in economies characterised by improving standards of living.

Finally, findings suggest that for the group of EU-15 countries only, a strong specialisation towards the production (and export) of medium-high-technology products is conducive to host country patenting activities.[108]

[108] This effect disappears, however, once the contribution of high-tech and medium-high-technology sectors to the manufacturing trade balance is used instead.

6.6. The impact of outward BERD on domestic R&D expenditure in the home country

A main concern brought forward by critics of globalisation is that R&D activities of domestic firms abroad may substitute domestic R&D activity. Hence, internationalisation of R&D may lead to a “hollowing-out” of national R&D capacity and, as a consequence, to a loss of domestic capabilities to develop and apply new technologies. Empirical evidence that can confirm or reject this claim, however, is scarce. Case studies (for example the one presented in section 7.3) suggest that R&D activities of domestic firms in the home country and abroad are complements rather than substitutes.

The main reason for this lack of empirical evidence are limitations in the data. Sufficient outward BERD is only available for very few countries. This is why all existing studies of the home country effect of R&D internationalisation (for example D’Agostin et al 2010) use patent data instead of R&D data. Patent data, however, has some important limitations (see Patel and Pavitt 1995, Smith 2005). In particular, information on the location of patent inventors and patent applicants does not seem reliable basis for the analysis since this information rather reflects intellectual property right strategies than the location of R&D activity.

This section follows a different approach. Outward BERD data of a particular country is proxied by the corresponding bilateral inward BERD data. Thus, total outward BERD is calculated as the sum of all inward BERD data from a particular country of origin available from any statistical office. We are aware of the limitations of this approach; huge differences appear when inward BERD and the corresponding outward BERD data is compared bilaterally (see Colecchia 2006). Moreover, there may a bias towards large countries, since inward BERD data by firms from small countries is often suppressed due to confidentiality. However, even an analysis based on this uncertain data seems superior to the alternative –to leave the home country effects of R&D internationalisation out of the analysis.

The data used for the analysis has been collected by AIT and wiiw in the course of the project and capture inward R&D expenditure of multinationals by investing country, total manufacturing (15-37). To derive a proxy for outward R&D expenditure, all available inward R&D expenditure are summed up by home country (investing country); again, we want to emphasize that this is an imperfect proxy for outward R&D: it underestimates the ‘true’ scale of outward R&D expenditure of small countries in particular, because this expenditure may not be available in some countries due to data confidentiality. Data are complemented by additional data from different sources: OECD STAN, World Development Indicators etc.

We estimate the following model:

$$\ln RDd_{it} = \alpha_i + \beta_1 \ln RDoutward + \beta_z X_{zit} + \varepsilon_{it} \quad (17)$$

where $lnRDd_{it}$ is the log of domestic R&D expenditure in the manufacturing sector in country i at time t, $lnRDoutward$ is the proxy for outward R&D and X_{zit} is a matrix of z explanatory variables.

At the sectoral level, X_{it} includes: the growth rate of size of the manufacturing sector (in terms of employment), labor cost over value added and openness to trade (as the share of the sum of exports and imports in output).

At the country level, X_{it} includes the growth rate of real GDP per capita, the share of graduates in the labor force (HC proxy), the share of R&D personnel in labor force (proxy for research potential), the share of total patents (per 1000 labor force), the contribution of medium-high-tech sectors to manufacturing trade balance, the share of government budgetary appropriations or outlays for R&D and a dummy for EU-membership.

The analysis only includes data for the manufacturing sector for the period from 2003 to 2007. Different estimation techniques are used to account for the panel nature of the data. The Hausman test rejects a fixed effects approach, the Breusch-Pagan-Test rejects the existence of random effects – hence, pooled OLS needs to be used.

Three different specifications of pooled OLS are estimated: basic pooled OLS (1) without time or country fixed effects, pooled OLS with time fixed effects (2) but no country fixed effects, and pooled OLS with both time and country fixed effects (3). Test statistics suggest that specification three is the preferred set-up for this regression.

Table 29: Impact of R&D internationalisation on the home country – domestic R&D expenditures

Dep.Var: log domestic R&D expenditure	(1)	(2)	(3)
Variables	pooledOLS_RDd	level_RDd	level_RDd
Constant	-1.494	-1.252	8.736***
	(1.12)	(1.00)	(3.20)
Sector level			
Log outward R&D expenditure	0.278***	0.326***	-0.056
	(4.46)	(5.23)	(1.23)
Size growth	0.012	0.065	-0.005
	(0.25)	(1.29)	(0.14)
Labor cost over VA	0.043***	0.038**	-0.001
	(2.83)	(2.61)	(0.04)
Openness to trade	-0.005*	-0.004	-0.013
	(1.85)	(1.44)	(1.01)
Country level			
Real GDP pc growth rate	-0.058**	-0.052*	-0.006
	(2.10)	(1.85)	(0.51)
Share graduates in labor force	0.629**	0.615**	-0.284
	(2.11)	(2.19)	(0.86)
Share R&D personnel	0.001***	0.001***	0.000
	(3.57)	(3.75)	(0.37)
Share total patents	0.218	0.113	0.006
	(0.70)	(0.38)	(0.02)
Contribution MHT sectors to manuf TB	0.224***	0.235***	0.022
	(3.45)	(3.76)	(0.34)
Share GBAORD in RGDP	1.524**	1.802**	-0.040
	(2.27)	(2.66)	(0.07)
Dummy: EU-member	1.271	0.935	
	(1.38)	(1.07)	
Country dummies	No	No	Yes
Year dummies	No	Yes	Yes
Observations	56	56	56
Adj. R^2	0.94	0.948	0.994

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

All regressions are based on pooled OLS. Column (1) uses pooled OLS without time or country fixed effects, column (2) uses pooled OLS with time but without country fixed effects; column (3 uses pooled OLS with time and country fixed effects

The regression considerably suffers from the low number of observations and data restrictions. It can, however, be said that a negative and significant relationship between domestic and outward BERD cannot be observed in any of the three specifications. Hence, the assumption that domestic R&D activity may be substituted by outward BERD is not supported by the analysis. Column 1 and column 2 even suggest a complementary relationship between domestic and outward BERD – this is also the result of other studies with patents, FDI or export data (D'Agostin et al 2010; Barba Navaretti and Falzoni 2004). Column 3, however, the preferred set-up of the estimation, does not find a positive and significant relationship between domestic and outward BERD.

6.7. Summary and Conclusion

The literature has identified several channels through which host countries can profit from the presence of R&D intensive foreign-owned firms: i) financially better endowed foreign firms may induce domestic firms to intensify own R&D activities to keep pace with growing competition from abroad, ii) inward R&D expenditure may give rise to non-negligible knowledge spillovers, iii) inward R&D expenditure may increase the demand for skilled employees, and iv) inward R&D expenditure and the presence of foreign firms may result in structural change and agglomeration effects. Hence, wooing these firms has been high on the political agenda of many economies.

Against that backdrop, the analysis seeks to shed light on whether and to what extent host countries profit from the presence of foreign affiliates and the extent of their R&D expenditure. For that purpose, it used a short unbalanced panel (2004-2007) covering the manufacturing sector only.

The analysis highlights that domestic firms profit in various ways: while R&D expenditure of domestic firms are independent of the level of R&D expenditure of foreign affiliates, a positive and significant relationship emerges between R&D intensities of domestic and foreign firms (as the share of R&D expenditure in value added). Hence, R&D intensities of both domestic and foreign-owned firms are found to complement each other. Moreover, these complementarities differ across sub-samples considered and tend to be strongest in the sample of EU-15 countries.

Furthermore, the analysis demonstrates that higher R&D efforts of foreign-owned affiliates spur labour productivity of domestic firms such that a 1% increase in business R&D expenditures of foreign affiliates increases labour productivity of domestic firms by 0.05%. Moreover, the presence of more productive foreign affiliates in a sector also renders domestic firms significantly more productive: a 1% increase in labour productivity of foreign affiliates is associated with a 0.4% increase in labour productivity of domestic firms. This relationship is again strongest in the sample of EU-15 countries.

Additionally, the analysis demonstrates that higher research efforts of foreign affiliates have no significant effect on the level of employment of domestic firms. In contrast, it points at a significant positive relationship between employment levels of domestic and foreign firms. In particular, a 1% increase in employment of foreign affiliates is associated with a 0.6% increase in employment of domestic firms. This relationship is slightly stronger for the sample of EU-12 countries. The analysis also explores the roles of both foreign and domestic R&D intensities in fostering host country patenting activities. Generally, the analysis reveals that host country patenting activities appear unrelated to both foreign affiliates' and domestic firms' R&D intensities. The only exception is the group of EU-15 countries for which a positive but small effect can be detected suggesting that R&D intensities of domestic firms matter for host country patenting activities.

Finally, we investigate the relationship between outward BERD and domestic R&D activity. The analysis finds no substitution of domestic R&D expenditure by outward BERD. The result, however, is considerably limited by the only few available data.

7. IMPACTS OF R&D INTERNATIONALISATION – A CASE STUDY APPROACH

7.1. R&D cooperation between foreign-owned firms and domestic universities: the case of France and Germany

National innovation systems can benefit considerably from the presence of foreign-owned firms. One of the biggest advantages are spillovers and the diffusion of technology and knowledge from foreign-owned enterprises to domestic organisations (Keller 2004; UNCTAD 2005; Veugelers 2005).

These transfers of knowledge, however, do not occur automatically. They are, on the one hand, a result of the institutional set-up of host innovation systems, which may facilitate or hamper knowledge transfers. On the other hand, the willingness of foreign-owned firms to transfer knowledge to domestic organisations is also a result of the characteristics and strategies of these firms.

The literature on spillovers from foreign-owned to domestic firms is very large, but also inconclusive. Most studies measure spillovers in an indirect way – by relating changes in the domestic firm population to changes in the foreign firm population occurs. This section goes a different way, by looking at one specific channel for knowledge transfer– innovation cooperation. The literature is clear that knowledge transfer is most likely in close partnerships where both partners actively contribute to a joint project, which should be the case in an innovation cooperation arrangement. Hence, our approach is to capture knowledge transfer by looking at the channel where is most likely to occurs.

This case study investigates the determinants of knowledge transfer between foreign-owned firms and domestic organisations for the case of science-industry transfers. We investigate innovation co-operation between foreign-owned firm and research organisations (universities and public research centres). Innovation co-operation is based on contractual agreements such as joint R&D pacts, joint development agreements, or equity-based joint R&D ventures (Hagedoorn 2002, p. 478). In a joint R&D project, two organisations can find common ground and develop a 'codebook' (Cowan et al. 2000) to facilitate the transfer of tacit knowledge, which is difficult by other channels such as imitation or reverse engineering.

We focus on two countries: Germany and France. Both are large EU member states with a high aggregate R&D intensity a medium level of R&D internationalisation, and similar levels of higher education and governmental expenditure on R&D as percentage of GDP. In both countries, research organisations include universities and large non-university research centres. There are, however, also large differences between the French and the German innovation system. In France, science and technology policy has been traditionally mission-oriented, science-push and top-down (Larédo and Mustar 2001). German science policy, in contrast, gives traditionally more room to self-governance, the provincial (Länder) level and had a specific focus on knowledge and technology transfer. This has gradually changed in recent years, as France moved to more bottom-up defined support, while the role of the federal level has been strengthened in Germany (EFI 2011 for Germany; Larédo 2011 for France).

Another, even more important difference is the institutional set-up. Both countries have large non-university R&D organisations; however, only in Germany hosts an organisation - the Fraunhofer Society – which has the dedicated goal to transfer knowledge between science and industry. Fraunhofer is an organisation that provides contract research to industry. It currently employs around 18,000 employees and has a total budget of around 1.8 billion EUR in 2011

(Fraunhofer-Gesellschaft 2011). This makes Fraunhofer one of the largest science organisations in Europe. France, in contrast, has no organisation dedicated to knowledge transfer. However, there ongoing initiatives in France to strengthen knowledge transfer out of universities and research organisations such as the pôles de compétitivité initiative.

7.1.1. Methodology

The hypothesis of this case study is that the differences in institutional set-up and policy focus between Germany and France described above should manifest itself in differences in the propensity of foreign-owned firms to co-operate with domestic science organisations in the respective host country.

We test this hypothesis with data from the European Community Innovation Survey (CIS). 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 empirical analysis proceeds in two steps: first, we compare the mean co-operation propensity of different groups of foreign-owned firms between the two countries. The second step is a multivariate analysis that corrects for firm-specific factors such as size, sector etc. which may influence co-operation behaviour and therefore distort the result.

7.1.2. Empirical analysis of the cooperation behaviour of foreign-owned firms with research organisations in France and Germany

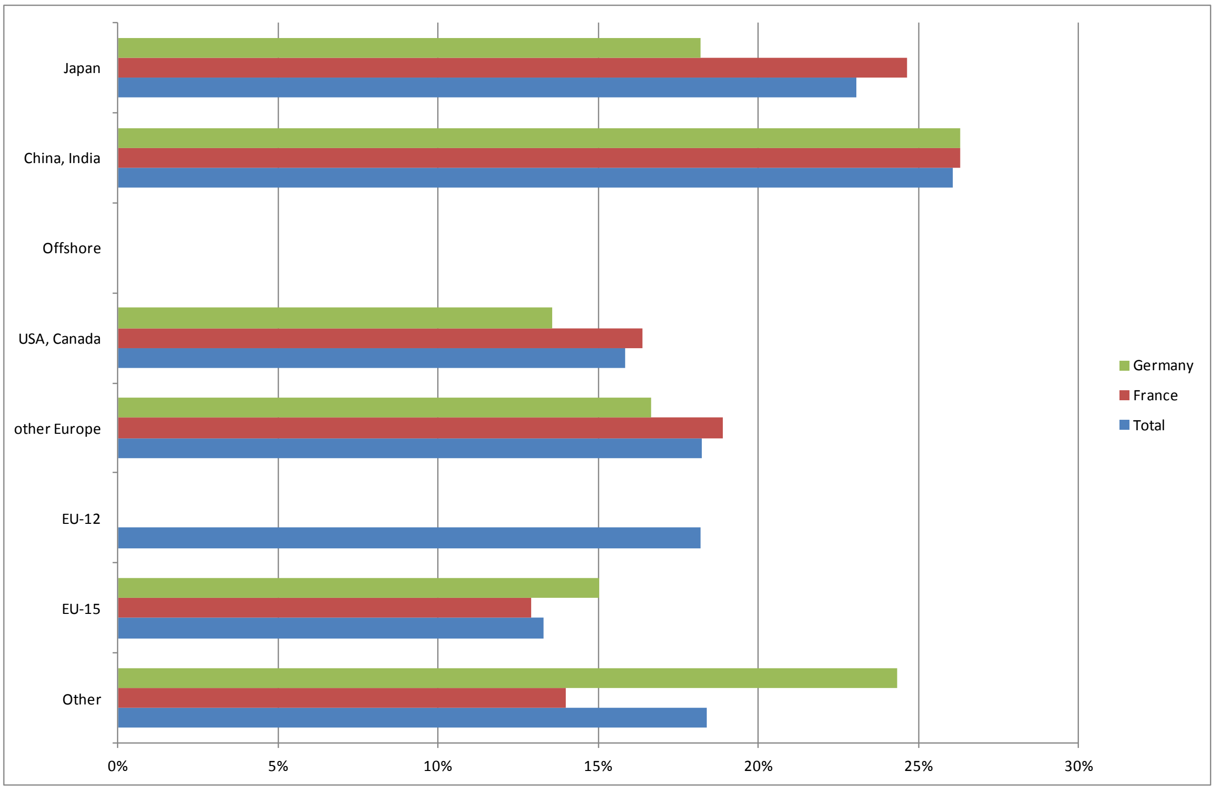
Descriptive statistics show a considerable variation in the share of foreign-owned firms that co-operate with research organisations across different countries of origin (Figure 66). Overall, the differences between France and Germany are surprisingly small, given the different institutional set-up of the two countries. The share of co-operating firms on all foreign-owned firms is around 15% in France, and around 16% in Germany.

We find the highest share of co-operating firms among Chinese and Indian affiliates, and the lowest share among affiliates of firms from offshore financial centres. In this group, no firm co-operates with science. This is a clear sign that the presence of Chinese and Indian affiliates in the two countries is very much science-driven and follows an asset-augmenting rationale. The opposite is true for firms from offshore financial centres. The number of firms in these two groups, however, is very small.

Among the largest groups of foreign-owned firms, US and Canadian firms and firms from other European, but non-EU countries (mainly Swiss firms) tend to co-operate more frequently than firms from EU-15 countries. This may again reflect the asset-augmenting motive.

There is no clear pattern whether firms are more likely to cooperate with domestic research organisations in France or Germany. In Germany, affiliates of Japanese multinational enterprises are less likely to cooperate with national research organisations; this is likewise the case if a firm is headquartered in the United States, Canada, or other European countries (i.e. not part of the European Union). In contrast, if the group is headquartered in the EU-15, i.e. the 'old' member states, the probability of scientific co-operations in innovation activities is higher when the affiliate is located in Germany rather than in France. The same is true for the case of all 'other' countries, i.e. countries, which are not included in any of the categories observed here.

Figure 66: Share of foreign-owned firms which co-operate with research organisations in France and Germany, 2006-2008



Note: data for the EU-12 is not reported for Germany and France due to confidentiality requirements

Source: Community Innovation Survey 2008, own calculations

To get a clearer picture of differences between France and Germany we conducted a multivariate analysis to take into account a broad range of possible determinants of cooperation behaviour. The results of the descriptive analysis may be distorted by firm characteristics that may influence a comparison between the two countries. For example, large firms tend to co-operate more frequently than small ones, and if one of the two countries has a larger population of large firms, co-operation frequency may be higher as well.

The variables included in the analysis are given in the table below. A first group of variables included describes internal capabilities for co-operation. *Firm size* is measured by the number of its employees; *international market-orientation* identifies enterprises which are mainly engaged at international markets; *public funding* indicates that the enterprises have received public financial support for innovation. Moreover, we included two variables that represent the absorptive capacities of firms: *Intramural R&D* identifies enterprises that are engaged in intramural (in-house) R&D activity, *external spillovers* capture the appreciation for various types of external information. The latter variable is constructed following the approach of Cassiman and Veugelers (2002).

Moreover, we included information about the firms' sectoral affiliation in the analysis. We employ a taxonomy of economic sectors according to their innovation intensity proposed by Peneder (Peneder 2010). Peneder classifies sectors according to cumulativeness of the knowledge base, appropriability conditions, technological opportunity and creative vs. adaptive strategies. This results in six groups of sectors with rising innovativeness. *None*, *low*, *med_low*, *med*, *med_high* and *high* are sectoral dummies, which refer to different levels of innovativeness according to this taxonomy. Furthermore, we included the dummy *kis*, referring to knowledge-intensive sectors, which tend to be highly internationalized and show a high number of co-operations.

Table 30: Overview of variables used in the model

Variable	**Indicator**
DEPENDENT VARIABLE	
Co-operation agreements with universities and research institutes	1 if the enterprise has co-operation agreements during 2006-2008 with universities, government or public research institutes on national level; 0 otherwise
INDEPENDENT VARIABLES	
Size	ln (total number of employees) in the reference year 2008
International market-orientation	1 if a firm exported goods or services during the years 2006-2008; 0 otherwise
Public funding	1 if the firm received public funding for innovation from local or regional authorities, or from central government, or from the EU; 0 otherwise
Intramural R&D	1 if the enterprise conducts intramural (in-house) R&D; 0 otherwise
External spillovers	Sum of scores of importance of the following information sources for the innovation process [number between 1 (low) and 3 (high)]: sources from Professional and industry associations, sources from scientific journals, trade/scientific publications and sources from professional conferences, trade fairs, meetings; (rescaled between 0 and 1)
Domestic Group	1 if the enterprise is part of a domestic group; 0 otherwise
Sectoral affiliation *(none, low, med_low, med_high, high, and kis)*	Taxonomy of economic sectors (six categories) according to their innovation intensity (Peneder 2010); sectors are classified according to cumulativeness of the knowledge base, appropriability conditions, technological opportunity and creative vs. adaptive strategies. Dummy for sectors referring to knowledge intensive services (equals 1); 0 otherwise
Countries	Country/regional dummies for each country/region of location of the firm

Source: CIS 2008

The following Table 31 presents the results of the regression analysis for the combined sample of both countries (1), and for France (2) and Germany (3) separately. The most important result of column (1) is the sign and the coefficient of the dummy for Germany (-0.022). This indicates that, all other variables equal, the probability that a firm co-operates with research organisations drops by 2.2% if the firm is located in Germany. In other words, factors related to the two countries such as the institutional set-up can explain only little of the variation between firms located in the two countries. Most of the variation can be explained by firm characteristics.

Table 31: Analysis of scientific co-operations in France and Germany – marginal effects

Co-operation agreements with universities and research institutes	**TOTAL (1)**		**FRANCE (2)**		**GERMANY (3)**	
Internal capabilities						
Size	0.027	***	0.034	***	0.017	***
	(0.002)		(0.003)		(0.002)	
International market orientation+	0.031	***	0.038	***	0.018	***
	(0.007)		(0.010)		(0.007)	
Public funding+	0.262	***	0.226	***	0.255	***
	(0.012)		(0.015)		(0.020)	
Intramural R&D+	0.105	***	0.085	***	0.121	***
	(0.007)		(0.009)		(0.011)	
Germany+	-0.022	***				
	(0.006)					
External spillovers	0.190	***	0.251	***	0.080	***
	(0.012)		(0.017)		(0.013)	
Domestic Group+	0.019	***	0.021	*	0.012	*
	(0.007)		(0.011)		(0.007)	
Countries of origin						
EU15+	0.017		0.013		0.020	
	(0.012)		(0.016)		(0.016)	
EU12+	0.069		0.385		-0.024	
	(0.129)		(0.313)		(0.040)	
Europe+	0.015		0.014		0.012	
	(0.025)		(0.035)		(0.027)	
US-CA+	0.019		0.034	*	-0.014	
	(0.015)		(0.022)		(0.013)	
CN-IN+	0.127		0.182		-0.005	
	(0.103)		(0.138)		(0.062)	
Japan+	0.105	**	0.145	**	0.025	
	(0.052)		(0.070)		(0.055)	
other+	0.112	***	0.148	**	0.070	**
	(0.041)		(0.071)		(0.038)	
Sectoral affiliation						
low+	-0.008		0.012		-0.014	
	(0.009)		(0.014)		(0.010)	
med_low+	0.003		0.003		0.009	
	(0.010)		(0.014)		(0.012)	
med_high+	0.003		0.004		0.007	
	(0.010)		(0.015)		(0.012)	
high+	0.080	***	0.105	***	0.047	***
	(0.019)		(0.029)		(0.021)	
kis+	0.011		0.006		0.027	**
	(0.009)		(0.013)		(0.013)	
Obs.	12595		7417		5178	
LR $chi^2(19)$	3228.84	***	1458.64	***	1891.23	***
Pseudo R2	0.2830		0.2066		0.4379	

Note: Coefficients significantly diverse from zero; probability values of 10% (*), 5% (**), or 1% (***).
+ dF/dx is for discrete change of dummy variables from 0 to 1

One of these firm characteristics are the internal capabilities. Variables describing these characteristics are all highly significant when related to the probability of scientific co-operation in innovation activities in France and Germany. Size and international market orientation are positively related to the probability of scientific cooperation in France and Germany. There are, however, some differences in the coefficients. The size coefficient, for example, is considerably larger in France than in Germany, which indicates that the probability of co-operation with science increases more with rising firm size in France than in Germany. In other words, co-operation is more frequent among smaller firms in Germany than in France. Hence, firm characteristics may also reflect the characteristics of the innovation system. The lower coefficient for Germany may indicate that smaller firms in Germany find it easier to co-operate because there exist potential partners (like Fraunhofer) in the country that provide services tailored to the needs of this group.

The relationship between public funding and co-operation and internal R&D, in contrast, is quite similar in the two countries, which indicates that funding has a similar impact on the decision to co-operate. Marginal effects may slightly differ from the overall dataset (including France and Germany), although not significantly.

Regarding the countries of origin of foreign-owned firms, we could only find a significant coefficient for firms from ‘other’ countries, which refer to all countries not included in any other category for all three regressions. The actual impact of the ‘other’ countries category on scientific co-operation however differs between the three regressions. Considering France (column (2)), the fact that a firm can be attributed to this category shows a coefficient almost twice as high as when looking at Germany (regression (3)). A significant difference was furthermore found for foreign-owned firms from Japan active in R&D in France and in Germany. Being a Japanese firm in France significantly increases the probability of a scientific cooperation with national research institutes and universities compared to being a Japanese firm in Germany. In contrast, there is no significant relationship for that case, if a Japanese firm is located in Germany.

Considering the sectoral affiliation, as no surprise, there is a significant relationship between firms in high-technology sectors and the probability of scientific cooperation. This, however, can be traced back to the need of high-technology firms for scientific co-operation, whereas firms with low or almost no innovativeness do not have the need to cooperate with scientific institutions. What remains an interesting point to discuss is the fact that firms active in the knowledge intensive services show a significant positive relationship with the probability to co-operate with national research organisations in Germany, but not in France. This may indicate that no potential partners for these firms exist in France.

7.1.3. Conclusions

In the case of France and Germany, the propensity of a foreign-owned firm to co-operate with research organisations – universities and research centres – in the host country is related to the characteristics of the firm – size, sector, R&D orientation, funding etc. - in the first place. Once we control for these firm characteristics, differences between the two countries become small. This is a surprising result if we consider the differences in institutional set-up between the two countries discussed above, in particular the stronger focus of Germany on technology transfer - if firms see the need to co-operate, they will find a partner. However, firm characteristics may also reflect the characteristics of the innovation system, for example if small firms have larger obstacles to find appropriate co-operation partners in one country.

The results also indicate that policy can foster co-operation between foreign-owned firms and domestic research organisations. Firms that received public funding for innovation have a significantly higher propensity to co-operate. We may also add that public policy can foster co-operation between the two groups by setting the right incentives for universities and research centres for co-operation and preparing them for joint research.

7.2. Inward BERD and aggregate R&D expenditure in Austria and Canada

One of the main impacts and benefits of the internationalisation of R&D for host countries are increases in aggregate R&D expenditure. If a multinational firm decides to take up or expand R&D activities in a country, this may lead to considerable increases in aggregate R&D expenditure in a short time, in particular in small countries. Foreign-owned firms which operate on a global basis may expect higher potential future sales from a newly developed product to cover R&D cost than firms that operate domestically. Moreover, foreign-owned firms are not restricted to their own internal funds to finance new R&D projects, but may also get financial support from the headquarters of affiliates in other countries, which makes it easier to perform large R&D projects.

This study and similar contributions have identified various drivers of inward BERD that help to understand why multinational firms select which countries for their R&D activities. 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.

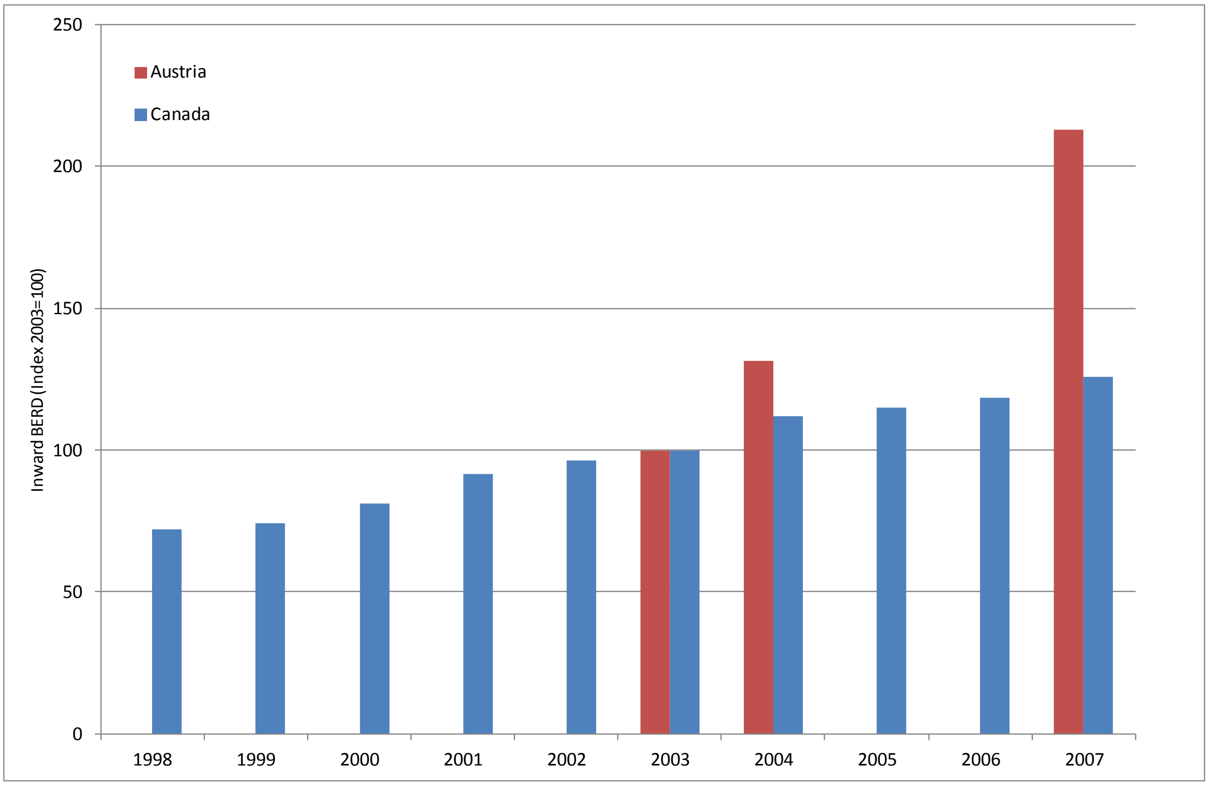
This becomes obvious if we compare Austria and Canada. Both countries share a lot of characteristics which have been identified as drivers of inward BERD:

- both are among the countries in the world with the highest GDP per capita;
- both offer political and economic stability and favourable business conditions to foreign-owned firms;
- both countries have a large pool of skilled researchers and vibrant research scene at universities;
- both countries are highly internationalized in terms of trade and FDI;
- both have the advantage of being proximate to a large R&D performing country – Germany and the US;
- both countries have large neighbouring countries with a high similarity in terms of culture and language, which reduces the "liability of foreignness" for firms from this neighbouring country to a minimum.

Despite these similarities, R&D expenditure of foreign-owned firms in Canada and Austria took different routes in recent years (see Figure 67). Between 2003 and 2007, inward BERD doubled in nominal terms in Austria, but only grew by about 25% in Canada during this period. A similar divergence can be observed for total business expenditure in the two countries.

We argue that the impact of foreign presence on total BERD and GERD 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.

Figure 67: Business R&D expenditure of foreign-owned firms in Austria and Canada, value of 2003 = 100



Source: OECD, own calculations

The paper explores several issues where similarities and divergences between the countries may affect inward BERD: the structure of the Austrian and the Canadian economy, the role of the automotive industry, indigenous multinationals, public support for R&D. For each of these factors we will discuss how differences might affect the impact of foreign presence on inward BERD.

7.2.1. Industrial structure and the national resource base

It has been noted before that Canada has a low BERD to GDP ratio and one that has not been improving[109]. It briefly rose to above 1.3 per cent in the early 2000s but has since dropped back to its longer term trajectory of around 1.0 per cent. The Canadian economy has a number of unique characteristics that need articulating in a discussion of the role of inward BERD for aggregate R&D expenditure. These features are:

- The natural resource base;
- The automobile parts and assembly cluster; and
- Indigenous multinationals.

[109] See for example: The Council of Canadian Academies (The Expert Panel on Business Innovation in Canada2009) and Science, Technology and Innovation Council (2011).

The natural resource economy

The Canadian economy has a significant dependence on natural resource based activities. This can be seen if we take the example of comparing Canada and with Austria. In Table 32 it is evident that the resource component of the Canadian economy contributes approximately 3 times the GDP as the equivalent activities in Austria.

Table 32: Percentage of Industry Value Added (Austria and Canada)

Activity	Canada (2009)	Austria (2008)
Resource base	6.5	2.1
Utilities	2.5	2.6
Construction	5.8	7.5
Manufacturing	12.7	20.2
Services sectors	71.8	67.6

Source: OECD and Statistics Canada

The resource base can be seen even more clearly in the export data (Table 33). With 37 per cent of Canadian exports (combining agriculture, forestry and energy) being from the natural resource base it represents a highly significant engine of the Canadian economy.

The corresponding share in Austrian exports is only 13%, mainly due to the lack of energy exports. In contrast, machinery and equipment contribute a considerably higher share to total exports in Austria than in Canada.

What makes this difference an important factor in Canada’s R&D profile is that the mining sector is not an R&D intensive industry and not a huge contributor to the nation’s aggregate R&D expenditure. In other words, Canada’s industrial structure may prevent a further increase in aggregate R&D intensity due to a high share of non-R&D intensive sectors on total output.

Table 33: Structure of Austrian and Canadian Exports 2009

Exports	Share on total exports: Austria	Share on total exports: Canada
Agriculture, Fish, food	8%	11%
Forestry products, wood	3%	2%
Energy products	2%	24%
Mining products	0%	2%
Industrial goods and materials	34%	27%
Machinery and equipment	31%	18%
Automotive products	11%	12%
Other consumer goods	9%	3%
	100%	100%

Source: United Nations COMTRADE.

It is interesting to see that similar arguments have been brought forward in Austria around the year 2000 to explain why Austria needs a pronounced structural change from ‘old’ industries towards high-technology sectors if the country wants to increase overall R&D intensity (see Peneder 1999). In contrast to these predictions, structural change mainly took place within the ‘old’ industries towards higher technology content and higher value added by unit of production (Dachs 2009a).

7.2.2. The Auto cluster

The previous section argued that the different composition of the two economies may explain the different impact of foreign presence on aggregate R&D expenditure. However, even a similar economic structure may not lead to similar outcomes, as can be seen in this section. The automotive industry has the same share in the two countries, but both industries took very different roots in the two countries with very different contributions to GERD.

But even identical industrial structure may lead to different outcomes in terms of impact of foreign presence on inward BERD. We can see this for the case of the automotive industry. Table 33 shows that the Austrian and the Canadian economy have almost identical shares of automotive products on total exports.

Although the Canadian automotive cluster has been a successful feature of the Canadian economy over many years (see Rutherford and Holmes 2008), it has been struggling recently. According to Industry Canada, value added from motor vehicles, light trucks and heavy trucks decreased from about 45 billion CAD in 2000 to around 13 billion CAD in 2009.

The economic geography of this cluster, which on the Canadian side of the border stretches up through southwest Ontario between Windsor and Toronto, in reality is a continuation of the US auto corridor that stretches south from Detroit (across the river from Windsor). This cluster has many of the characteristics of a cluster complex (Wixted 2009) because it has strong supply interaction with the US cluster and because command and control lies in other countries (USA, Japan and Europe).

Similar international supply linkages can be observed in the Austrian automotive industry, which is located in two main agglomerations in Graz and in Upper Austria. Austrian firms are mostly specialized in the production of automotive parts and produce only a limited number of complete cars. Most firms in the Austrian automotive sector are suppliers to the German automotive industry, and a considerable share of the firms is part of a foreign multinational group. Currently, seven of the ten largest firms in this sector are foreign-owned.

In contrast to the Canadian automotive cluster the Austrian auto industry does quite well. Value added in motor vehicles and parts increased from 2 billion EUR in 2000 to around 2.5 billion EUR in 2009 according to data from the structural business statistics of Statistics Austria.

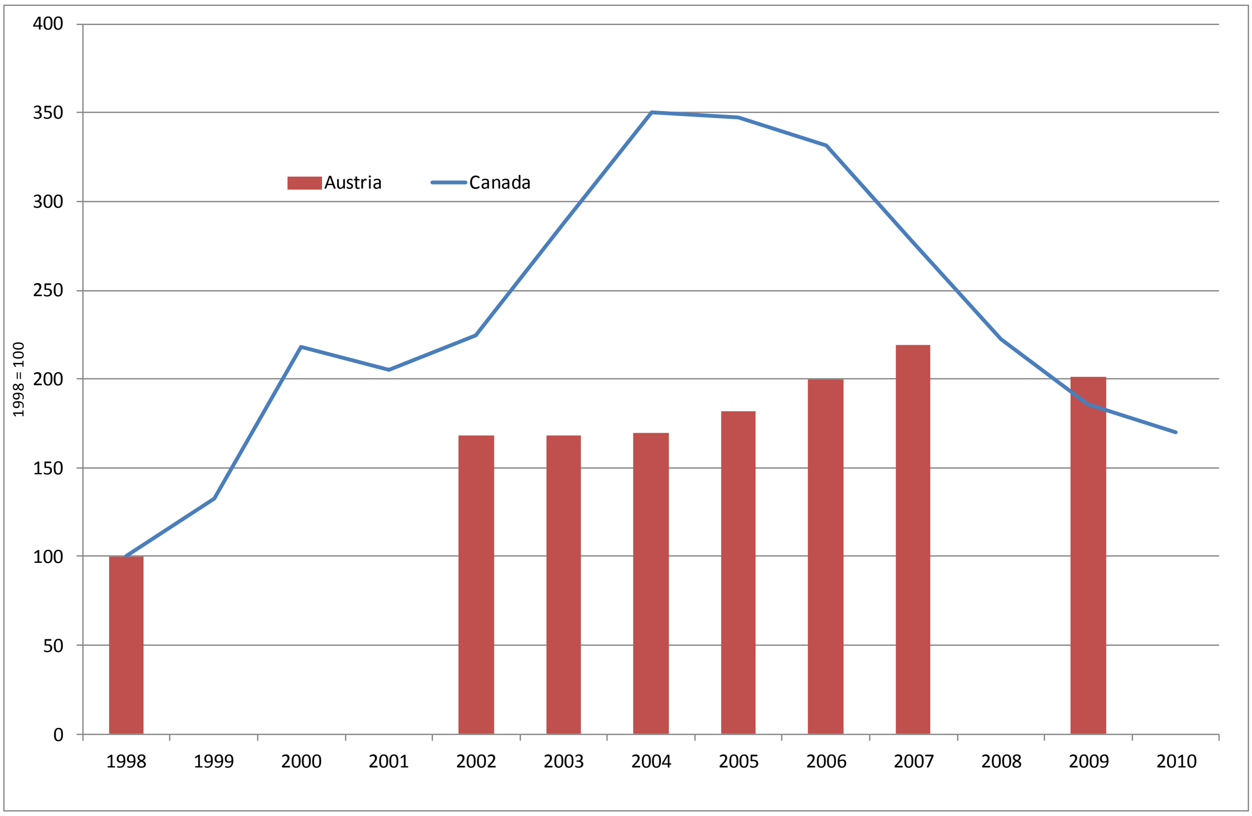
What makes the difference between the Austrian and the Canadian auto industry? One important difference lies in their main respective customer – the US and the German automotive industry – which took very different routes since 2000. While German car makers could increase domestic production slightly from 5.5 million units in 2000 to 5.9 million units in 2010, US domestic production slumped from 12.8 million units in 2000 to 7.7 units in 2010 according to the figures published by International Organization of Motor Vehicle Manufacturers (OICA 2012).

Despite having a large production base, Canada has not been a traditional location for auto R&D. This is demonstrated in Figure 68. The reason for the brief trebling of R&D during the

2000s while revenues were falling is unclear from available sources. However, the trend appears to be for R&D to be moving back towards historical norms.

We see a different development in the Austrian automotive industry. Here, R&D expenditure increased from 183 Million EUR in 1998 to 368 Million EUR in 2009. There was also a decrease between 2007 and 2009 (data for 2008 is not available); however, this reduction was much smaller than in Canada. The figure suggests that Austria could establish as a location for R&D in the automotive industry, despite the fact that more than 80% of R&D expenditure in the sector is from foreign-owned firms.

Figure 68: Austrian and Canadian Auto Industry R&D expenditure (current million CAD and EUR)



Source: Statistics Austria, Statistics Canada

What is thought-provoking in the Canadian case is that even with the halving of R&D expenditure over recent years because the decline in value added has been even more precipitous, R&D intensity of the Canadian automotive industry actually rose from below two percent in 2000 to above five percent in 2006 and has then plateaued. Even so, it is about half of the latest published OECD average for motor vehicles (for the year 1999 see OECD 2003, p. 157).

In contrast to Canada, R&D intensity in the Austrian automotive industry remained steady at around 15% of value added from 1998 to 2009. This means that R&D expenditure increased at the same rate as value added in the industry.

7.2.3. *Indigenous Multinational Corporations*

The existence of R&D intensive domestic multinational corporations can be an important incentive for the location of foreign-owned R&D activities. Strong domestic multinationals may create a large pool of skilled personnel and knowledge spillovers which may attract foreign-owned firms. Moreover, foreign-owned affiliates may also benefit from proximity to domestic multinational when they are their suppliers. Domestic multinationals may also serve as the focal point of clusters, which may further increase the attractiveness of a country.

While Canadian BERD is low and two sectors (resources and auto) in particular appear to have less impact on the total than they might in other countries, Canada has been surprisingly successful in international business. A number of home grown Canadian firms have emerged as significant multinationals. There are two categories worth analysing – the industrial multinationals and what we will call here the digital economy multinationals. Canada has a range of global corporations, a few of them in the mining, exploration and oil and gas activity, but as already indicated they have a minor impact on overall Canadian R&D spending. However, there are notable other corporations worth looking at, including.

- Magna International (a large car components supplier); and
- Bombardier (aerospace and rail transportation)

Started in the 1950s, Magna International, a global auto components corporation, has maintained a pattern of remarkable growth. During the 1970s the company grew from less than 1 million CAD in sales to 4.5 million CAD. During the 1970s this expanded to just over 100 million CAD (the Canada/US Auto pact certainly contributed to this) and by the end of the 1980s that had grown to 1.4 billion CAD– approximately a 10fold growth. The company expanded by nearly as much again during the 1990s (9.3 billion CAD) and by 2008 its annual sales were 23.7 billion CAD. Automotive News (2010) has ranked Magna International the fifth largest auto supplier in the world.

A second firm that has done exceptionally well is Bombardier. Started as company building transportation equipment for winter climates the company has gradually expanded into aerospace and rail transportation. Bombardier Aerospace is now the third largest in the civil aerospace sector supplying private jets and smaller commercial passenger planes. Bombardier Transport, a subsidiary, is now one of the largest builders of passenger rail rolling stock. Both areas of the company have expanded through aggressive acquisition strategies (Baghai et.al. 1997).

Rather than asking why is Canadian R&D low, it is worth asking the non-obvious question – why has Canadian BERD been so high for a resource economy? The scale of Canadian BERD has been significantly influenced in terms of scale and growth by the success of Canada growing indigenous medium and high technology corporations that have a global presence over a long period of time. These firms include, amongst others:

- Novatel (first commercial cell phone system in North America - bankrupt early 1990s);
- Nortel (now bankrupt but was a large global supplier of telecommunications equipment);
- RIM (makers of the Blackberry);

These three companies have at various points in time been significant players in either mobile phones or commercial telephony equipment. Taken together and before Nortel collapsed just RIM and Nortel accounted for 2 billion CAD in R&D expenditure. The existence of such global players has helped maintain Canada's BERD to GDP ratio. Without them Canada's

BERD would look much worse. Indeed, with the collapse of Nortel we would expect to see a fall in BERD to GDP over coming years.

In contrast to Canada, domestic multinational firms with high R&D expenditure are rare in Austria. Some have emerged only recently, after the completion of the EU Single market and the accession of the EU-12 to the European Union, and are still small compared to domestic multinationals in Switzerland, Sweden, or Canada. Today, only five of the ten companies with the highest R&D expenditure in Austria are domestically owned. These five domestic multinationals account for only 23% of total R&D expenditure of the Top 10 R&D performers in Austria, while the Austrian subsidiaries of Siemens and Infineon contribute around 60% of the R&D expenditure of the Top 10 R&D performers.

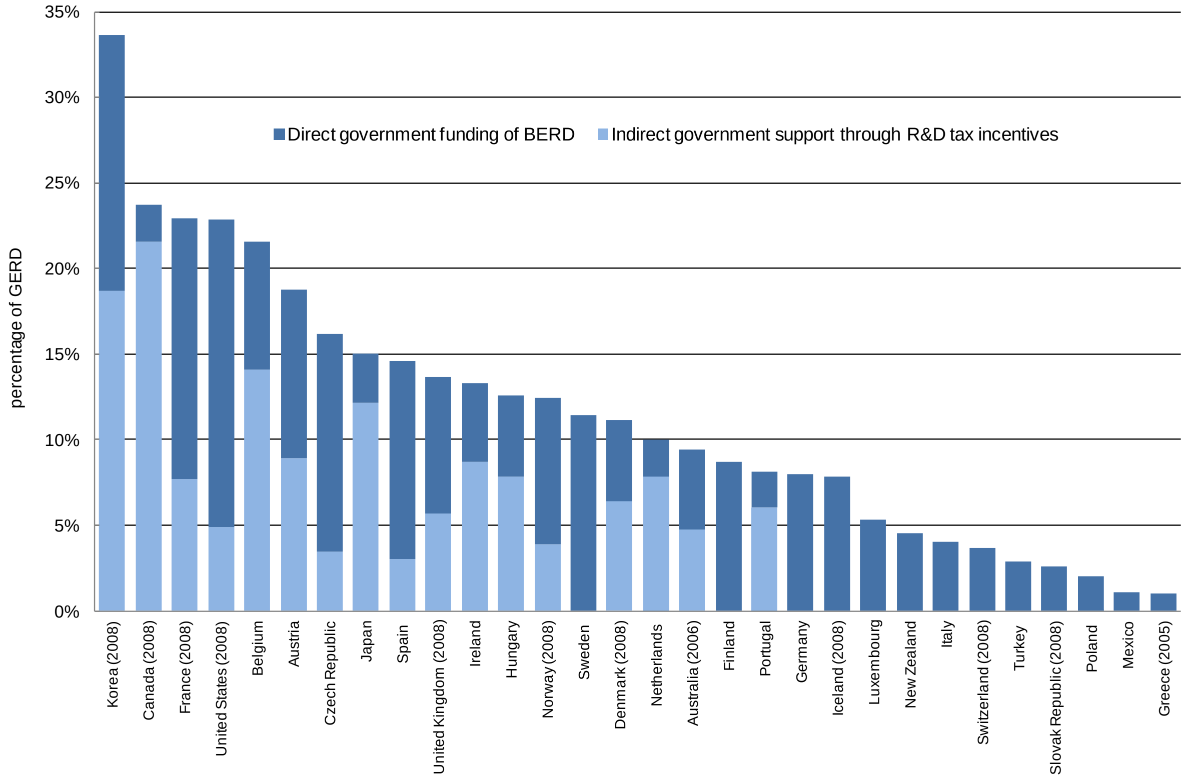
It can, however, be questioned if Siemens Austria and Infineon Austria are foreign-owned firms in a strict sense; Siemens Austria has been founded in the 1880s, long before most of existing domestic firms, and enjoys a high degree of independence within the corporate group, including a regional mandate for Central and Eastern Europe and world-wide mandates for different product groups (Dachs 2009b). Thus, these two firms may provide some of the functions of domestic multinationals in the Austrian innovation system.

7.2.4. Public support for R&D

There is a consensus in the literature that financial incentives tailored to foreign-owned firms are not sufficient to attract R&D of foreign multinational firms. Governments should rather focus on a stable economic framework - provide a healthy business environment, political stability, good public infrastructure, reasonable tax rates, a stable legal system including the protection of intellectual property rights.

The funding system for business R&D is an important part of a stable business environment, because it creates predictable framework conditions for doing R&D at a location and can help firms to overcome obstacles such as uncertainty which may lead to an under-investment in R&D. Both countries have a number of significant programs to support business R&D and are among the most generous countries in the OECD in terms of public support for business R&D (Figure 69).

Figure 69: Direct and indirect governmental support for business R&D in the OECD, 2007



Source: OECD 2010, page 77

In Canada, the Scientific Research and Experimental Development (SR&ED) Tax Incentive Program is the largest and the most significant support for R&D. There are two variants of funding in the SR&ED: Canadian-controlled private corporations with sales of less than 2 million CAD can get 35% as a cash payment at the end of a year. Any public corporation with more than 2 million CAD and foreign controlled corporations can only get 20% and that as a tax credit, not in cash. So, smaller foreign-owned firms do not have access to SR&ED, but domestic and foreign-owned corporations above 2 million CAD sales (not even R&D) are treated equally in the SR&ED. It is not clear if this treatment does hamper R&D of foreign-owned firms in Canada; it, however, since R&D is strongly concentrated in large firms, severe effects seem unlikely.

Direct measures include IRAP, a broad-based program that provides advisory services and contribution funding to support high-risk R&D projects by small and medium-sized enterprises (SMEs), and sector-specific programmes.

The SR&ED program is not targeted towards attracting R&D to Canada but it combined with the long lasting low Canadian dollar helped make Canada an attractive location. However, the Canadian dollar regained parity with the US dollar in the late 2000s and has remained there for a number of years. Further, the increasing complexity of the SR&ED program seems to have combined recently to be reducing Canada's competitiveness for R&D.

The SR&ED program, in view of its scale and scope, drew considerable commentary. Much was positive: the program is seen to encourage new investment in R&D, offset the high cost of exploratory work, directly support operations, generate cash flow, and facilitate access to credit, while leaving the specific choice of R&D activity up to the individual business. At the same time, reflecting the fact that it is the best known of the programs being reviewed, the SR&ED program also drew more critical commentary than any other R&D program. Many stakeholders called the claims process cumbersome, complex and time-consuming. Uncertainties associated with qualification and timing are sometimes so great that the SR&ED program is excluded from R&D investment decisions. Many smaller businesses find the claims process so unwieldy that they are forced to engage SR&ED "consultants," sometimes surrendering significant percentages of their refunds as contingency fees.

Jenkins Review (2011: 5.4)

Like in Canada, indirect funding in Austria is implemented via a federal R&D tax credit. The measure does not distinguish between foreign-owned and domestic firms. Direct funding included direct governmental funds, provincial funds and federal funds provided by various agencies. From Figure 69 we see that direct and indirect funding is about the same size in Austria. However, direct funding goes to research institutes organized as firms and therefore included in the business sector to a considerable degree; if we exclude these organisations, the relationship of direct to indirect funding in the Austrian business sector is about 60:40, so the Canadian and the Austrian funding system is even more similar than it appears in Figure 69. This is important information, because there is evidence that foreign-owned firms in Austria, in contrast to domestic firms, prefer indirect over direct government funding (Schibany et al 2011, p. 102). More than 70% of public R&D funding for foreign-owned firms comes from the tax credit, compared to only 31% for domestically owned firms. This may be due to the fact that foreign-owned firms are larger and may derive more benefits from tax allowances due to their group structure than domestically owned firms which are often smaller.

If we look at the role of direct and indirect governmental support in total funding of business R&D, however, it becomes obvious that despite a generous funding system, public support for R&D has only a limited role in the funding of R&D of foreign-owned firms in Austria. Only 8% of total direct and indirect (including the tax credit) R&D funding of foreign-owned firms comes from public sources (Schibany et al 2011, p. 101; please note that the descriptors are wrong at Figure 39 at this page). Most of the funds for R&D (61%) are raised internally by the Austrian affiliates, and another 32% comes from abroad. The literature usually assumes that public funding does not have a decisive influence on location decisions of foreign-owned firms – the low share of public funding on overall funding for R&D of foreign-owned firms in Austria may support this claim.

7.2.5. Conclusions

The analysis of drivers of inward BERD is important to understand the patterns of the internationalisation of business R&D we observe. However, there seems to be a layer of additional factors in place that decide if foreign presence in a country has an impact on business R&D expenditure and may help to raise the country's aggregate expenditure on R&D. These factors are related to the structures and the institutional set-up of national innovation systems. We are hesitant to call them drivers, since there does not seem to be a linear relationship between these factors and the impact.

The case study has investigated four of these factors for Austria and Canada. Both countries are similar in a number of drivers; inward BERD, however, has developed differently in Austria and Canada. The high degree of resource-based industries in Canada and their economic success following the surge in prices for raw materials, for example, may help to understand why total and inward BERD stagnated in recent years; these industries have only limited opportunities for R&D; hence, foreign investments in this country may have only little impact on aggregate R&D expenditure. But even industries which a similar share on economic activity may lead to very different impacts on aggregate R&D expenditure, as can be seen in the example of the automotive industry in the two countries.

These observations suggest considering the evolution of inward BERD in a country, just like the evolution of total R&D expenditure, as a complex process that may depend on more than a handful of drivers.

7.3. Implications of overseas R&D for the home country: the case of India

The internationalisation of research and development (R&D) may lead to a new division of labour in R&D within multinational companies, and different tasks may be shifted to locations abroad. This can have, in some cases, negative implications for the home country, but may also help to increase R&D activities in the home country, when the headquarter activities can benefit from a higher overall demand due to expansion into new markets. This case study investigates this issue for the case of two European firms doing R&D in India[110]. We have selected two German multinationals, viz. Bosch and Siemens, for the purpose of this study. Both firms are technology leaders and have strong R&D capabilities at the home base as well as in India.

7.3.1. Company Profiles

7.3.1.1. Bosch

(a) Group Information

Germany's Bosch Group is "a leading global supplier of technology and services" in the areas of automotive & industrial technology, consumer goods and building technology. In fiscal year 2010 it employed nearly 283,500 people worldwide and generated sales of over € 47 billion (Bosch Group 2011). The group comprises of the flagship company Robert Bosch GmbH and over 300 subsidiaries spread across 60 countries. The group has business interests in about 150 countries. Bosch maintains a worldwide network for development, manufacturing, and sales activities. More than 90% of the share capital of Robert Bosch GmbH is held by Robert Bosch Stiftung GmbH, a charitable trust. The remaining shares are held by the Bosch family and by Robert Bosch GmbH (Bosch Group 2011). Table 34 shows some key business indicators for the Bosch group.

Table 34: Key business indicators of the Bosch Group, 2006-2010 (based on various annual reports)

	2006	2007	2008	2009	2010
Sales (billion EUR)	43.68	46.32	45.13	38.17	47.26
Yearly growth in sales (%)	5.40%	6.0%	-2.6%	-15.4%	23.8%
Profit before tax (billion EUR)	3.08	3.80	0.94	-1.20	3.49
Profit to sales ratio (%)	7.1%	8.2%	2.1%	-3.1%	7.4%
Employees (annual average)	257,754	267,562	282,758	274,530	283,500
- In Germany (approx.)	110,500	112,300	114,000	112,000	114,000
- R&D employees	25,300	29,000	32,600	33,000	34,000
R&D expenditure (billion EUR)	3.35	3.58	3.89	3.60	3.81
R&D intensity (ratio to sales)	7.7%	7.7%	8.6%	9.4%	8.1%

[110] This case study has benefitted from personal communication with four senior level R&D managers at Bosch India (vice president and above) in Bangalore and Pune as well as with one senior R&D manager at Siemens India (vice president) in Bangalore. Interview partners wish to remain anonymous.

Patent applications filed	>3,000	3,280	3,850	3,870	>3800

With a revenue of nearly 11 billion EUR (23% of total sales), Germany constituted the largest market for the Bosch group, followed by the USA (5.5 billion EUR) and China (4.2 billion EUR). Region-wise Europe was the primary market accounting for over 58% of the sales, followed by Asia (21%) and the Americas (18%). All other areas (e.g. Africa and Australia) accounted for less than 2% of total sales.

The share of individual business fields in the business and R&D in 2010 was as follows:

Table 35: Share of individual business fields in Bosch Group's business and R&D in 2010

(figures in billion EUR)	Sales	R&D expenditure
Automotive technology	28.1	3.0
Industrial technology	6.7	0.3
Consumer goods & building technology	12.5	0.5

With its 125 years old history Bosch is a renowned technology leader. Its 34,000-strong R&D workforce (12% of total employees) generates more than 3,000 patent applications a year.

Impact of R&D Globalization on Home Base

The bulk of Bosch's R&D is based at its home base in Germany. With over 16,000 researchers and developers in 2006, Germany continued "to be a key research and development location" (Bosch Group 2007, p. 21). Even though its relative share in total workforce has gone down from 64% in 2006 to an estimated 50% in 2010, the absolute numbers of R&D personnel in Germany has continued to grow. The relative growth has been stronger elsewhere: "Our R&D workforce showed the strongest growth in Asia, where the number of engineers rose [within one year] from some 7,000 to over 8,000" (Bosch Group 2011, p. 58).

(b) India Operations

Bosch has been operating in India for 90 years (Bosch India 2011a). First manufacturing operations were established in 1953 (Bosch India 2012a). Robert Bosch GmbH holds 71.18% stake in Bosch Limited. Bosch's India operations however also include further "sister firms", viz. Bosch Chassis Systems India Ltd., Bosch Rexroth India Ltd., Robert Bosch Engineering and Business Solutions Ltd. (RBEI), Bosch Automotive Electronics India Private Ltd. and Bosch Electrical Drives India Private Ltd. The flagship company Bosch Ltd. is headquartered in Bangalore (Bosch India 2011a). Bosch India runs 14 manufacturing and 3 development centres (Bosch India 2012a). In 2008 it increased its shareholding in the Indian subsidiary from around 60 % to around 70 % (Bosch Group 2008, p. 13).

It is active across all the segments of the parent concern, i.e. automotive technology, industrial technology, consumer goods and building technology. It manufactures and trades products such as fuel injection systems, automotive aftermarket products, auto electricals, special purpose machines, packaging machines, electric power tools and security systems (Bosch India 2011a). In fiscal year 2010 Bosch Ltd. employed 11,700 associates. Group-wide headcount in India stood at 22,500 (Bosch India 2012a).

Table 36: Selected business performance indicators for Bosch Ltd., India, 2006-2010[111]

	2006	2007	2008	2009	2010
Sales (in millions EUR)	651	751	697	708	1101
Growth (in %, local currency base)	27,1%	13.1%	6.1%	4.6%	39.6%
Profit before tax (in millions EUR)	137	150	132	118	200
Profit to sales ratio	21.1%	20.0%	18.9%	16.7%	18.1%

Automotive Division

Bosch has established a "futuristic Technical Centre" in Bangalore that is supposedly "the first-of-its-kind in the country" and intends to provide "world-class technological solutions for the auto industry" (Bosch India 2012b). It is also the first global development centre for the Bosch Group to be set up outside Europe. It works in close cooperation with vehicle and engine manufacturers to develop electronic diesel control and petrol injection systems to match specific needs of new generation vehicles. It has been entrusted with the global responsibility for designing, developing and manufacturing certain products like single cylinder pumps, multi-cylinder pumps and mechanical distributor pumps for the entire Bosch group (Bosch India 2012b). Over 350 qualified and experienced R&D engineers and technicians work at the Technology Centre (Bosch India 2011b). In addition to the Technology Centre, also an "Application Centre" has been established which houses a full-fledged application test facility for electronic diesel control, petrol injection, spark plug and auto electrical products. This centre is targeted at Indian auto manufacturers (Bosch India 2012b).

Engineering and IT Services

The Engineering and Information Technology division of Bosch in India is the largest development centre of Bosch outside Germany (Bosch India 2012a). RBEI with a headcount of over 9,000 is directly owned by Robert Bosch GmbH and is specialized in offering offshore technical services to global customers "with a focus on Europe" (RBEI 2011). All employees "have to undergo basic German language training in addition to intercultural orientation" (RBEI 2011). The company has two state-of-the-art facilities in Bangalore and a development centre in Coimbatore. With proper selection of projects and clearly defined interfaces RBEI claims to be able to offer a cost advantage of 30-50% in comparison to developed countries (RBEI 2011). The company has also gone global with own presence in places like the USA, Europe and Vietnam.

7.3.1.2. Siemens

(a) Group Information

Siemens AG is a German multinational firm primarily active in business sectors Energy, Healthcare, Industry, and Infrastructure & Cities. It is headquartered in Munich and has

[111] Based on: Bosch Ltd.'s Annual Report 2010. Values converted from Indian rupees to euro, using the Reserve Bank of India's official average exchange rates for the respective fiscal years (RBI 2011: Table 147). The original extent of growth in rupee terms was much higher as suggested by the growth rate in row 2 (throughout positive). It has been however impacted by the depreciation in the rupee's exchange rate vis-á-vis euro.

business interests in close to 190 countries. Siemens calls itself “an integrated technology company”, because – as the company puts it: “Our closely aligned business units enable us to offer a wide range of products and solutions that help customers drive competitiveness, enhance business performance, cut costs and reduce CO2 emissions” (Siemens 2011a).

Table 37: Key business indicators of the Siemens Group, 2007-2011 (based on various annual reports)

	2007	2008	2009	2010	2011
Sales (billion EUR)	64.24	69.58	70.05	68.98	73.52
Yearly growth in sales (%)	-3.4%	8.3%	0.7%	-1.5%	6.6%
Profit before tax (billion EUR)[112]	3.43	1.57	2.53	4.26	7.01
Profit to sales ratio (%)	5.3%	2.3%	3.6%	6.2%	9.5%
Employees (annual average)	320,000	346,000	333,000	336,000	360,000
- In Germany (approx.)	126,100	128,000	128,000	128,000	116,000
- R&D employees	32,500	32,200	31,800	27,200	27,800
R&D expenditure (billion EUR)	3.40	3.78	3.90	3.85	3.93
R&D intensity (ratio to sales)	5.3%	4.9%	5.1%	5.1%	5.3%
Patent applications filed	5,060	5,000	4,200	4,300	4,300

With revenues worth 10.8 billion EUR (14.7% of total sales) Germany accounts for the second largest market for Siemens, after the USA (19.6%). China (8.7%) and India (3.2%) are also rapidly taking an increasingly important role for Siemens with double-digit growth rates (Siemens 2011a). Table 5 shows the contribution of individual business fields to Siemens’ revenues and R&D expenses.

Table 38: Share of individual business fields in Siemens’ business and R&D in 2011

(figures in billion EUR)	Sales	R&D expenditure
Industry (e.g. automation, mobility)	32,94	1.6
Energy (e.g. power generation, transmission)	27,61	1.0
Healthcare (diagnostics)	12.52	1.2
Rest	00.45	0.1

116,000 employees (32% of the total workforce) in fiscal year 2011 worked for Siemens in Germany, this was up from 110,000 in the previous year. Siemens has advanced to No. 1 in Germany and No. 3 in Europe (Siemens 2011a: 15). Siemens has 18 R&D locations worldwide (Siemens India 2012a) and the R&D activities are targeted on: a) ensuring long-term future viability, b) enhancing technological competitiveness, and c) optimizing the allocation of R&D resources (Siemens 2011a: 60).

112 “Income from continuing operations”

Impact of R&D Globalization on Home Base

In fiscal year 2011 there were 27,800 R&D employees at 160 Siemens research centres around the globe. Out of these 11,800 R&D employees were located in Germany and approximately 16,000 R&D employees in close to 30 countries abroad including in China and India (Siemens 2011a). In 2009, Siemens had employed 12,700 employees for R&D in Germany and 19,100 employees abroad (Siemens 2009: 52) indicating a decrease in the number of overall R&D. The decrease in Germany was 7% and abroad even 16%. The decrease has however also resulted from selling off of certain business units.

(b) India Operations

Siemens has a very long association with India. Way back in 1867 it laid the 1st Indo-European telegraph line connecting London and Kolkata (Kundu 2005). Siemens' operations in India today are conducted under the flagship of its publically listed subsidiary, Siemens Ltd., headquartered in Mumbai (erstwhile Bombay). In fiscal 2011 Siemens AG increased its stake in the Indian "daughter concern" from 55.3% to 75% with an express desire "to continue driving our booming business in India and boost its influence on our operations on the subcontinent" (Siemens 2011a: 48).

Table 39: Selected business performance indicators for Siemens in India, FY 2007 – FY 2011[113]

	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011
Sales (in millions €)	1,676	1,885	1,680	1,877	2,353
Growth (in %, local currency base)	69.6%	7.4%	4.9%	5.9%	28.7%
Profit before tax (in millions €)	150.4	156.5	219.8	187.6	211.7
Profit to sales ratio	11.0%	10.4%	16.0%	13.3%	10.5%

The Siemens Group in India comprises of 17 companies (Siemens India 2012b), providing direct employment to over 18,000 persons, which amounts to 5% of the global workforce (Siemens 2011a: 71). Currently, the group has 21 manufacturing plants, a wide network up of Sales and Service offices across the country as well as over 500 channel partners (Siemens India 2012b). In fiscal year 2010-11 Siemens India spent Rs. 555.34 million (€ 9.2 million) on R&D (Siemens India 2011). This was a significant increase from the previous year when total R&D expenditure amounted to only Rs. 86.83 million (€ 1.3 million) (Siemens India 2010).[114]

Corporate Technology

While business units at Siemens "concentrate their R&D efforts on the next generation of their products and solutions", R&D specialists at Corporate Technology "are focused two

[113] Revenue data varies considerably across Annual Reports due to sell of various business entities by Siemens, source for sales data: (Siemens 2009, 2010, 2011a). Furthermore, some fluctuation in the growth is caused by volatile exchange rates. Data source for growth and profit: (Siemens India 2011). Profit before tax has been converted from Indian rupees into euro, using RBI's average exchange rates for the respective fiscal year (RBI 2011: Table 147).

[114] Currency conversion using the official average exchange rate for the respective fiscal year (RBI 2011).

generations ahead and prepare the technological basis for that generation" (Siemens 2010: 61). The Corporate Technology division has a total strength of about 5,500.

The Corporate Development Centre, with its 3,160 employees (Siemens 2011c), is an internal solution provider and responsible for software development for Siemens products. It is a part of the Corporate Technology division and has three locational clusters, Central Eastern Europe, India and China. The Development Centre in India is the largest; employing approximately 2,300 engineers and IT specialists (over 75% of the global strength) at five locations, i.e. Bangalore, Pune, Calcutta, Chennai (erstwhile Madras) and Gurgaon. "One of India's great strengths — the very high number of young, highly-trained IT specialists it produces — is therefore also contributing to Siemens' success" (Siemens 2011d: 2). Software engineers in India develop software for all of Siemens' Sectors (Siemens 2011d).

The Bangalore research location of Corporate Technology was established in 2004 and employs 105 researchers. It specializes on software technologies, decentralized energy systems, embedded systems and SMART technologies (see next section). Furthermore, it also operates an innovation centre for renewable energies (Siemens 2011c). Researchers from Corporate Technology in India have developed a low-cost Algae-bacteria based Wastewater Treatment system, which needs about "60 percent less energy for treating wastewater than conventional sewage treatment plants" (Siemens 2011c: 29).

SMART Project

Siemens has launched an initiative called "SMART", which stands for "simple, maintenance-friendly, affordable, reliable, and timely to market" products (Siemens 2011a: 134). SMART products are conceptualized as "high-tech low-cost innovations that work reliably and, as far as possible, without requiring maintenance" (Siemens 2011c). It is hoped that the capability to design, manufacture and sell SMART products will help Siemens gain market share and increase revenue in strategic growth markets like India and China, "where customers may consider price more strongly than product features when making a purchase decision" (Siemens 2011a: 134).

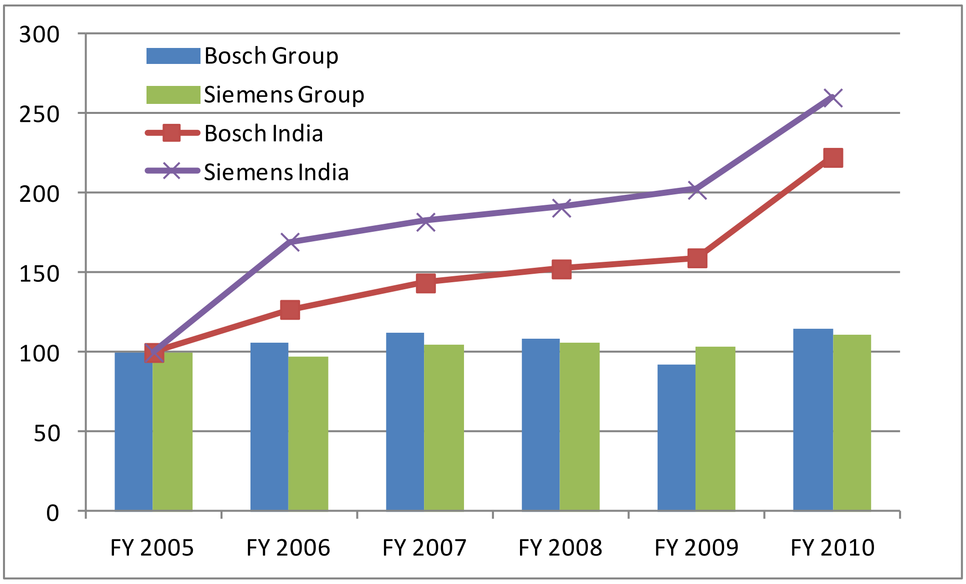
Out of a total of 160 SMART projects worldwide (Siemens 2011a: 52) 60 have been launched in India (37%) to target an estimated market worth over 7 billion EUR (Siemens 2011b). These "value-based products have relevant, functional features and uncompromised quality. Siemens India has developed several SMART products, including a Fetal Heart Rate Monitor, which has been launched also in developed country markets (Siemens 2011c; Siemens India 2011).

Siemens has recently also launched a "Lighthouse" project in India in the field of medical care in remote areas, which utilizes a scalable IT system. Siemens describes those projects as "Lighthouse projects", which are considered strategically important for their potential to open up new fields of business for the company through the development of groundbreaking technologies. Worldwide Siemens is working on 10 Lighthouse projects (Siemens 2011c).

7.3.2. Motives for R&D in India

The sections above have illustrated two multinational firms from Germany, which can be considered technology leaders in their respective fields, as underscored by their R&D resources on both, input and output side. Both of the firms have significantly globalized their R&D operations in various countries. The two companies have long-standing and relatively large-sized business interests in India, where they have been experiencing steady and sustained growth, even during the recent financial crisis.

Figure 70: Revenue growth for Bosch and Siemens at group and India levels (Base FY 2005 = 100)[115]



The figure above shows that the respective subsidiaries in India have thoroughly outperformed the parent concern in recent years, once the effect of fluctuating exchanging rates is filtered out by using local currencies. This market growth is also an important motive for establishing R&D competencies in India. In the following we highlight a few key motivations for doing R&D in India based on the two cases discussed above:

- Markets in India – owing to several peculiarities: e.g. large (rural) markets, price sensitivity, infrastructural deficits and high customer aspirations of a young and consumption-friendly population – require new solutions that are "high-tech, low-cost". Merely stripped-down versions of existing technologies do not suffice as solutions.
- Indian market is seeing intense competition from domestic and global players, so that time-to-market plays an important role.
- Firms anticipate new trends (e.g. fuel efficiency, low maintenance, small cars) to emerge in India and wish to participate in these processes, such as Bosch's engagement with the Tata Nano, the world's cheapest car. Firms hope for positive image and business effects.
- High growth in India enables financing of local R&D operations. The subsidiaries are profit centres and do not cause burden on the parent.
- India's low-cost advantage continues to act as a significant leverage instrument. In some instances firms are able to reduce project costs by 30-50%. In other instances, it is impressive to see the performance of the Indian subsidiary in the light of to their "meagre" budgets not exceeding single-digit millions in euro.

[115] The graphic is intended to illustrate only the growth trend of recent years, since the definitions of the respective fiscal years are not necessarily identical across the four entities.

- Last but not least, firms expect new impulse for internal innovation processes in the form of a “diversity dividend”. For instance, Bosch says, it profited from coming together of engineers of many nationalities to develop new technologies and products for the Tata Nano. “Such collaboration in international teams is becoming more and more central to our business (Bosch Group 2010: 63; Schuster and Holtbrügge 2011).

7.3.3. Implications for the Home Country

The impact of India’s integration into increasingly internationalized R&D networks of the two firms can be summarized in the following:

- Opening of new markets in India (and other developing economies) has been made possible by the complementary role of a strong knowledge base at the home and new competence centres in India. None of the two could have substituted the other.
- R&D operations in India have been configured in a way that they do not compete against R&D operations at the headquarters, as the growing number of R&D personnel at the home base (Bosch) confirms. Growth in absolute numbers has been possible simultaneously. As in the case of Siemens the home base has been more insulated from lay-offs than the overseas operations (7% decrease vs. 16% decrease within 2 years).
- The relative share of the headquarters in the number of R&D personnel has nonetheless decreased and may be expected to decrease further, even though it is set to retain its key role as a provider of basic research into next generation products, as coordinator of knowledge synergies and transfer, and as formulator of the corporate R&D strategy.
- Basic research, so far, continues to remain largely concentrated at the headquarters. The firms expect, however, that the global development centres coming India shall be entrusted with basic research in foreseeable future. This would be generally focused on new business fields with specific relevance to India and other comparable markets in the developing world.
- The two companies have significant programs for internal knowledge transfer. Apart from the usual electronic mediums of knowledge sharing, both firms reported employee exchange programmes between the headquarters and global R&D units. For example, many Indian and German engineers (and over 2,000 associates worldwide) are currently working on multi-year assignments outside their home country of origin. This is done with an express purpose of creating and sharing tacit knowledge.

Overall speaking, the two cases do not provide evidence to suggest any significant trend of offshoring of R&D jobs to India. Rather, they indicate towards creation of new jobs as a result of emergence of new markets in India with positive effects on headquarters. The growth challenge could not have been mastered, had the respective companies insisted on retaining the locational proportion of R&D employees at the headquarters.

7.3.4. Summary & Conclusions

In this study we have examined two cases of German multinational firms, i.e. Bosch and Siemens, which have deliberately established and carefully cultivated engineering and development capacities in India. Their respective software development units are the largest in the concern outside of the headquarters or even worldwide. The development work is however not limited to software alone. There are several examples of successful product and process innovations for the local and global markets, which have been initialized and developed by the Indian unit.

As the indicators of business performance for both firms amply demonstrate, the R&D engagement in India has largely had an exceptionally well impact on the competitiveness of the parent firm, opening new markets in India and other emerging economies. Many products could be commercialized also in developed countries. Cost reduction has helped strengthen the competitiveness of the parent units. Moreover, India as a low-cost location with a large pool of skilled labour has helped firms to react flexibly to market developments both during upswing, when the developed countries faced shortage of skilled labour owing to demographic changes (Müller 2006: 38-48), or during market turbulences, as the low-cost basis in India is financially more manageable and acts as a strategic asset once the market picks up because capacities do not have to be re-created (Doval and Nambiar 2011).

The two examples also show that both the home and host country capacities can grow simultaneously, as is the case with Bosch (see section 2.1.1.). In case of Siemens, this effect is too ambiguous to give a straight answer, since Siemens has sold some of its business units in the period under discussion leading to fluctuation in the number of employees owing to external events. In the past there have also been certain reports of acceptance issues at the Siemens headquarters (cf. Buse, Tiwari and Herstatt 2010: 224). The present study, however, did not find any indication of such discord.

Summarizing, we find positive correlation between the home country R&D activities and Indian R&D engagement of the firms examined here. The results are in line with other academic studies, e.g. (Asakawa and Som 2008; Herstatt, Tiwari, Ernst et al. 2008; Bruche 2009; Ernst, Dubiel and Fischer 2009; Tiwari and Herstatt 2012).

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APPENDIX 3 DRIVERS OF R&D INTERNATIONALISATION (QUANTITATIVE)

Table 40: List of sectors

ISIC Rev. 2	Sector
01-02	**AGRICULTURE, HUNTING AND FORESTRY**
10-14	**MINING AND QUARRYING**
15-37	**MANUFACTURING**
15-16	Food, beverages and tobacco
17-19	Textiles, fur and leather
20-22	Wood, paper, printing, publishing
23	Coke, refined petroleum products and nuclear fuel
24	Chemicals and chemical products
24x	Chemicals and chemical products (less pharma)
24.4	Pharmaceuticals
25	Rubber and plastic products
26	Non-metallic mineral products
27-28	Basic and fabricated metals
29	Machinery and equipment, n.e.c.
30	Office, accounting and computing machinery
31	Electrical machinery and apparatus n.e.c.
32	Radio, TV and communications etc.
33	Medical, precision and optical instruments, etc.
34	Motor Vehicles, trailers and semi-trailers
35	Other Transport Equipment
35.1	Shipbuilding and repairing
35.3	Aircraft and spacecraft
36-37	Furniture, other manufacturing nec
40-41	**ELECTRICITY, GAS and WATER SUPPLY**
45	**CONSTRUCTION**
50-99	**SERVICES SECTOR**
50-52	Wholesale, retail trade and motor vehicle repair
55	Hotels and restaurants
60-64	Transport, storage and communications
64.2	Telecommunications
65-67	Financial intermediation (includes insurance)
70-74	Real estate, renting and business activities
72	Computer and related activities
73	Research and development
74	Other business activities
75-99	Community, social and personal service activities

Table 41: R&D and value added shares of foreign affiliates (2004-2007)

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
01-02	2004	R&D share		61.4			17.2		43.3										9.0										
01-02	2004	VA share																											
01-02	2005	R&D share		57.7			26.9		38.1							0.0													
01-02	2005	VA share																											
01-02	2006	R&D share		73.7			16.2		24.6																				
01-02	2006	VA share																											
01-02	2007	R&D share		73.1			15.6		28.7				64.0																
01-02	2007	VA share																											
01-99	2004	R&D share	44.9			33.5	48.7		27.0		16.4		40.4		73.9			25.8	5.1			24.0	16.8			27.1			14.4
01-99	2004	VA share					26.8					9.6	14.3					5.3	0.8									16.4	4.4
01-99	2005	R&D share				33.5	51.5		26.2		16.1	23.5	40.4	27.5	73.2	70.3		25.2	5.1			23.9	30.4	34.0		30.7		44.7	13.8
01-99	2005	VA share					28.2				9.1	10.0	15.3					5.3	0.8									17.0	4.4
01-99	2006	R&D share				34.6	58.6				17.0	20.9	39.1		69.9			26.6	5.4			24.3	30.1			37.3			14.0
01-99	2006	VA share					25.7				9.6	11.9	15.8					5.9	0.9									17.6	4.7
01-99	2007	R&D share					54.7											30.9				26.5				42.0		35.1	
01-99	2007	VA share					36.7					12.6	17.4					6.2										17.5	4.8
10-14	2004	R&D share		19.8			54.5								0.0			0.0	0.0								0.0		
10-14	2004	VA share					16.8		5.9				56.9					3.1	0.1			37.3						10.3	6.7
10-14	2005	R&D share		21.5		34.4	0.5							12.4	0.0	0.0		0.0	0.0					75.7					
10-14	2005	VA share					5.3		7.1		33.6		58.3		21.5			2.0	0.2			38.8						7.7	6.8
10-14	2006	R&D share		23.8		46.8	0.0			0.0								0.0	0.0										
10-14	2006	VA share					7.1		4.6		35.9		47.1		42.8			2.4	0.5			37.3				10.3		10.9	9.2
10-14	2007	R&D share	90.6	31.5	0.0		0.0		89.8	0.0			30.1	20.4					0.0						662.9				9.1
10-14	2007	VA share	10.1				70.8		6.1				57.3					2.3				33.9				16.6		9.9	9.1
15-16	2004	R&D share	29.2	56.9			58.2		6.3	9.0			43.0		83.1			17.6	0.3	15.9			44.3		8.1				17.8
15-16	2004	VA share					40.6		17.2			25.7	35.9		53.0	132.3		13.4	0.3		40.7	17.8		17.3		27.7		37.1	11.9
15-16	2005	R&D share		58.2			64.0		11.2	13.9	7.1	44.3	50.1	57.2	48.2	36.2		18.3	0.2				67.1	47.1	0.0	85.1		42.9	16.6
15-16	2005	VA share					39.6		17.2		15.0	25.2	39.4		53.0	130.4			0.4		38.3	17.9		18.2		23.8		40.3	14.1
15-16	2006	R&D share		60.7		23.8	68.1		9.2	23.7	20.7	44.1	40.4				215.6	16.5	0.1				83.8		16.0	129.6	0.0		15.8
15-16	2006	VA share					39.2		18.4		20.2	25.6	44.7			121.7		11.7	0.4			16.8		24.1		23.8		40.5	14.6
15-16	2007	R&D share	36.2	57.9			64.8	6.0	15.5	5.3			41.6	52.6	28.8			19.4	0.2		70.2	6.3			64.5	107.6		36.0	18.3
15-16	2007	VA share					49.2		17.8			22.8	42.7			121.4		10.4				18.5						38.6	13.9
15-37	2004	R&D share	54.5	65.3	22.8	38.2	65.0		36.3	37.7	10.2	22.7	27.1		47.3			25.7	5.6	7.7			20.9		3.1	52.6	45.3		13.9
15-37	2004	VA share					49.5		21.4		13.2	33.9	32.8		54.8	162.7		14.6	2.5		35.4	25.3		21.3		45.5		36.9	14.6
15-37	2005	R&D share		65.3	14.6	37.7	66.1		38.8	40.5	11.4	24.9	40.5	28.8	55.3	75.9		25.4	5.6	5.0		29.0	34.6	47.7	5.2	52.1		47.7	13.5
15-37	2005	VA share					47.1		21.2		16.0	34.4	34.5		54.7	171.4		14.2	2.6		31.6	25.8		21.9		44.9		39.6	15.2
15-37	2006	R&D share		65.4	11.7	32.9	71.6		40.0	43.0	12.5	22.2	40.7		53.3		36.0	24.1	6.0	3.8		29.8	32.0		3.1	67.2	31.8		14.5
15-37	2006	VA share					51.1		25.9		18.0	33.7	36.4		57.1	158.6		14.4	2.3			28.1		22.9		44.5		39.9	15.7
15-37	2007	R&D share	63.2	65.9	10.1		67.6	13.2	39.4	25.0	14.4		52.9	27.2	57.5		34.0	27.2	5.6			25.9		34.5	1.9	83.1		35.4	16.3
15-37	2007	VA share	34.3				57.4		24.3			32.8	38.3			161.8		14.4				26.5				49.7		37.7	15.5
17-19	2004	R&D share		16.9			13.6		9.1	241.0			26.8		0.0			8.7	0.0	0.0			28.2		0.0		0.0		4.7
17-19	2004	VA share					26.6		4.0			16.7	9.3					2.5										27.0	3.4
17-19	2005	R&D share		15.4	0.0		14.4		7.6			27.4	49.7	3.2	0.0	34.6		8.7	0.3	0.0				5.4	149.1			41.0	4.5
17-19	2005	VA share					22.1		4.2		7.3	18.3	11.9			52.8		2.1										27.5	3.5

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
17-19	2006	R&D share		19.9	0.0		24.1		12.2	63.9		22.4	29.9		30.3		5.5	8.0	0.3				22.3		0.0		0.0		6.6
17-19	2006	VA share					25.4		4.2		7.6	18.2	9.9		40.4	17.2		2.1										22.2	3.8
17-19	2007	R&D share	42.0	20.5	0.0		25.1		10.3				38.8	5.8	0.0			35.6	0.1			14.1		5.1	0.0			20.5	4.8
17-19	2007	VA share	29.0				32.4		5.2			19.1	12.1					2.5				14.6						29.5	4.2
20-22	2004	R&D share	41.2	25.0			34.4		6.1	0.0			41.7		7.9			31.3	0.1	0.0			0.0		0.0		0.0		
20-22	2004	VA share					34.2		10.6			28.0	24.1		31.3	245.0		8.9			22.1			11.0		21.8		26.0	3.3
20-22	2005	R&D share		23.2			0.0		13.2	0.0	3.3	57.1	34.6	25.2		16.7		15.0	0.1	0.0			0.0	32.3	0.0			20.2	
20-22	2005	VA share					33.8		9.6		3.9	27.2	23.8		35.3	230.3		8.9								27.6		26.5	3.0
20-22	2006	R&D share		18.0		5.3	0.0		19.5	0.0	5.4	44.0	27.4		3.1				0.2						0.0				1.5
20-22	2006	VA share					34.7		9.6		4.3	27.0	24.9		39.1	236.0		9.1								15.2		26.3	2.6
20-22	2007	R&D share	56.4	16.6			0.0	8.4	16.4	0.0	6.2		37.7	23.1	3.7						39.9	15.2		46.6				20.1	
20-22	2007	VA share	30.0				36.4		9.5			25.7	24.6			270.0		9.3				19.6				24.8		24.9	2.4
23	2004	R&D share	0.0	66.8			0.0						0.3					100.0	1.7				0.0						
23	2004	VA share										36.9	60.3					24.6	0.0					0.0				54.2	37.8
23	2005	R&D share		67.6			0.0				0.0		47.0	79.9		0.0		78.9					0.0		0.0			19.1	
23	2005	VA share									0.0	38.6	69.3					20.8	0.1					0.0				57.3	31.3
23	2006	R&D share		82.8		86.4	99.5				0.0	8.2	0.7					59.0					0.0						
23	2006	VA share									0.0	19.3	67.1					20.4	0.1					0.0				45.0	30.8
23	2007	R&D share		82.6			0.0				0.0		271.6					200.0	0.0									27.1	
23	2007	VA share										20.7	77.8					13.6										39.0	42.0
24	2004	R&D share	67.3	75.8	38.9		64.6		44.3	22.0			13.2		29.7			54.7	8.8	0.0			8.2		0.0	32.2			25.3
24	2004	VA share					45.8		34.4			69.1	44.5		46.3	187.4		47.6	8.7		57.8					23.9		85.9	22.8
24	2005	R&D share		76.4	6.2		65.8		42.6	37.8	27.7	26.3	38.6	33.2	46.1	94.5		55.7	7.8	0.0			26.9		2.4	52.4		134.1	23.0
24	2005	VA share					51.0		38.3		42.3	63.1	42.9		48.9	219.8		49.5	11.0		60.8			53.6		21.3		91.9	24.7
24	2006	R&D share		72.2	9.5	53.5	89.6		44.0		25.0	25.2	37.6		47.2		24.2	47.5	7.5	0.0			17.0		1.4	85.5	54.9		27.8
24	2006	VA share					73.7		39.1		47.1	61.5	37.1		42.8	197.7		49.0	9.9							33.7		92.3	25.7
24	2007	R&D share	85.7	74.8	4.6		68.7	10.9	53.1	28.2			61.7	35.5	41.8			44.6	7.0	0.0	33.4	51.4		20.0		89.0		86.0	
24	2007	VA share	59.5				76.8		34.2			66.2	37.2			195.6		49.7								54.6		92.5	26.5
24.4	2004	R&D share	73.3	78.7			81.1		47.3				11.5																27.6
24.4	2004	VA share							38.3			66.2	42.2			165.5		57.2										93.9	34.8
24.4	2005	R&D share		80.9			87.1		49.4		16.4	23.3	38.8	44.1		96.3			12.9									142.5	25.0
24.4	2005	VA share							46.1		65.8	61.9	43.2			172.1		58.9	19.6									98.4	38.3
24.4	2006	R&D share		75.5			96.6				18.8	22.5	37.1						11.3										29.9
24.4	2006	VA share							43.9		82.0	56.7	25.6			180.2			18.6									92.8	43.8
24.4	2007	R&D share	93.3	76.5			87.7							52.8					10.0			0.0		21.0		103.2		81.8	
24.4	2007	VA share							36.3			62.1	24.9			186.2												92.3	
24x	2004	R&D share	57.3	70.0			38.1		37.7				21.8																16.1
24x	2004	VA share							32.8			71.4	46.1			192.7		40.4										69.1	15.0
24x	2005	R&D share		67.9			36.6		25.9		55.6	33.4	37.4	20.9		80.0			1.6									90.6	14.4
24x	2005	VA share							34.9		37.1	64.1	42.7			231.7		43.4	4.9									78.6	16.4
24x	2006	R&D share		62.8			45.2				38.6	32.2	40.3						2.5										16.5
24x	2006	VA share							36.8		37.8	65.5	46.1			202.3			3.9									91.3	14.2
24x	2007	R&D share	70.8	69.4			38.6							17.4					2.6			79.2		15.9		31.6		121.2	
24x	2007	VA share							33.3			69.2	46.7			199.0												92.8	
25	2004	R&D share	6.6	51.1			17.8		50.8				24.9		53.9			24.6	0.3	0.0			0.0		25.6	26.7			19.5
25	2004	VA share					61.9		43.3			35.5	30.5		58.9	43.3		17.8	0.3		37.6			43.1		38.5		19.6	14.3

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
25	2005	R&D share		52.7			63.7		43.5		5.4	22.6	34.4	36.7	53.2	28.6		22.0	0.4	0.0			7.6		29.9			14.8	19.4
25	2005	VA share					61.6		41.4		17.2	37.7	28.4		61.5	38.9		17.5	0.4		38.4			30.4		41.2		25.9	15.9
25	2006	R&D share		61.5		65.0	64.5		44.2	0.0	4.8	12.8	30.1		35.0		9.7	20.2	0.5				13.6		9.6		12.0		21.8
25	2006	VA share					61.0		41.1		15.1	35.7	34.0		59.7	38.8		17.9	0.7					44.9		35.9		26.9	16.4
25	2007	R&D share	22.9	60.6			58.5		38.8	0.0			38.6	35.6				21.7	0.4		35.9	15.0		9.9	29.7	107.4	10.6	7.9	
25	2007	VA share	28.0				60.7		40.3			35.1	34.1			34.5		18.0				27.1				59.9		30.6	16.6
26	2004	R&D share	11.7	53.7			16.1		20.7				21.5		7.6			14.0	0.6	95.2					7.4				26.3
26	2004	VA share					58.7		16.6			30.0	31.0		54.6	22.8		9.7	1.3		51.5	42.0		10.3		46.5		57.6	33.1
26	2005	R&D share		52.0			16.7		14.1	46.7	94.0		25.0	42.8	27.3	24.7		13.8	0.2				5.7	63.7	10.6			30.1	24.5
26	2005	VA share					54.2		15.1		47.2	28.1	31.1		53.7	25.3		8.9	1.7		45.9	43.2		12.0		48.2		61.0	36.2
26	2006	R&D share		51.0			14.9		8.1	101.0	64.4	19.2	70.2		27.0			15.0	0.3	69.0			9.0		0.0	81.1	70.4		21.6
26	2006	VA share					55.0		15.2		44.8	30.7	51.6		69.9	23.0		9.4	0.9			42.7		12.7		51.2		61.3	36.5
26	2007	R&D share	17.0	48.2	0.0		23.1	28.0	31.5	87.0	44.6		41.1	39.2	34.7			10.1	2.0			31.6		30.9	17.9	85.4	75.3	42.6	24.6
26	2007	VA share	21.2				72.2		16.7			28.5	45.2			18.8		9.6				44.9				56.1		49.4	38.8
27-28	2004	R&D share	12.6	29.3			38.1		17.0	55.9			21.7		88.4			15.9	0.3				2.0		45.5		11.5		11.0
27-28	2004	VA share					44.6		12.3			29.0	18.1		44.1	22.0		7.2	0.2		39.0			10.9		54.0		21.2	9.1
27-28	2005	R&D share		30.3			27.0		14.1	43.0			45.6	21.3	78.8	39.9		21.8	0.2	0.0			3.4	38.2	18.3	257.3		15.9	13.5
27-28	2005	VA share					34.5		12.5		12.6	30.5	18.8		39.9	17.8		7.5	0.5		35.3			11.2		49.9		18.1	11.1
27-28	2006	R&D share		33.6		7.9	32.0		18.7	0.0	18.0	52.8			64.5			8.1	0.3				4.6		0.0	252.2	5.9		12.0
27-28	2006	VA share					41.2		15.0		22.2	29.9	22.1		47.8	13.3		8.7	0.5					10.6		51.9		20.6	10.2
27-28	2007	R&D share	17.7	34.0	0.0		46.8	12.2	18.4	17.6	26.3		62.5	20.7	51.5			20.3	0.3		66.4	11.5			6.8	196.5	6.2	11.0	11.2
27-28	2007	VA share					49.3		14.3			28.6	33.4			15.2		8.8				19.7				46.5		19.7	8.8
29	2004	R&D share	38.2	46.4			28.6		22.1	0.0			39.2		55.1			37.0	0.4	0.0			8.3		1.4	46.7	47.5		24.9
29	2004	VA share					36.7		24.3			43.3	33.6		41.0	54.5		19.0	0.7		23.2	31.9		27.5		47.1		32.6	21.0
29	2005	R&D share		49.1			36.3		22.3	0.0	32.6	33.7	42.2	21.3	69.7	62.2		36.3	0.3	0.0			34.8	41.1	1.6	55.6		50.0	18.2
29	2005	VA share					35.0		24.6		21.3	43.3	35.2		43.3	67.3		17.9	0.8		22.7	33.6		29.4		43.6		38.6	17.8
29	2006	R&D share		60.2		20.0	43.9		22.3	55.3	31.6	35.5	46.0		54.1		55.9	35.3	0.3				27.8		0.0	58.5	35.3		17.8
29	2006	VA share					39.1		23.2		21.8	46.4	38.3		43.6	75.2		17.8	0.5			37.5		27.3		42.1		38.5	16.8
29	2007	R&D share	49.7	62.2			47.4	31.1	18.9	51.1	27.4		56.5	18.5	63.9			37.1	0.1		16.6	13.5		41.9	0.0	44.4	32.3	51.3	19.7
29	2007	VA share	42.2				43.5		22.3			47.6	41.9			19.4		18.8				36.5				46.4		37.1	18.7
30	2004	R&D share		37.1			12.9			0.0			87.2		0.0			578.0	0.1	0.0			0.0						2.8
30	2004	VA share					130.2		9.9			27.0	64.3		77.9	380.7		19.8	34.5									7.6	7.1
30	2005	R&D share		38.5			18.3					32.5	48.0	78.0	0.0	64.8		630.2	0.3	0.0				15.9				6.1	
30	2005	VA share					76.9				0.0	34.3	24.5		10.9	324.2		4.9	56.6		6.0							24.1	6.3
30	2006	R&D share		45.4	0.0	20.2	0.0		87.0			31.0	36.2		0.0			462.2	1.3				29.8						
30	2006	VA share					79.0					35.6	22.0		57.1	269.9			56.5							19.6		41.0	3.9
30	2007	R&D share	78.3	44.7	0.0		0.0	23.0	86.5				38.2	77.0	0.0			719.9	1.8		168.4	66.7		0.0				4.7	1.5
30	2007	VA share					70.9					30.1	18.6			279.6										37.0		10.9	
31	2004	R&D share	18.8	56.4			53.6		30.9	19.1			27.0		44.4				1.5	0.0			26.5		0.0	16.1			
31	2004	VA share					56.6		36.9			40.4	43.3		84.3	104.5		16.0	3.1		42.1			66.9		66.7		73.4	11.3
31	2005	R&D share		64.4	0.0		48.4		38.2	5.0		38.7	35.8	32.5	72.5	59.2			2.0				44.6	57.6		29.3		107.5	
31	2005	VA share					54.6		34.9		59.1	40.8	40.5		90.3	143.8		15.0	1.9		47.7			70.3		59.3		77.4	17.0
31	2006	R&D share		91.6			44.5		36.4	49.6		27.8	25.1		82.6		25.4		1.7	100.0			49.1		0.0	80.5	5.2		16.9
31	2006	VA share					54.0		38.9		62.0	38.0	39.2		92.0	150.2			3.3					67.2		52.3		80.0	15.1
31	2007	R&D share	74.4	66.4			46.3	5.4	45.9	76.9	59.4		54.0	30.6	92.5				3.3			21.9		52.7	0.6	61.8	7.2	23.8	16.5
31	2007	VA share					59.1		35.8			41.6	44.7			147.3						43.0				56.4		75.6	14.2

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
32	2004	R&D share	95.3	82.7			58.7		30.7	67.6			43.8		116.7				0.3	0.0			11.3		0.0	86.6			
32	2004	VA share					95.0		26.5			51.8	44.1		87.2			21.3	0.7							56.2		8.2	9.9
32	2005	R&D share		80.2	0.0		70.8		36.6	90.5		42.0	58.5	29.3	81.8	88.6			0.0					90.0	0.0	88.9		2.4	
32	2005	VA share					57.8		31.2		3.5	51.4	37.3		93.9			17.0			10.9			134.5		38.6		8.2	12.8
32	2006	R&D share		67.8		7.1	71.4		34.0	89.0		32.9	64.3		78.6		39.9		0.0							89.0	1.6		
32	2006	VA share					66.0		30.3		3.1	51.1	53.7		90.8									138.6		95.3		6.7	15.0
32	2007	R&D share	81.0	73.0			66.9	5.7	27.5				48.3	34.5	85.4				0.0			29.9		75.9		92.9		1.8	10.8
32	2007	VA share					64.6		29.1			34.4	47.8									8.7				124.7		8.7	
33	2004	R&D share	18.1	25.9			41.2		11.3	12.3			28.6		15.6				0.4				4.4			11.8			10.9
33	2004	VA share					42.9		18.3			23.2	41.9		27.9			16.5	5.1					29.0				32.7	41.8
33	2005	R&D share		26.4			38.0		12.6	17.9		18.8	49.1	20.8	41.5	77.9			0.4				7.0	7.0	0.0	11.6		29.2	11.4
33	2005	VA share					34.8		18.7		37.8	30.1	49.2		23.3			19.2	5.2		39.9							36.5	39.8
33	2006	R&D share		17.7	0.0		67.3		10.9			22.6	45.3		11.1		42.1		0.2	71.4			12.9		2.1	5.8			11.8
33	2006	VA share					34.4		20.1		37.7	28.4	42.2		31.7				2.9							21.7		40.2	
33	2007	R&D share	43.4	15.3	0.0		68.4	18.6	11.6				51.2	16.9	7.8				0.1			33.3			0.0	16.8		24.6	3.4
33	2007	VA share					36.2		19.5			30.8	45.8									51.9				25.9		37.7	
34	2004	R&D share	50.3	68.3			98.9		58.4				71.1		81.5			23.6	21.1	100.0			72.7		7.6		0.0		20.9
34	2004	VA share					81.8		55.5			30.9	75.7		94.8			24.1	6.9		86.9			74.0		76.8		43.0	29.1
34	2005	R&D share		68.5			97.9		71.0		16.5	21.1	87.5	16.1	95.5	86.0		23.8	19.9	100.0			84.4	73.6	4.5			52.0	22.8
34	2005	VA share					88.4		54.9		29.1	34.4	65.0		90.4			27.5	6.4		86.7			74.8				49.8	30.2
34	2006	R&D share		73.7		65.6	96.4		76.7		29.6	15.1	87.0		96.8			37.7	21.0	100.0			81.0		11.0				20.5
34	2006	VA share					91.8		57.4		26.7	37.5	78.6		93.1				5.1							92.9		45.8	30.3
34	2007	R&D share	86.0	75.1			95.1	12.1	80.1				92.0	14.9	107.3			41.4	18.9		80.8	28.3		65.4	0.9			47.8	15.2
34	2007	VA share					95.5		58.5			39.8	83.4									26.4						41.6	28.9
35	2004	R&D share	33.6	89.7			14.7		60.6				24.2		0.0				0.7	0.0			0.0		0.0	0.0	0.0		2.4
35	2004	VA share					38.5		26.1			26.3	25.5		47.3			23.3	0.7		22.7			9.8		11.5		26.1	6.4
35	2005	R&D share		84.7			8.6		71.1			1.7		87.5		0.0			0.6				14.9	0.0	1.6			12.6	2.9
35	2005	VA share					31.9		28.0		36.0	28.1	33.7		43.1			26.6	0.6		7.6							21.0	5.6
35	2006	R&D share		90.2		60.8	6.6		70.5			2.3	28.6		69.2				0.4				19.5		0.0				3.1
35	2006	VA share					27.0		29.7			18.2	33.0		44.1				0.5							2.5		28.4	9.0
35	2007	R&D share	62.8	88.5			9.8	129.0	56.6		10.3		31.3	81.2	71.4				1.5			36.6			0.0			10.5	16.7
35	2007	VA share					55.3		23.9			9.2	38.1									28.2						28.4	14.9
35.1	2004	R&D share		13.1									0.7										0.0						
35.1	2004	VA share							2.3			3.8	21.6					8.2										36.2	4.0
35.1	2005	R&D share		14.4																			0.0	0.0				20.6	
35.1	2005	VA share							2.7		55.2	1.7	28.1					7.2										40.3	3.1
35.1	2006	R&D share		0.0								3.1	1.5										0.0						
35.1	2006	VA share							2.1		55.2	2.7	25.2															27.7	1.9
35.1	2007	R&D share		0.0																		29.6						53.5	
35.1	2007	VA share							3.5			12.8	12.0															28.3	
35.3	2004	R&D share		95.6			4.0						25.7										0.0						3.1
35.3	2004	VA share							51.0			36.7	26.5					23.1										3.2	6.2
35.3	2005	R&D share		90.0			2.4				0.0	1.1	19.9	94.6									0.0					0.0	3.8
35.3	2005	VA share							57.0		0.0	38.6	31.2					35.7										-0.3	6.4
35.3	2006	R&D share		91.9			4.2				0.0	1.5	30.6										25.4						3.8
35.3	2006	VA share							55.1		0.0	22.7	32.3															11.5	11.2

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
35.3	2007	R&D share		90.6			8.4							88.9								99.3						0.0	2.2
35.3	2007	VA share							46.0			6.1	45.1															9.4	
36-37	2004	R&D share		9.3			13.0		5.2				104.0		0.0			54.9	0.7				0.0		29.4		0.0		
36-37	2004	VA share					30.2		4.8			15.1	13.8		22.7	49.9		4.1	1.5		2.2			15.8		32.7		24.3	2.1
36-37	2005	R&D share		9.1			23.6		5.8	40.7			28.8	12.7	0.0	1.2		40.4	0.4	0.0				24.6	16.9			17.0	
36-37	2005	VA share					31.7		4.2		8.9	15.9	15.7			78.9		3.3	0.4		2.2			14.9		32.5		16.3	2.1
36-37	2006	R&D share		1.2			27.2		4.4	0.0	6.3	24.9	35.9		0.0			35.2	0.2						0.0				
36-37	2006	VA share					33.6		4.4		9.8	14.8	13.2		24.6	61.9		4.0	1.9					12.2		34.1		21.7	
36-37	2007	R&D share	14.1	1.0	0.0		29.1	3.8	5.5	38.2			53.5	27.4	23.8			39.1				40.1			0.0			1.3	
36-37	2007	VA share	9.7				32.3		5.6			13.7	15.7					4.1				18.3				24.1		21.1	2.1
40-41	2004	R&D share		81.2			0.0			0.0			5.2		6.0					0.0									0.0
40-41	2004	VA share																											3.6
40-41	2005	R&D share		93.3			0.1			0.0			47.6			0.0								6210.3				33.0	0.0
40-41	2005	VA share																											3.8
40-41	2006	R&D share		11.5			3.3			0.0			48.8		13.8										0.0				0.0
40-41	2006	VA share																											3.4
40-41	2007	R&D share		11.3			2.4		2.9	0.0			69.0		44.8							20.4		0.5	0.5			29.6	0.4
40-41	2007	VA share																								974.0			3.3
45	2004	R&D share		34.9			6.0		4.3				6.2		0.0				0.1	0.0					0.0				0.4
45	2004	VA share																											1.2
45	2005	R&D share		37.3			4.7		1.2				8.5		0.0	0.0				0.0					2.4				0.4
45	2005	VA share																											1.2
45	2006	R&D share		53.5			3.7		2.9				5.5		5.9										0.0				0.8
45	2006	VA share																											1.2
45	2007	R&D share	4.0	44.0	0.0		0.8	0.0	3.4				9.3		0.0						3.2				0.0				0.0
45	2007	VA share																								164.3			1.4
50-52	2004	R&D share	42.9	15.7			68.4			376.8			442.4					58.7	19.7	0.0					0.0		0.0		
50-52	2004	VA share																				27.9							8.7
50-52	2005	R&D share		11.1			60.9		16.3	123.2						0.0		57.0	18.7	0.0				27.0	275.0			2196.3	
50-52	2005	VA share																				28.9							8.4
50-52	2006	R&D share		20.4			40.5		18.3	30.8								71.5	36.3				74.0		319.1		0.0		173.4
50-52	2006	VA share																											8.4
50-52	2007	R&D share	65.8	23.7			56.4			22.8			63.5					63.8		0.0		69.1		39.7	25.6			788.3	116.9
50-52	2007	VA share																											7.6
50-99	2004	R&D share		18.5			24.6		15.7	19.4			100.2					27.1	1.6	0.0					0.0	1.2	0.0		15.8
50-99	2004	VA share																											
50-99	2005	R&D share		17.0			30.0		11.7	18.9						59.5		25.6	1.6	0.0			17.4	6.3	6.6	0.0			14.2
50-99	2005	VA share																											
50-99	2006	R&D share		39.2			36.1		11.9	23.0								36.4	1.6				39.6		3.4	3.5	2.9		12.3
50-99	2006	VA share																											
50-99	2007	R&D share	30.8	35.5			40.4		12.9	29.3			31.3					44.4		0.0		31.9		18.9	10.4	4.2	5.4		12.8
50-99	2007	VA share																											
55	2004	R&D share		1.2			68.6													0.0									
55	2004	VA share																				11.2							3.6
55	2005	R&D share		1.4			0.0		0.0																				
55	2005	VA share																				12.4							3.6

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
55	2006	R&D share		98.4			90.9		0.0																				
55	2006	VA share																											3.6
55	2007	R&D share		99.2			0.0						4.9																
55	2007	VA share																											3.6
60-64	2004	R&D share		9.2			10.9		31.8	9.4			5.3					1.4	1.9	0.0					0.0				
60-64	2004	VA share																											3.8
60-64	2005	R&D share		9.2			8.9		20.9	0.0			19.2			67.9		0.8						6.3	0.0				
60-64	2005	VA share																											3.6
60-64	2006	R&D share		34.2			92.0		15.0									2.0							0.0				
60-64	2006	VA share																											4.3
60-64	2007	R&D share		23.7			95.4		21.7	1.1			6.3					3.5		0.0				1.1					
60-64	2007	VA share																											
64.2	2004	R&D share		8.8			64.9		44.3				5.5																
64.2	2004	VA share																											
64.2	2005	R&D share		9.4			22.8		29.1							72.0													
64.2	2005	VA share																											
64.2	2006	R&D share		33.6			97.5		17.0																				
64.2	2006	VA share																											
64.2	2007	R&D share		22.0			98.4		28.3																				
64.2	2007	VA share																											
65-67	2004	R&D share		58.2			70.6		9.8				1.8					13.9		0.0									0.5
65-67	2004	VA share																											2.8
65-67	2005	R&D share		60.2			77.5		4.3							78.8		7.4		0.0									0.2
65-67	2005	VA share																											2.9
65-67	2006	R&D share		26.2		295.0	93.2		6.6									6.2											0.3
65-67	2006	VA share																											3.5
65-67	2007	R&D share		23.2			92.9		9.2				43.6					1.3		0.0		215.8		6.5					
65-67	2007	VA share																											6.9
70-74	2004	R&D share	21.1	20.5			21.6		15.4	19.6			156.8						0.5	0.0					0.0	1.2	0.0		
70-74	2004	VA share																											1.6
70-74	2005	R&D share		18.6			27.5		11.4	21.7				16.9		59.0		27.3	0.9	0.0			58.5	2.1	0.7	0.0		37.4	
70-74	2005	VA share																											1.7
70-74	2006	R&D share		46.0			28.6		11.3	35.1			46.8					42.5	0.7				41.4			3.6	3.1		
70-74	2006	VA share																											1.9
70-74	2007	R&D share	25.6	43.4			28.5		12.1	42.5			33.5	16.2				56.2		0.0				35.7	11.0	4.4	5.6	48.9	
70-74	2007	VA share																											1.9
72	2004	R&D share		21.3			40.1		10.5	17.1			36.5					37.5	1.0	0.0					0.0	0.0	0.0		0.8
72	2004	VA share																				28.6							3.7
72	2005	R&D share		19.4			50.4		8.3	30.9			44.8			59.7		37.6	1.9				60.7		8.1	0.0			0.5
72	2005	VA share																				24.8							3.4
72	2006	R&D share		35.1			56.8		14.6	53.0			41.2				71.0	47.9	1.8				74.5		1.3	31.0	3.9		0.7
72	2006	VA share																											3.7
72	2007	R&D share	35.5	31.6			52.7		20.4				46.4				66.0	55.9		0.0				41.6	0.4	0.0			1.1
72	2007	VA share																											3.9
73	2004	R&D share		11.1			9.6		20.0				636.4					17.9		0.0					0.0	1.5	0.0		9.6
73	2004	VA share																											

ISIC	YEAR	VAR	AUT	BEL	BUL	CAN	CZE	DNK	ESP	EST	FIN	FRA	GBR	GER	HUN	IRL	ISR	ITA	JPN	LVA	NLD	NOR	POL	PRT	ROM	SVK	SVN	SWE	USA
73	2005	R&D share		9.5			11.0		15.3				48.0			61.5		20.0					46.8		0.0	0.0			10.2
73	2005	VA share																											
73	2006	R&D share		4.5			9.3		12.6				32.2				75.0	25.0								3.1	4.7		9.9
73	2006	VA share																											
73	2007	R&D share	20.7	66.9			10.3		12.0				31.6				74.0	23.2							0.0	3.3			7.7
73	2007	VA share																											
74	2004	R&D share		19.7			35.9		4.9	32.6								40.1	4.2	0.0					0.0	0.0	0.0		
74	2004	VA share																											
74	2005	R&D share		17.9			32.7		4.0	17.7						7.1		37.7	7.1				82.6	1.7		0.0			
74	2005	VA share																											
74	2006	R&D share		56.1			30.5		3.7	7.9								59.4	6.6							0.0	0.0		
74	2006	VA share																											
74	2007	R&D share		53.5			41.8		3.5	11.9			29.1					152.7						35.7	7.4	9.7			
74	2007	VA share																											
75-99	2004	R&D share		3.2			1.1			14.5			36.1					16.7											
75-99	2004	VA share																											0.7
75-99	2005	R&D share		2.4			0.9		6.1	0.0								15.0											
75-99	2005	VA share																											0.8
75-99	2006	R&D share		7.1			1.3		7.5				7.2					11.9											
75-99	2006	VA share																											0.7
75-99	2007	R&D share		7.8			0.9		7.7				33.0					17.0											
75-99	2007	VA share																											0.7

Source: own calculations

Note: due to insufficient or lacking data on R&D expenditures of foreign affiliates, value added of foreign affiliates, total R&D expenditures or total value added, R&D and/or value added shares are not available for the following counties: Australia, Cyprus, Greece, Iceland, Korea, Lithuania, Luxembourg, Malta, Switzerland, Taiwan and Turkey. To conserve space, these countries are not reported here.

In the graphical analysis above (section 3.1), negative shares as well as shares in excess of 100 which are due to data inconsistencies were rescaled to either 0 or 100, respectively. In contrast, the actual values are presented here.

Table 42: R&D intensities (2004-2007)

ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
01-02	2004	Domestic firms															
01-02	2004	Foreign affiliates															
01-02	2005	Domestic firms															
01-02	2005	Foreign affiliates															
01-02	2006	Domestic firms															
01-02	2006	Foreign affiliates															
01-02	2007	Domestic firms															
01-02	2007	Foreign affiliates															
01-99	2004	Domestic firms		0.6				0.8			0.5	2.2					1.6
01-99	2004	Foreign affiliates		1.6				3.4			2.8	14.9					5.9
01-99	2005	Domestic firms		0.7		2.6	1.2	0.8			0.5	2.3				2.0	1.6
01-99	2005	Foreign affiliates		1.9		5.0	3.4	3.1			2.9	14.8				7.8	5.7
01-99	2006	Domestic firms		0.6		2.6	1.3	0.9			0.5	2.4					1.7
01-99	2006	Foreign affiliates		2.6		5.1	2.6	3.0			2.8	15.8					5.6
01-99	2007	Domestic firms		0.8							0.4					2.3	
01-99	2007	Foreign affiliates		1.6			2.2	2.8			3.0	14.0				5.9	6.1
10-14	2004	Domestic firms		0.1							0.6	2.9					
10-14	2004	Foreign affiliates		0.3				0.1			0.0	0.0					1.7
10-14	2005	Domestic firms		0.4					0.0		0.6	3.9					
10-14	2005	Foreign affiliates		0.0				0.1	0.0		0.0	0.0				0.1	1.4
10-14	2006	Domestic firms		0.2							3.6	2.0					
10-14	2006	Foreign affiliates		0.0			0.7	0.1			0.0	0.0					1.7
10-14	2007	Domestic firms	0.1	0.6	0.5			0.3							0.0		0.5
10-14	2007	Foreign affiliates	6.9	0.0	71.1			0.1			0.0	0.0	0.1		0.0	0.0	0.5
15-16	2004	Domestic firms		0.1	1.0			1.0	0.1		0.3	2.1					1.6
15-16	2004	Foreign affiliates		0.3	0.3			1.4	0.3		0.5	1.9					2.6
15-16	2005	Domestic firms		0.1	1.0	2.8	1.2	1.0	0.2	-2.1		2.3		0.2	0.0	1.4	2.0
15-16	2005	Foreign affiliates		0.3	0.6	1.2	2.8	1.6	0.2	0.3		0.9		0.6	0.2	1.5	2.4
15-16	2006	Domestic firms		0.1	1.1	2.9	1.3	1.5			0.5	2.6			0.0		2.0
15-16	2006	Foreign affiliates		0.4	0.5	3.0	3.0	1.3			0.8	0.7			0.3		2.2
15-16	2007	Domestic firms		0.2	0.9			1.3			0.4		3.0			1.5	1.6
15-16	2007	Foreign affiliates		0.4	0.8		2.9	1.2			0.7	2.1	0.9			1.3	2.2
15-37	2004	Domestic firms		1.4	1.8	10.2	11.2	7.5	1.8		1.9	9.5			0.3		9.6
15-37	2004	Foreign affiliates		2.7	3.8	7.6	6.4	5.7	1.3		3.9	22.4			0.4		9.1
15-37	2005	Domestic firms		1.6	1.8	10.8	10.7	6.4	1.7	-0.9	2.1	10.2	4.1	0.7	0.3	10.5	10.0
15-37	2005	Foreign affiliates		3.4	4.3	7.3	6.8	8.2	1.7	1.2	4.2	22.4	4.9	2.4	0.5	14.6	8.7
15-37	2006	Domestic firms		1.7	2.0	10.7	11.8	6.6	2.0		2.1	10.4	4.2		0.2		10.2
15-37	2006	Foreign affiliates		4.0	3.8	7.0	6.6	8.0	1.8		4.0	27.6	4.6		0.5		9.3
15-37	2007	Domestic firms	3.8	1.8	1.9			3.3			1.9		4.4		0.1	13.1	10.6
15-37	2007	Foreign affiliates	12.4	2.9	3.9		6.2	5.9			4.2	27.2	4.3		0.6	11.8	11.2
17-19	2004	Domestic firms		0.9	1.1			0.4			0.2						1.4
17-19	2004	Foreign affiliates		0.4	2.8			1.3			0.9						2.0
17-19	2005	Domestic firms		0.9	1.3		1.3	0.2		1.1	0.3					1.9	2.0
17-19	2005	Foreign affiliates		0.5	2.5		2.2	1.8		0.5	1.4					3.5	2.6

ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
17-19	2006	Domestic firms		1.2	1.5		2.0	0.3	0.1		0.5						1.5
17-19	2006	Foreign affiliates		1.1	4.7		2.6	1.2	0.0		1.9						2.7
17-19	2007	Domestic firms	2.2	1.1	1.7			0.3			0.2		2.5			5.5	2.2
17-19	2007	Foreign affiliates	3.8	0.8	3.6		2.2	1.3			4.6		2.4			3.4	2.6
20-22	2004	Domestic firms		0.0	0.5			0.1	0.2		0.1				0.0		
20-22	2004	Foreign affiliates		0.0	0.3			0.3	0.0		0.5				0.0		
20-22	2005	Domestic firms		0.1	0.4	1.7	0.2	0.2		-0.1	0.2				0.0	2.5	
20-22	2005	Foreign affiliates		0.0	0.5	1.5	0.7	0.3		0.0	0.3				0.0	1.7	
20-22	2006	Domestic firms		0.1	0.4	1.5	0.3	0.2	0.5						0.0		1.5
20-22	2006	Foreign affiliates		0.0	1.0	2.0	0.6	0.3	0.0						0.0		0.8
20-22	2007	Domestic firms	0.4	0.1	0.4			0.2					1.2			1.8	
20-22	2007	Foreign affiliates	1.4	0.0	0.8		0.7	0.3					0.9		0.0	1.4	0.9
23	2004	Domestic firms						25.7			0.0	0.7					
23	2004	Foreign affiliates						0.1			0.3	25.6					
23	2005	Domestic firms				1.7		17.9			0.0					9.0	
23	2005	Foreign affiliates						7.1			0.3					1.6	
23	2006	Domestic firms				3.8	5.7	39.9			0.1						
23	2006	Foreign affiliates					2.1	0.1			0.5						
23	2007	Domestic firms						-7.3			-0.1					3.1	
23	2007	Foreign affiliates					2.1	3.3			0.7					1.8	
24	2004	Domestic firms		2.7	5.1			38.7	11.1		3.7	19.6			1.7		19.1
24	2004	Foreign affiliates		5.8	7.8			7.3	5.4		4.9	19.7			2.6		21.9
24	2005	Domestic firms		2.7	5.9	18.3	41.8	25.7	11.8	-0.1	4.1	23.2			1.0	-69.7	21.8
24	2005	Foreign affiliates		4.9	7.1	9.6	8.7	21.5	10.5	1.2	5.2	15.9			4.1	24.3	19.9
24	2006	Domestic firms		4.8	6.3	22.0	41.0	24.8	10.9		4.3	26.8			0.3		19.1
24	2006	Foreign affiliates		14.8	7.7	8.2	8.7	25.2	13.1		4.1	20.0			3.9		21.2
24	2007	Domestic firms	3.6	6.1	4.7			2.9			5.3				0.4	35.3	
24	2007	Foreign affiliates	14.7	4.1	10.1		8.3	8.0			4.3	13.9	10.0		3.0	17.6	24.1
24.4	2004	Domestic firms			12.0			79.8									44.7
24.4	2004	Foreign affiliates			17.3			14.2									31.9
24.4	2005	Domestic firms			14.1	140.6	66.7	52.9		-0.6		32.2				-549.9	55.4
24.4	2005	Foreign affiliates			16.1	14.3	12.4	44.3		7.0		19.6				30.1	29.7
24.4	2006	Domestic firms				226.6	59.1	41.1				40.3					53.0
24.4	2006	Foreign affiliates				11.5	13.1	70.2				22.4					29.1
24.4	2007	Domestic firms														63.2	
24.4	2007	Foreign affiliates					13.3	17.1				13.7				23.5	33.5
24x	2004	Domestic firms			2.5			9.6									6.3
24x	2004	Foreign affiliates			3.1			3.1									6.9
24x	2005	Domestic firms			3.0	3.6	20.8	6.9		-0.1		18.0				3.6	6.7
24x	2005	Foreign affiliates			1.9	7.8	5.9	5.6		0.1		5.6				9.5	5.8
24x	2006	Domestic firms				6.1	21.7	7.2				19.0					5.0
24x	2006	Foreign affiliates				6.3	5.4	5.7				12.1					6.0
24x	2007	Domestic firms														-16.2	
24x	2007	Foreign affiliates					4.9	4.2				15.3				7.2	6.8
25	2004	Domestic firms		1.8	1.2			0.9	0.3		1.5	5.3			2.3		2.7
25	2004	Foreign affiliates		0.2	1.7			0.7	0.2		2.3	5.6			1.3		3.9

ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
25	2005	Domestic firms		1.5	1.5	6.0	7.7	0.7	0.5	1.5	1.7	6.0				3.9	2.5
25	2005	Foreign affiliates		1.7	1.7	1.6	3.7	0.9	0.3	0.9	2.2	6.8			0.8	2.0	3.2
25	2006	Domestic firms		1.6	1.6	7.1	9.7	1.3	1.4		2.1	6.5					3.2
25	2006	Foreign affiliates		1.8	1.9	2.0	2.6	1.1	0.5		2.4	4.5			0.8		4.6
25	2007	Domestic firms	6.0	1.1	1.8			1.0			1.7		2.7		-0.2	4.6	
25	2007	Foreign affiliates	4.6	1.0	1.7		2.5	1.2			2.1	4.3	1.3		2.0	0.9	3.8
26	2004	Domestic firms		2.0	0.7			1.3	0.4		0.3	3.9					1.8
26	2004	Foreign affiliates		0.3	0.9			0.8	0.0		0.5	1.9			0.3		1.3
26	2005	Domestic firms		2.0	0.8	0.1		0.9	0.3	1.8	0.4	4.2		0.1		3.6	2.0
26	2005	Foreign affiliates		0.3	0.8	2.3		0.7	0.1	1.7	0.6	0.5		1.6	0.4	1.0	1.1
26	2006	Domestic firms		1.8	1.1	0.9	3.2	0.5	0.5		0.5	4.2			0.1		2.2
26	2006	Foreign affiliates		0.3	0.5	2.0	1.7	1.2	0.1		0.8	1.4			0.4		1.0
26	2007	Domestic firms	2.7	2.1	0.8			0.6			0.4		1.4		0.1	2.5	2.5
26	2007	Foreign affiliates	2.0	0.2	1.8		1.7	0.5			0.4	6.0	0.8		0.5	1.9	1.3
27-28	2004	Domestic firms		0.7	0.8			0.7	0.0		0.2	3.0					1.3
27-28	2004	Foreign affiliates		0.5	1.1			0.9	0.3		0.5	4.3			0.3		1.6
27-28	2005	Domestic firms		0.7	0.8			0.5	0.1	0.9	0.2	2.7		0.2	-0.2	3.2	1.1
27-28	2005	Foreign affiliates		0.5	0.9			1.7	0.3	2.9	0.7	1.1		0.8	0.4	2.7	1.3
27-28	2006	Domestic firms		0.7	0.9	2.8	1.1		0.2		0.4	3.1			-0.3		1.1
27-28	2006	Foreign affiliates		0.5	1.2	2.1	2.9		0.3		0.4	1.9			0.4		1.3
27-28	2007	Domestic firms		0.6	0.8			0.3			0.2		2.6		-0.2	3.0	1.3
27-28	2007	Foreign affiliates		0.5	1.1		2.9	1.1			0.6	2.6	1.4		0.5	1.5	1.6
29	2004	Domestic firms		2.8	3.1			5.6	1.0		2.0	8.8			0.4		6.0
29	2004	Foreign affiliates		1.9	2.7			7.2	1.8		4.9	5.0			0.4		7.5
29	2005	Domestic firms		3.0	3.4	5.0	7.2	5.4	0.6	6.5	2.0	8.9		1.2	0.4	8.3	7.6
29	2005	Foreign affiliates		3.2	3.0	8.9	4.8	7.3	1.9	5.2	5.3	3.2		2.1	0.6	13.2	7.8
29	2006	Domestic firms		2.7	3.1	5.3	7.5	5.4	1.0		2.1	8.7			0.3		8.1
29	2006	Foreign affiliates		3.3	2.9	8.7	4.8	7.5	1.5		5.3	5.3			0.6		8.7
29	2007	Domestic firms	6.9	2.8	3.4			6.4			1.9		11.0		0.9	7.4	7.8
29	2007	Foreign affiliates	9.3	3.3	2.7		4.3	11.6			4.8	1.8	3.0		0.9	13.2	8.3
30	2004	Domestic firms		-4.3				0.9	0.4		-39.0	177.4					32.5
30	2004	Foreign affiliates		0.1				3.2	0.0		191.6	0.3					12.1
30	2005	Domestic firms		4.6			23.1	1.4	0.1	-0.6	-36.3	531.8				36.7	
30	2005	Foreign affiliates		0.3			21.3	4.0	0.0	0.8	835.7	1.2				7.5	
30	2006	Domestic firms		7.3			32.4	0.9	1.5			513.4					
30	2006	Foreign affiliates		0.0			26.4	1.7	0.0			5.0			0.0		
30	2007	Domestic firms		3.2				3.9								41.2	
30	2007	Foreign affiliates		0.0			19.2	10.6				2.6			0.0	16.7	12.0
31	2004	Domestic firms		1.9	5.5			11.6	6.8			21.8			0.7		
31	2004	Foreign affiliates		1.6	4.2			5.6	1.0			10.5			0.1		
31	2005	Domestic firms		2.0	4.0		10.8	9.1	3.3	-4.3		20.6		0.6	0.5	-3.9	
31	2005	Foreign affiliates		1.5	4.7		9.9	7.4	0.9	1.9		21.6		0.4	0.1	16.3	
31	2006	Domestic firms		2.1	4.2		15.0	10.8	2.5			20.6			0.1		4.0
31	2006	Foreign affiliates		1.4	3.7		9.4	5.6	1.0			10.4			0.5		4.6
31	2007	Domestic firms		2.4	2.7			3.8					13.2		0.3	36.3	4.5
31	2007	Foreign affiliates		1.5	4.1		9.5	5.5				19.6	4.9		0.3	3.7	5.4

ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
32	2004	Domestic firms		39.2	11.9			23.1	-2.4			26.0			0.9		
32	2004	Foreign affiliates		2.9	14.6			22.8	2.5			9.8			4.3		
32	2005	Domestic firms		5.0	12.6		56.8	17.2	6.0					-6.5	0.4	50.8	
32	2005	Foreign affiliates		8.8	16.1		39.0	40.6	1.7					14.9	5.0	14.1	
32	2006	Domestic firms		5.2	12.0		68.5	18.0	4.7						2.7		
32	2006	Foreign affiliates		6.6	14.3		32.2	28.0	1.7						1.1		
32	2007	Domestic firms		5.3	18.4			10.8					15.4		-0.4	58.9	
32	2007	Foreign affiliates		5.8	17.0		33.5	11.0					69.2		1.1	11.4	34.9
33	2004	Domestic firms		2.7	7.4			10.7	1.7			33.7					69.1
33	2004	Foreign affiliates		2.5	4.2			5.9	0.8			2.6					11.8
33	2005	Domestic firms		3.0	7.1		19.0	7.9	1.8			37.6				21.4	64.2
33	2005	Foreign affiliates		3.4	4.4		10.2	7.9	4.2			2.5				15.4	12.6
33	2006	Domestic firms		3.6	7.8		19.8	7.2	3.0			32.8			1.0		
33	2006	Foreign affiliates		14.0	3.8		14.6	8.2	0.8			2.7			0.2		
33	2007	Domestic firms		4.7	8.1			10.3					23.1		0.8	25.7	
33	2007	Foreign affiliates		17.8	4.4		12.4	12.8				2.2	10.7		0.5	13.9	11.0
34	2004	Domestic firms		0.4	2.0			10.6	5.2		10.4	13.7					16.3
34	2004	Foreign affiliates		8.4	2.2			8.4	1.3		10.1	49.3			0.0		10.5
34	2005	Domestic firms		1.5	1.7	4.7	28.7	3.0	0.6		12.3	14.4		1.2		24.4	18.1
34	2005	Foreign affiliates		9.1	3.3	2.3	14.6	11.2	1.3		10.1	52.3		1.1		26.7	12.3
34	2006	Domestic firms		3.2	1.3	2.7	44.0	5.5	0.5			13.6					19.3
34	2006	Foreign affiliates		7.6	3.1	3.2	13.1	10.1	1.2			67.4			0.1		11.5
34	2007	Domestic firms		7.4	1.1			4.5					12.6			25.2	19.4
34	2007	Foreign affiliates		6.9	3.0		13.0	10.3				88.4	13.8			32.4	8.6
35	2004	Domestic firms		12.4	7.1			29.4	0.0			3.4			2.0		26.0
35	2004	Foreign affiliates		3.4	31.0			27.4	0.0			3.5			0.0		9.4
35	2005	Domestic firms		15.4	5.2		45.9		0.0			4.8				21.8	25.5
35	2005	Foreign affiliates		3.1	32.9		2.0		0.0			4.7				11.8	12.8
35	2006	Domestic firms		15.3	6.2		32.1	25.8	0.1			3.8					25.1
35	2006	Foreign affiliates		2.9	35.0		3.3	21.0	0.2			3.5			0.0		8.0
35	2007	Domestic firms		21.2	5.6			25.7					1.8			25.5	20.3
35	2007	Foreign affiliates		1.9	23.4		7.6	19.0					2.6			7.5	23.3
35.1	2004	Domestic firms						13.3									
35.1	2004	Foreign affiliates						0.3									
35.1	2005	Domestic firms														5.6	
35.1	2005	Foreign affiliates														2.2	1.5
35.1	2006	Domestic firms					4.5	14.0									
35.1	2006	Foreign affiliates					5.1	0.6									0.9
35.1	2007	Domestic firms														1.8	
35.1	2007	Foreign affiliates					0.0	0.5								5.4	
35.3	2004	Domestic firms						37.5									25.5
35.3	2004	Foreign affiliates						36.1									12.4
35.3	2005	Domestic firms				12.6	75.9	46.4								29.3	25.1
35.3	2005	Foreign affiliates					1.4	25.5								0.0	14.4
35.3	2006	Domestic firms				17.3	46.4	31.0									26.6
35.3	2006	Foreign affiliates					2.4	28.7									8.4

ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
35.3	2007	Domestic firms														39.5	
35.3	2007	Foreign affiliates					12.2	22.0								0.0	5.0
36-37	2004	Domestic firms		0.6	0.8			0.0	0.1		0.2	7.8			0.0		
36-37	2004	Foreign affiliates		0.2	0.9			3.9	0.0		5.9	3.6			0.1		
36-37	2005	Domestic firms		0.4	0.8			0.4		7.3	0.3	6.4		0.1	0.0	2.4	
36-37	2005	Foreign affiliates		0.3	1.1			0.8		0.0	5.6	6.9		0.2	0.1	2.6	
36-37	2006	Domestic firms		0.4	0.8	5.8	2.4	0.3	0.2		0.3	6.4			0.0		
36-37	2006	Foreign affiliates		0.3	0.8	3.6	4.5	1.0	0.0		4.2	0.6			0.0		
36-37	2007	Domestic firms	3.1	0.3	0.9			0.6			0.3		1.4		0.0	7.0	
36-37	2007	Foreign affiliates	4.8	0.3	0.9		4.8	3.5			4.1		4.2		0.0	0.3	2.7
40-41	2004	Domestic firms															0.1
40-41	2004	Foreign affiliates															0.0
40-41	2005	Domestic firms															0.1
40-41	2005	Foreign affiliates															0.0
40-41	2006	Domestic firms															0.1
40-41	2006	Foreign affiliates															0.0
40-41	2007	Domestic firms															0.1
40-41	2007	Foreign affiliates															0.0
45	2004	Domestic firms															0.3
45	2004	Foreign affiliates															0.1
45	2005	Domestic firms															0.2
45	2005	Foreign affiliates															0.1
45	2006	Domestic firms															0.2
45	2006	Foreign affiliates															0.1
45	2007	Domestic firms															0.1
45	2007	Foreign affiliates															0.0
50-52	2004	Domestic firms															
50-52	2004	Foreign affiliates															
50-52	2005	Domestic firms															
50-52	2005	Foreign affiliates															
50-52	2006	Domestic firms															-0.2
50-52	2006	Foreign affiliates															4.3
50-52	2007	Domestic firms															-0.1
50-52	2007	Foreign affiliates															4.4
50-99	2004	Domestic firms															
50-99	2004	Foreign affiliates															
50-99	2005	Domestic firms															
50-99	2005	Foreign affiliates															
50-99	2006	Domestic firms															
50-99	2006	Foreign affiliates															
50-99	2007	Domestic firms															
50-99	2007	Foreign affiliates															
55	2004	Domestic firms															
55	2004	Foreign affiliates															0.0
55	2005	Domestic firms															
55	2005	Foreign affiliates															0.0

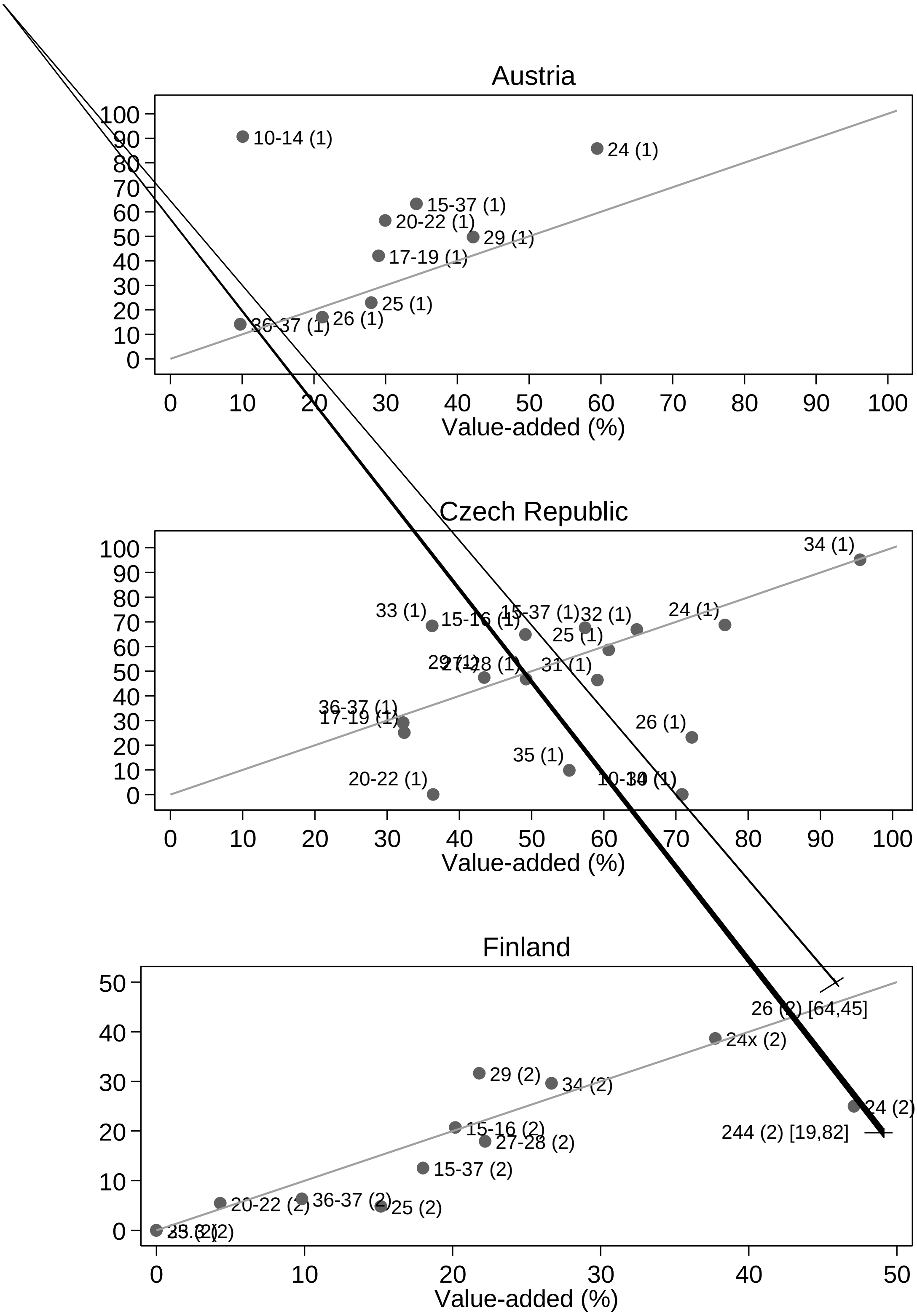
ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
55	2006	Domestic firms															
55	2006	Foreign affiliates															0.0
55	2007	Domestic firms															
55	2007	Foreign affiliates															0.0
60-64	2004	Domestic firms															
60-64	2004	Foreign affiliates															
60-64	2005	Domestic firms															
60-64	2005	Foreign affiliates															
60-64	2006	Domestic firms															
60-64	2006	Foreign affiliates															
60-64	2007	Domestic firms															
60-64	2007	Foreign affiliates															
64.2	2004	Domestic firms															
64.2	2004	Foreign affiliates															
64.2	2005	Domestic firms															
64.2	2005	Foreign affiliates															
64.2	2006	Domestic firms															
64.2	2006	Foreign affiliates															
64.2	2007	Domestic firms															
64.2	2007	Foreign affiliates															
65-67	2004	Domestic firms															0.2
65-67	2004	Foreign affiliates															0.0
65-67	2005	Domestic firms															0.3
65-67	2005	Foreign affiliates															0.0
65-67	2006	Domestic firms															0.2
65-67	2006	Foreign affiliates															0.0
65-67	2007	Domestic firms															
65-67	2007	Foreign affiliates															0.0
70-74	2004	Domestic firms															
70-74	2004	Foreign affiliates															3.2
70-74	2005	Domestic firms															
70-74	2005	Foreign affiliates															3.2
70-74	2006	Domestic firms															
70-74	2006	Foreign affiliates															
70-74	2007	Domestic firms															
70-74	2007	Foreign affiliates															2.7
72	2004	Domestic firms															15.7
72	2004	Foreign affiliates															3.2
72	2005	Domestic firms															16.0
72	2005	Foreign affiliates															2.3
72	2006	Domestic firms															16.0
72	2006	Foreign affiliates															3.1
72	2007	Domestic firms															15.2
72	2007	Foreign affiliates															4.3
73	2004	Domestic firms															
73	2004	Foreign affiliates															134.9

ISIC	Year	Variable	AUT	CZE	ESP	FIN	FRA	GBR	HUN	IRL	ITA	JPN	NOR	PRT	SVK	SWE	USA
73	2005	Domestic firms															
73	2005	Foreign affiliates															126.1
73	2006	Domestic firms															
73	2006	Foreign affiliates															131.3
73	2007	Domestic firms															
73	2007	Foreign affiliates															122.6
74	2004	Domestic firms															
74	2004	Foreign affiliates															
74	2005	Domestic firms															
74	2005	Foreign affiliates															
74	2006	Domestic firms															
74	2006	Foreign affiliates															
74	2007	Domestic firms															
74	2007	Foreign affiliates															
75-99	2004	Domestic firms															
75-99	2004	Foreign affiliates															
75-99	2005	Domestic firms															
75-99	2005	Foreign affiliates															
75-99	2006	Domestic firms															
75-99	2006	Foreign affiliates															
75-99	2007	Domestic firms															
75-99	2007	Foreign affiliates															3.7

Source: own calculations

Note: no data are available for Australia, Belgium, Bulgaria, Canada, Cyprus, Denmark, Estonia, Germany, Greece, Iceland, Israel, Korea, Latvia, Lithuania, Luxembourg, Malta, Poland, Romania, Switzerland, Slovenia, Taiwan and Turkey. In the graphical analysis above (section 3.1), negative shares as well as shares in excess of 100 which are due to data inconsistencies were rescaled to either 0 or 100, respectively. In contrast, the actual values are presented here.

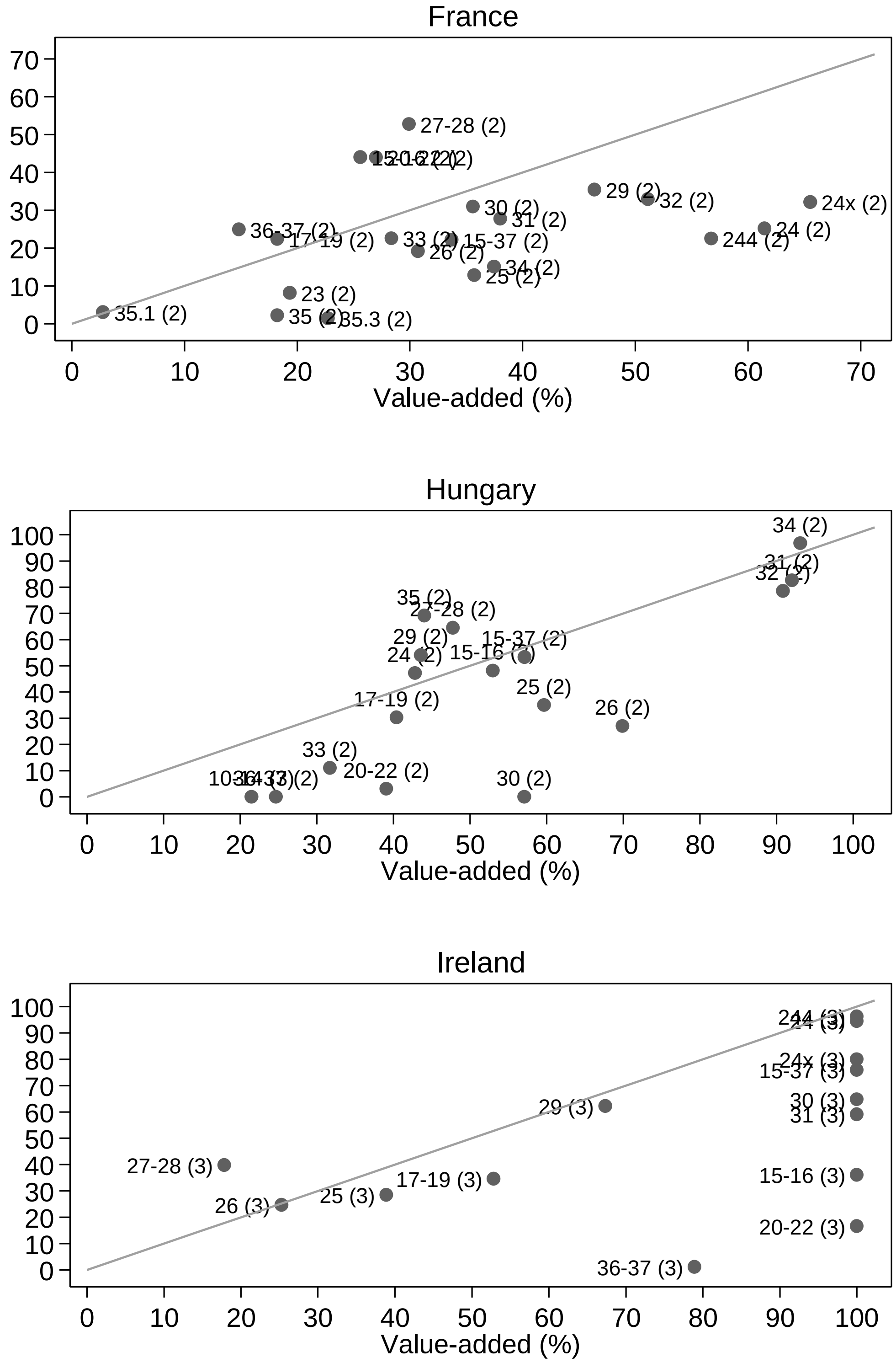
Figure 71: R&D and value added shares of foreign affiliates – a country perspective (2004-2007) – Austria, the Czech Republic and Finland



Note: (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

Figure 72: R&D and value added shares of foreign affiliates – a country perspective (2004-2007) – France, Hungary and Ireland

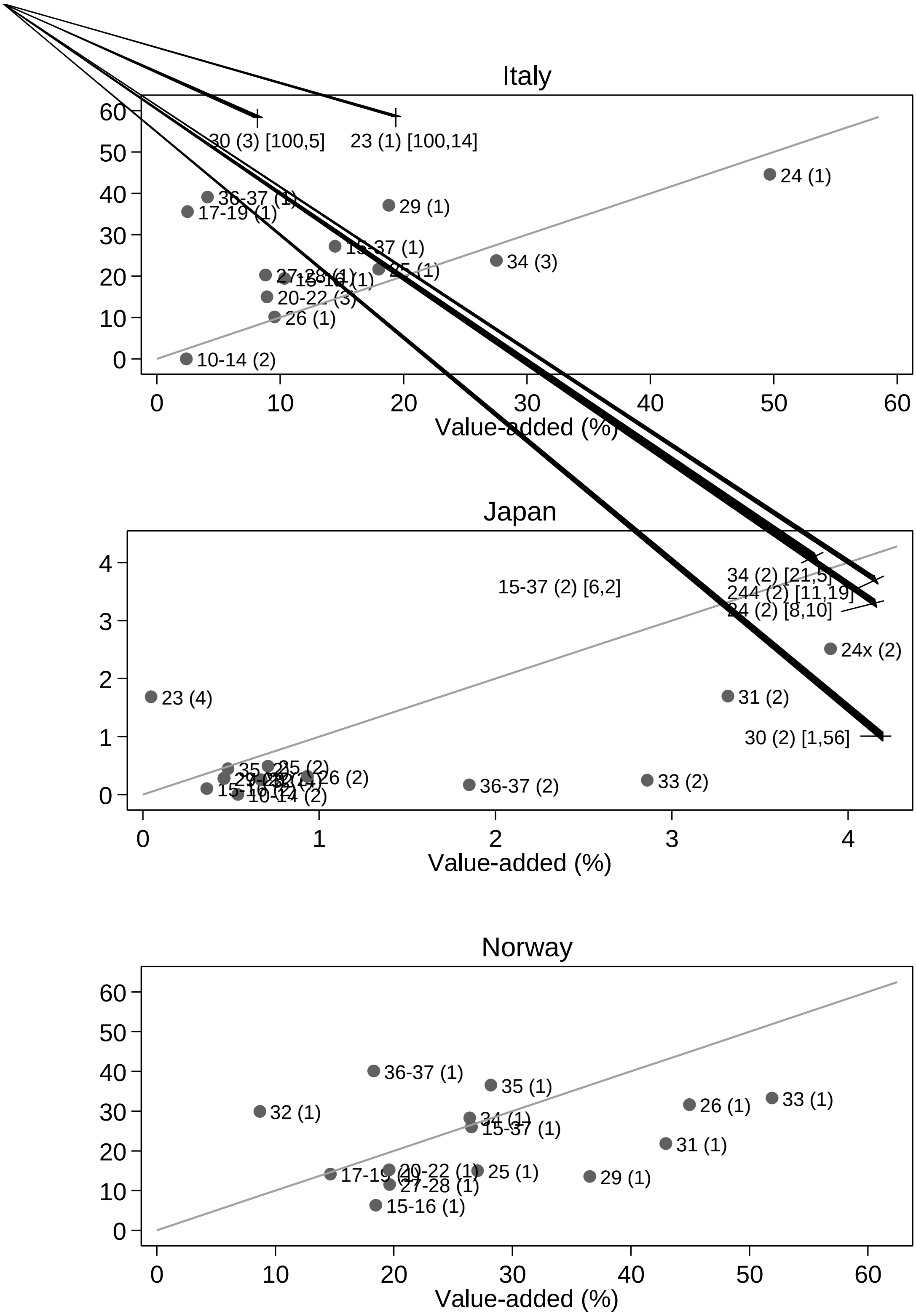


Notes: for Ireland: several sectoral value added shares were rescaled to 100

(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

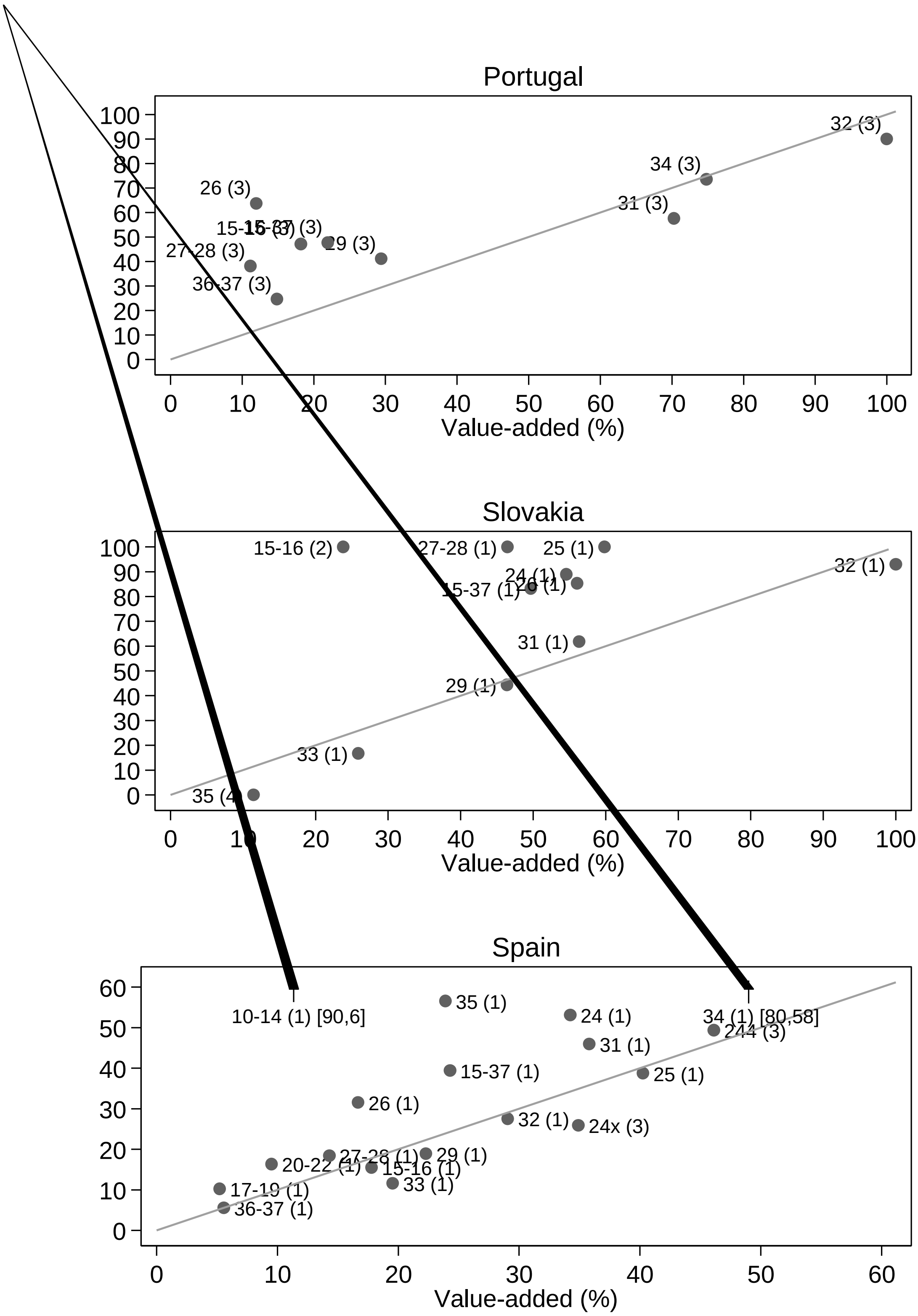
Figure 73: R&D and value added shares of foreign affiliates – a country perspective (2004-2007) – Italy, Japan and Norway



Notes: for Italy: the share of inward R&D for 23 and 30 were 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

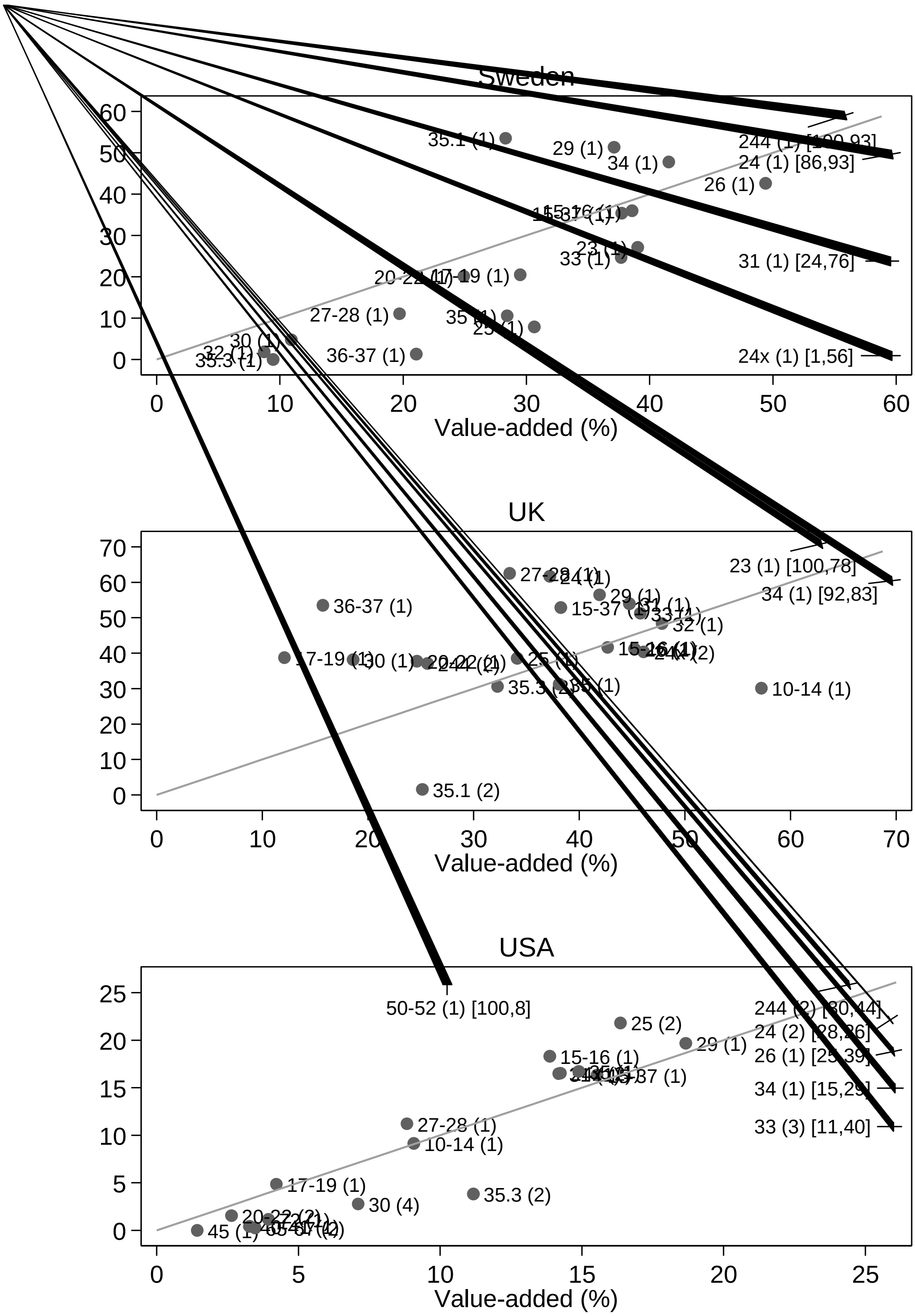
Figure 74: R&D and value added shares of foreign affiliates – a country perspective (2004-207) – Portugal, Slovakia and Spain



Notes: for Portugal and Slovakia: the share of value added for 32 was rescaled to 100; for Slovakia: the share of R&D for 15-16 and 27-28 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

Figure 75: R&D and value added shares of foreign affiliates – a country perspective (2004-207) – Sweden, the UK and the US

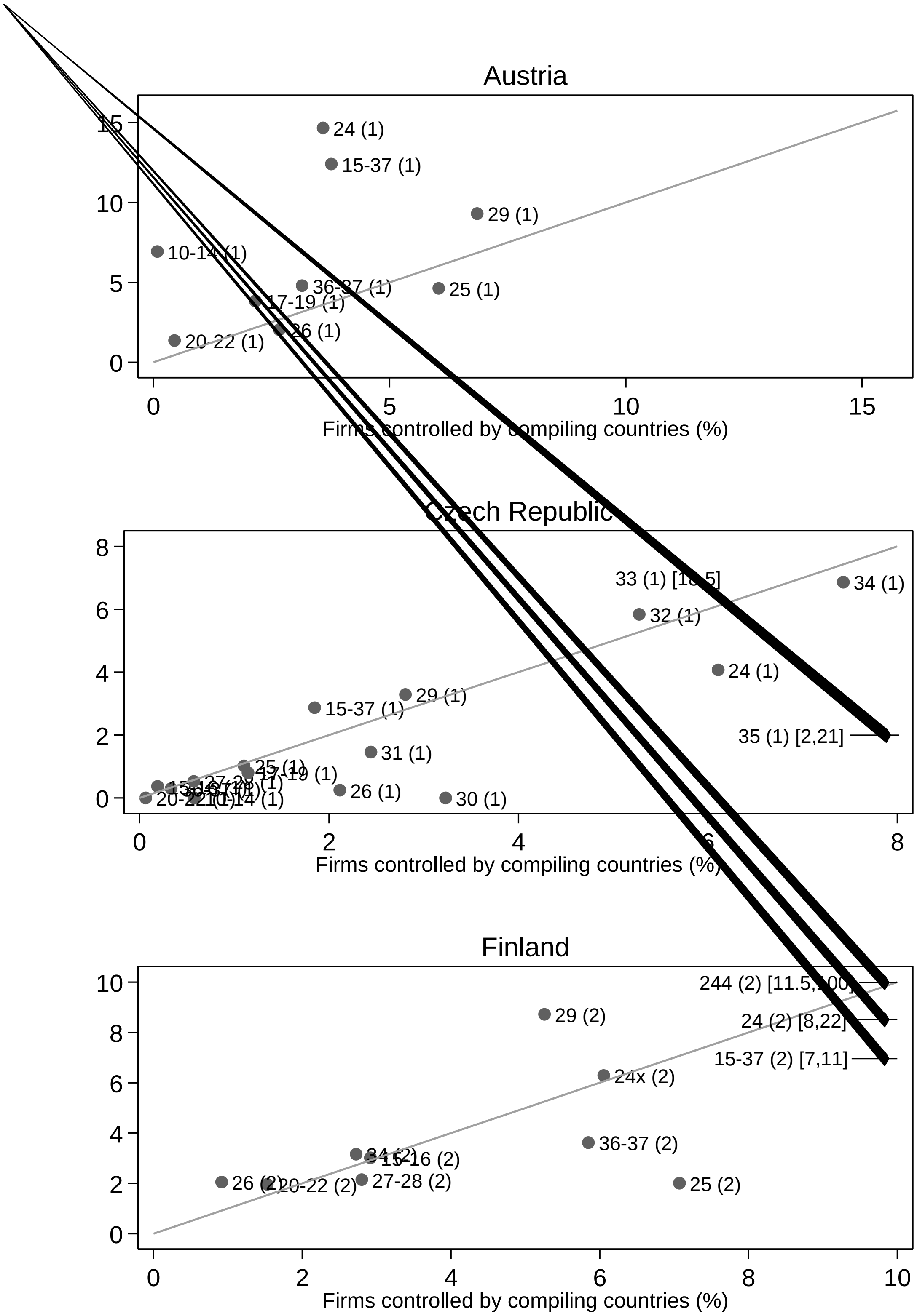


Notes: for the UK: the share of R&D for 32 was rescaled to 100; for the USA: the share of R&D for 50-52 was rescaled to 100

(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

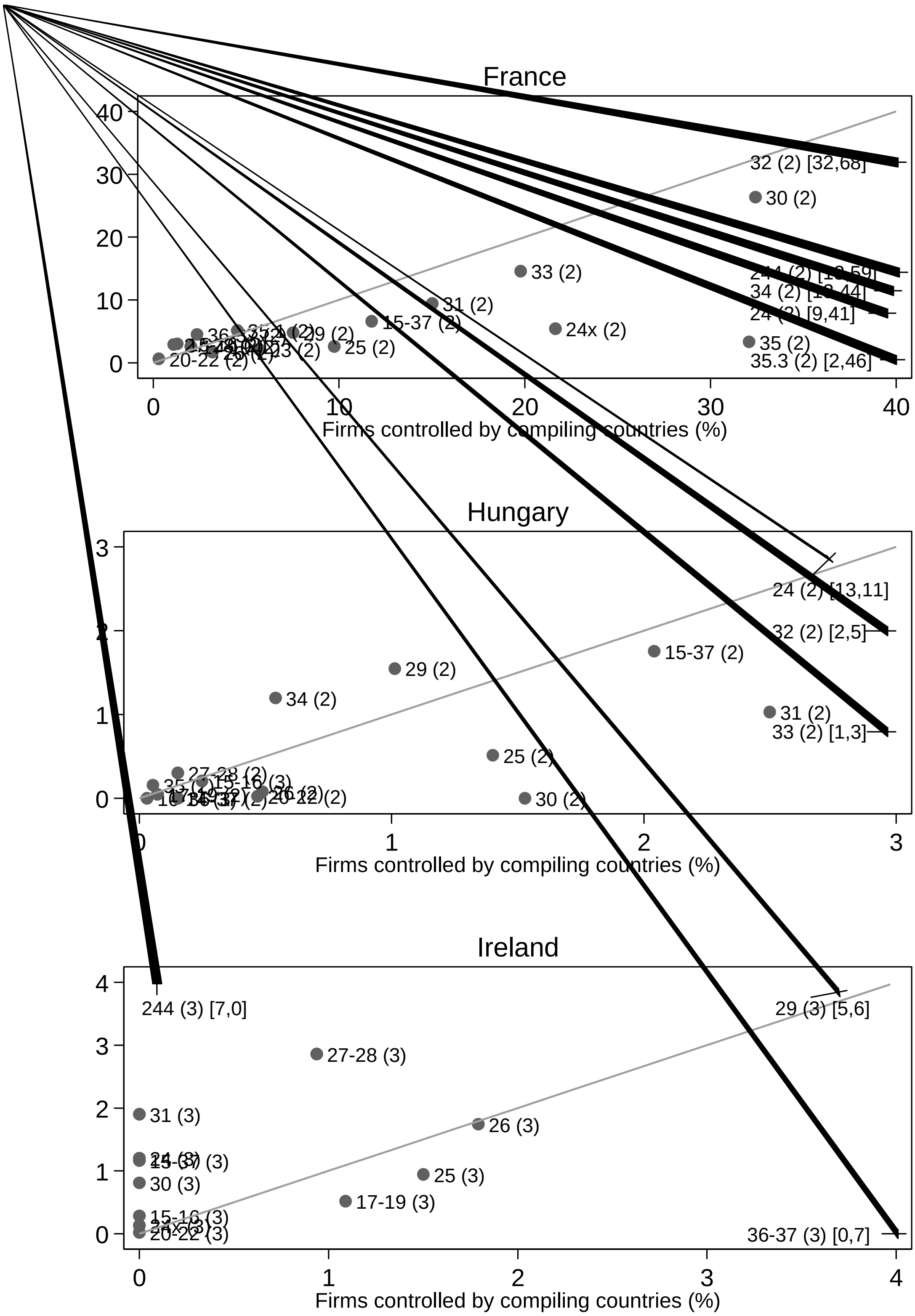
Figure 76: R&D intensities – a country perspective (2004-2007) – Austria, the Czech Republic and Finland



Notes: for Finland: the R&D intensity of domestic firms in 244 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

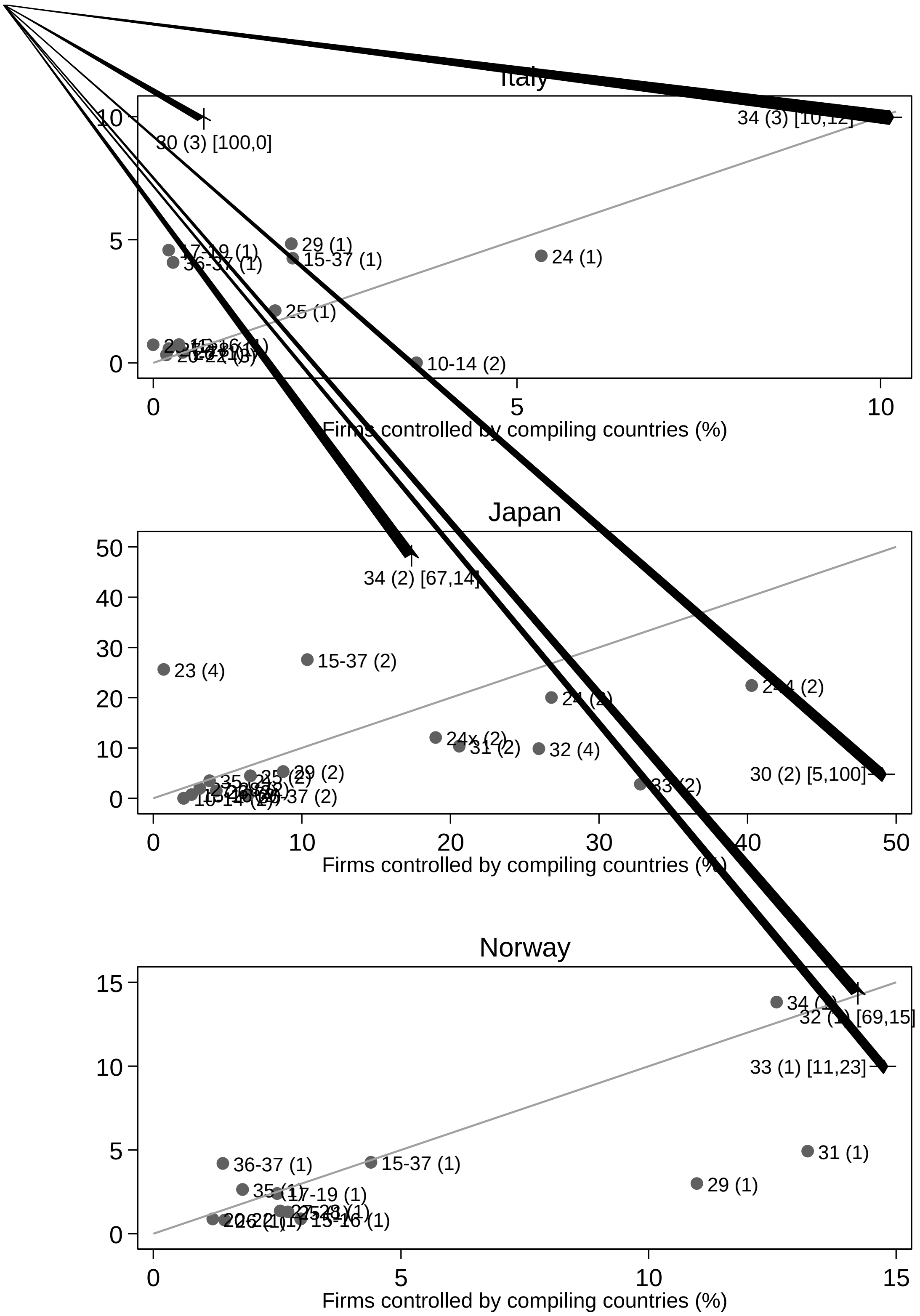
Figure 77: R&D intensities – a country perspective (2004-2007) – France, Hungary and Ireland



Notes: for Ireland: the R&D share of foreign firms in 15-37, 15-16, 244, 30 and 31 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

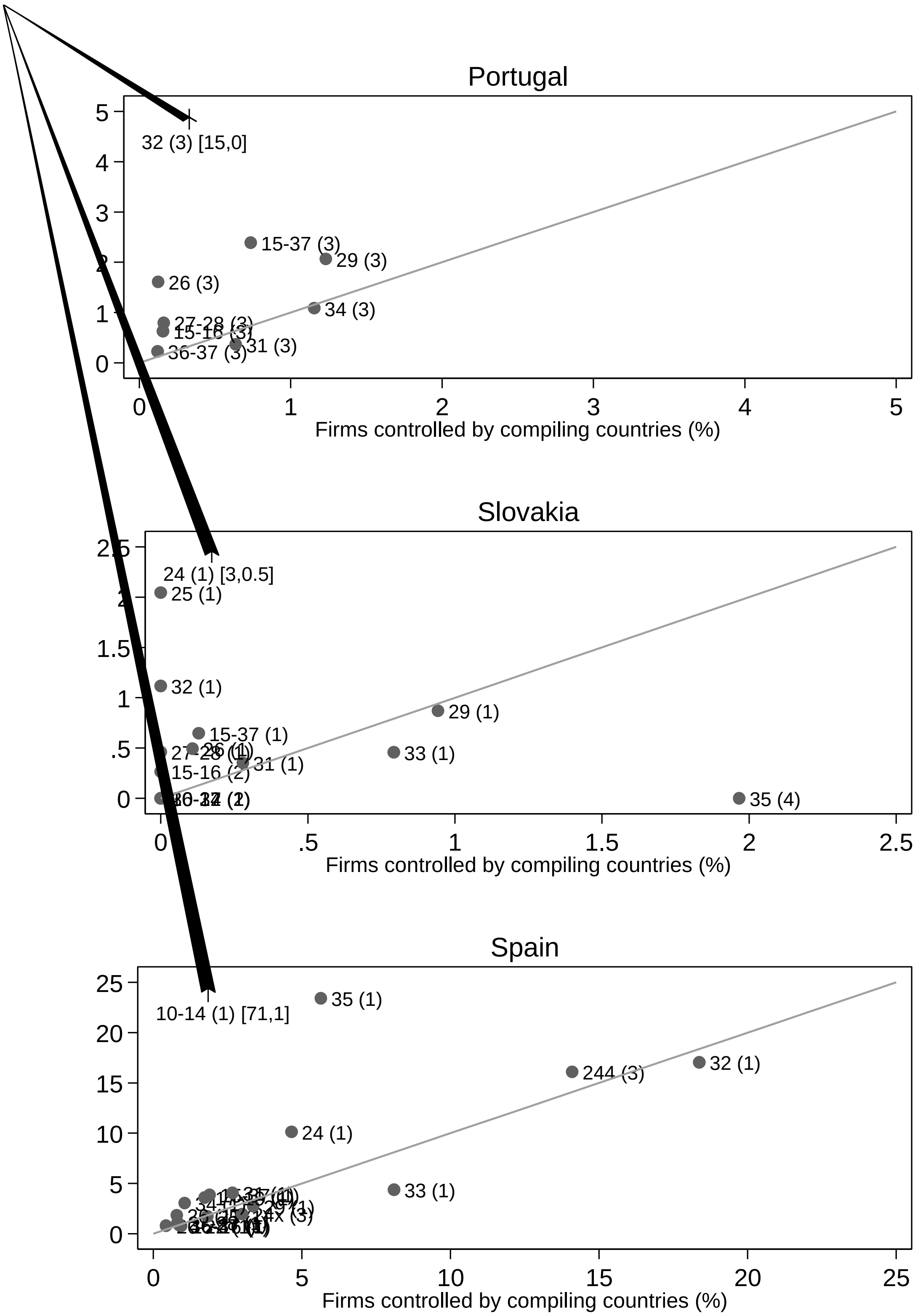
Figure 78: R&D intensities – a country perspective (2004-2007) – Italy, Japan and Norway



Notes: for Italy: the R&D share of foreign firms in 30 was rescaled to 100; for Japan: the R&D share of domestic firms in 30 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

Figure 79: R&D intensities – a country perspective (2004-2007) – Portugal, Slovakia and Spain

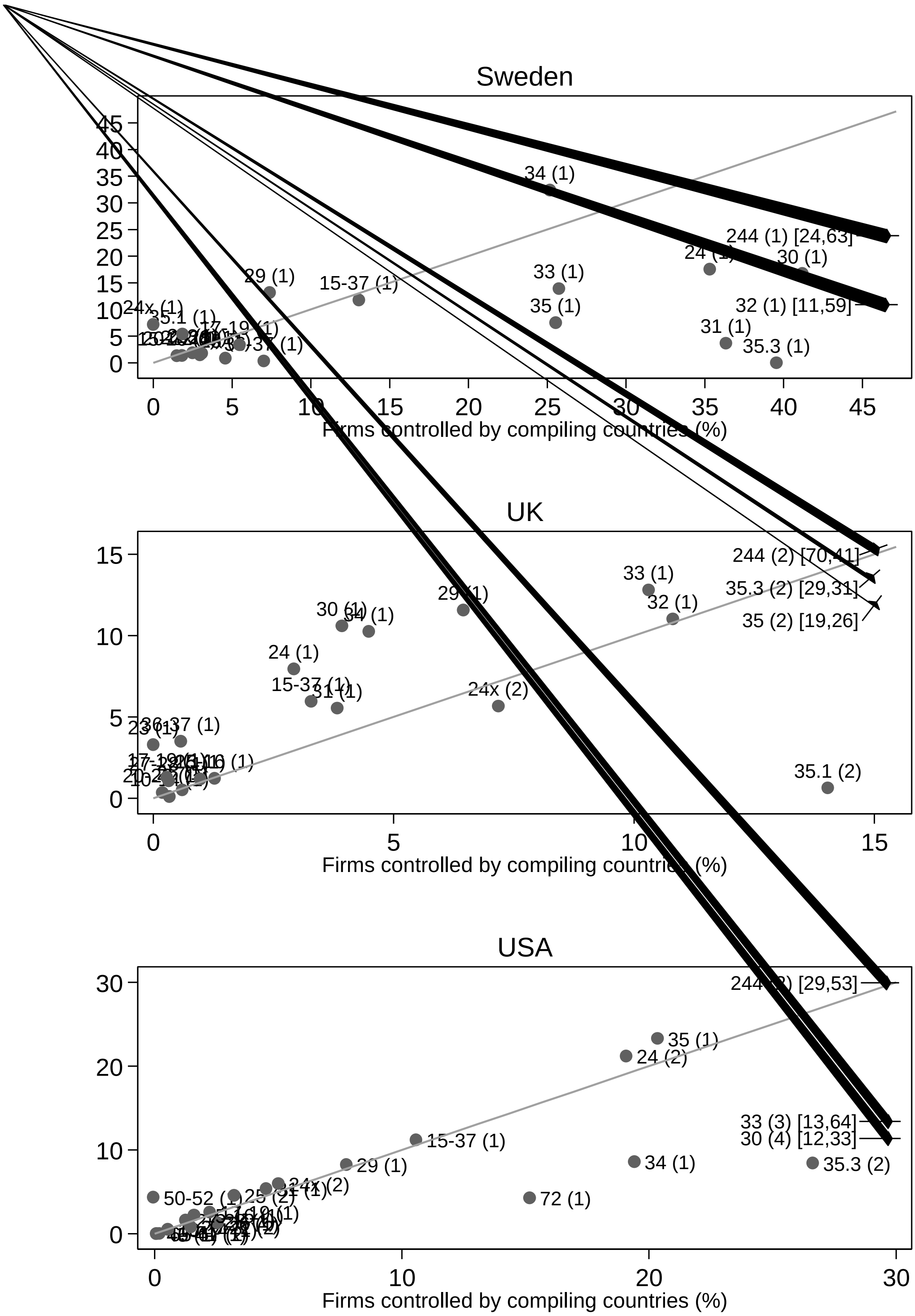


Notes: for Portugal: the R&D share of domestic firms in 32 rescaled to 0; for Slovakia: the R&D share of domestic firms in 25, 27-28 and 32 rescaled to 0

(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

Figure 80: R&D intensities – a country perspective (2004-2007) – Sweden, the UK and the US



Notes: for Sweden: the R&D share of domestic firms in 24x was rescaled to 0; for the UK: the R&D intensity of domestic firms in 23 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 43: Results for host country determinants of R&D internationalisation (2004-2007) – and alternative specification

Dep.Var.: log inward R&D expenditure	OVERALL	EU	EU-15	EU-12
Variables	(1)	(2)	(3)	(4)
Constant	-12.504***	-12.416***	-9.661***	-12.297
	(7.38)	(5.68)	(3.69)	(1.11)
Country level				
Log real GDP	1.001***	1.076***	0.796***	0.587
	(9.16)	(6.65)	(4.53)	(0.48)
Share of tertiary graduates	1.448	1.233	-0.084	11.128***
	(1.06)	(0.91)	(0.05)	(2.80)
Share of GBAORD in real GDP	1.786***	1.087*	0.278	4.494**
	(3.35)	(1.93)	(0.32)	(2.00)
Sector level				
Labour cost over value added	0.000	-0.003	0.033***	-0.029**
	(0.06)	(0.30)	(3.11)	(2.15)
FDI intensity	0.020***	0.018***	0.017***	0.092***
	(4.17)	(3.70)	(3.35)	(4.70)
Value added share of foreign affiliates	0.016***	0.014***	0.014***	0.011*
	(4.57)	(3.88)	(3.28)	(1.78)
Size	0.066	0.184*	0.151	0.000
	(0.64)	(1.75)	(0.98)	(0.00)
Dummy: EU15	0.405			
	(1.19)			
Dummy: EU12	0.000	-0.211		
	0.00	(0.47)		
No of observations	253	202	121	81
Adj. R^2	0.603	0.546	0.301	0.560

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

All regressions are based on pooled OLS 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.

Correlation matrices - cross country analysis

Table 44: Correlation matrix for host country determinants of R&D internationalisation – whole sample

	RGDP	GRAD_T	GBAORD_SH	LCVA	FDI_INT	RD_INT	SIZE
RGDP	1						
GRAD_T	-0.010	1					
GBAORD_SH	0.157	-0.361	1				
LCVA	0.241	0.018	0.149	1			
FDI_INT	-0.133	-0.040	-0.003	-0.160	1		
RD_INT	0.345	0.110	0.097	0.261	0.168	1	
SIZE	-0.253	0.013	0.006	-0.204	-0.109	-0.413	1

Table 45: Correlation matrix for host country determinants of R&D internationalisation – EU countries only

	RGDP	GRAD_T	GBAORD_SH	LCVA	FDI_INT	RD_INT	SIZE
RGDP	1						
GRAD_T	0.362	1					
GBAORD_SH	-0.065	-0.315	1				
LCVA	0.283	0.098	0.087	1			
FDI_INT	-0.063	-0.116	-0.015	-0.203	1		
RD_INT	0.312	0.261	0.057	0.152	0.222	1	
SIZE	-0.209	-0.064	0.102	-0.174	-0.120	-0.376	1

Table 46: Correlation matrix for host country determinants of R&D internationalisation – EU-15

	RGDP	GRAD_T	GBAORD_SH	LCVA	FDI_INT	RD_INT	SIZE
RGDP	1						
GRAD_T	0.193	1					
GBAORD_SH	-0.170	0.075	1				
LCVA	0.299	0.190	-0.075	1			
FDI_INT	-0.127	-0.101	-0.043	-0.232	1		
RD_INT	0.092	0.261	0.076	0.095	0.263	1	
SIZE	-0.262	-0.040	-0.010	-0.066	-0.235	-0.435	1

Table 47: Correlation matrix for host country determinants of R&D internationalisation – EU-12

	RGDP	GRAD_T	GBAORD_SH	LCVA	FDI_INT	RD_INT	SIZE
RGDP	1						
GRAD_T	-0.296	1					
GBAORD_SH	0.885	-0.633	1				
LCVA	0.213	-0.095	0.206	1			
FDI_INT	-0.031	-0.231	0.027	-0.367	1		
RD_INT	0.280	-0.118	0.260	0.180	0.001	1	
SIZE	0.169	0.051	0.130	-0.181	0.093	-0.300	1

Descriptive statistics - cross country analysis

Table 48: Descriptive statistics for host country determinants of R&D internationalisation – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	229	3.728	2.282	-2.303	9.235
Log real GDP	229	13.150	1.780	10.522	16.146
Share of tertiary graduates	229	0.291	0.085	0.167	0.446
Share of GBAORD in RGDP	229	0.803	0.198	0.341	1.102
Labour cost over VA (ULC)	229	59.213	14.560	23.782	127.793
FDI intensity	229	18.169	19.733	0.058	254.021
R&D intensity	229	8.519	13.041	0	69.062
Size	229	1.280	0.979	0.028	4.686
Dummy: EU15	229	0.463	0.500	0	1
Dummy: EU12	229	0.328	0.470	0	1

Table 49: Descriptive statistics for host country determinants of R&D internationalisation – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	181	3.336	2.088	-2.303	7.843
Log real GDP	181	12.597	1.399	10.522	14.505
Share of tertiary graduates	181	0.310	0.087	0.167	0.446
Share of GBAORD in RGDP	181	0.779	0.197	0.341	1.102
Labour cost over VA (ULC)	181	57.842	13.125	23.782	85.208
FDI intensity	181	19.908	21.243	0.208	254.021
R&D intensity	181	7.165	12.064	0	68.478
Size	181	1.359	1.039	0.028	4.686
Dummy: EU15	181	0.586	0.494	0	1
Dummy: EU12	181	0.414	0.494	0	1

Table 50: Descriptive statistics for host country determinants of R&D internationalisation – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	106	4.353	1.646	1.076	7.843
Log real GDP	106	13.630	0.820	11.921	14.505
Share of tertiary graduates	106	0.337	0.086	0.209	0.446
Share of GBAORD in RGDP	106	0.751	0.156	0.486	0.979
Labour cost over VA (ULC)	106	62.146	11.916	23.782	85.208
FDI intensity	106	19.516	26.788	0.208	254.021
R&D intensity	106	9.931	14.387	0	68.478
Size	106	1.190	0.916	0.028	3.773

Table 51: Descriptive statistics for host country determinants of R&D internationalisation – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	75	1.899	1.786	-2.303	5.619
Log real GDP	75	11.138	0.347	10.522	11.584
Share of tertiary graduates	75	0.271	0.074	0.167	0.409
Share of GBAORD in RGDP	75	0.819	0.239	0.341	1.102
Labour cost over VA (ULC)	75	51.760	12.391	30.371	79.309
FDI intensity	75	20.463	8.884	2.010	53.115
R&D intensity	75	3.256	5.819	0	39.212
Size	75	1.598	1.156	0.183	4.686

Correlation matrices – cross country analysis (alternative specification)

Table 52: Correlation matrix for alternative host country determinants of R&D internationalisation – whole sample

	RGDP	GRAD_T	GBAORD_ SH	LCVA	FDI_INT	VA_SH	SIZE
RGDP	1						
GRAD_T	-0.063	1					
GBAORD_SH	0.277	-0.400	1				
LCVA	0.175	-0.086	0.201	1			
FDI_INT	-0.133	0.002	-0.098	-0.163	1		
VA_SH	-0.308	0.239	-0.310	-0.196	0.288	1	
SIZE	-0.269	0.019	-0.026	-0.154	-0.078	-0.032	1

Table 53: Correlation matrix for alternative host country determinants of R&D internationalisation – EU countries only

	RGDP	GRAD_T	GBAORD_ SH	LCVA	FDI_INT	VA_SH	SIZE
RGDP	1						
GRAD_T	0.296	1					
GBAORD_SH	0.043	-0.322	1				
LCVA	0.275	-0.069	0.182	1			
FDI_INT	-0.056	-0.078	-0.084	-0.217	1		
VA_SH	-0.192	0.142	-0.286	-0.238	0.247	1	
SIZE	-0.218	-0.052	0.068	-0.186	-0.094	-0.063	1

Table 54: Correlation matrix for alternative host country determinants of R&D internationalisation - EU-15

	RGDP	GRAD_T	GBAORD_ SH	LCVA	FDI_INT	VA_SH	SIZE
RGDP	1						
GRAD_T	0.116	1					
GBAORD_SH	0.133	-0.044	1				
LCVA	0.330	-0.143	0.207	1			
FDI_INT	-0.253	-0.097	-0.147	-0.253	1		
VA_SH	-0.304	0.243	-0.558	-0.360	0.256	1	
SIZE	-0.221	0.027	-0.089	-0.117	-0.156	-0.083	1

Table 55: Correlation matrix for alternative host country specification of R&D internationalisation – EU-12

	RGDP	GRAD_T	GBAORD_ SH	LCVA	FDI_INT	VA_SH	SIZE
RGDP	1						
GRAD_T	-0.384	1					
GBAORD_SH	0.893	-0.695	1				
LCVA	0.222	-0.114	0.207	1			
FDI_INT	0.056	-0.278	0.125	-0.379	1		
VA_SH	0.251	-0.122	0.197	0.048	0.253	1	
SIZE	0.183	-0.011	0.162	-0.206	0.179	-0.093	1

Descriptive statistics – cross country analysis (alternative specification)

Table 56: Descriptive statistics for alternative host country determinants of R&D internationalisation – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	253	3.752	2.310	-2.303	9.359
Log real GDP	253	13.169	1.785	10.522	16.146
Share of tertiary graduates	253	0.299	0.088	0.167	0.488
Share of GBAORD in RGDP	253	0.787	0.204	0.341	1.102
Labour cost over VA (ULC)	253	58.858	15.101	14.669	127.793
FDI intensity	253	18.511	21.127	0.058	254.021
Value added share	253	37.806	31.621	0.362	324.207
Size	253	1.251	0.965	0.026	4.686
Dummy: EU15	253	0.478	0.501	0	1
Dummy: EU12	253	0.320	0.467	0	1

Table 57: Descriptive statistics for alternative host country determinants of R&D internationalisation – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	202	3.369	2.126	-2.303	7.843
Log real GDP	202	12.636	1.426	10.522	14.505
Share of tertiary graduates	202	0.318	0.088	0.167	0.488
Share of GBAORD in RGDP	202	0.759	0.201	0.341	1.102
Labour cost over VA (ULC)	202	57.609	14.004	14.669	90.858
FDI intensity	202	20.071	22.731	0.208	254.021
Value added share	202	43.200	32.758	3.866	324.207
Size	202	1.320	1.022	0.026	4.686
Dummy: EU15	202	0.599	0.491	0	1
Dummy: EU12	202	0.401	0.491	0	1

Table 58: Descriptive statistics for alternative host country determinants of R&D internationalisation – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	121	4.427	1.617	1.076	7.843
Log real GDP	121	13.657	0.835	11.921	14.505
Share of tertiary graduates	121	0.346	0.085	0.209	0.488
Share of GBAORD in RGDP	121	0.733	0.159	0.372	0.979
Labour cost over VA (ULC)	121	61.553	13.351	14.669	85.208
FDI intensity	121	20.071	28.501	0.208	254.021
Value added share	121	36.515	36.329	3.866	324.207
Size	121	1.158	0.899	0.026	3.773

Table 59: Descriptive statistics for alternative host country determinants of R&D internationalisation – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log inward R&D	81	1.787	1.790	-2.303	5.619
Log real GDP	81	11.109	0.355	10.522	11.584
Share of tertiary graduates	81	0.276	0.075	0.167	0.409
Share of GBAORD in RGDP	81	0.798	0.247	0.341	1.102
Labour cost over VA (ULC)	81	51.717	12.910	30.371	90.858
FDI intensity	81	20.072	8.934	0.918	53.115
Value added share	81	53.187	23.407	21.298	130.207
Size	81	1.561	1.146	0.175	4.686

Gravity analysis

Table 60: Correlation matrix for host and home country determinants of R&D internationalisation – a simple model

	Log DIST	COMLANG	COMBORD	Log RGDP HOST	Log RGDP HOME	Log POP HOST	Log POP HOME
Log DIST	1						
COMLANG	0.024	1					
COMBORD	-0.415	0.196	1				
Log RGDP HOST	0.168	0.096	0.008	1			
Log RGDP HOME	0.235	0.074	0.025	-0.016	1		
Log POP HOST	0.133	0.031	0.029	0.885	-0.016	1	
Log POP HOME	0.306	0.009	-0.002	-0.013	0.780	-0.015	1

Table 61: Correlation matrix for host and home country determinants of R&D internationalisation – an extended model

	Log DIST	COMLANG	COMBORD	Log RGDP HOST	Log RGDP HOME	Log POP HOST	Log POP HOME	ENR_TER HOST	ENR_TER HOME	PA_SH HOST	PA_SH HOME	HTX_SH HOST	HTX_SH HOME	TDIST
Log DIST	1													
COMLANG	-0.064	1												
COMBORD	-0.432	0.255	1											
Log RGDP HOST	0.259	0.093	-0.037	1										
Log RGDP HOME	0.341	0.094	-0.038	-0.027	1									
Log POP HOST	0.213	0.029	-0.001	0.863	-0.024	1								
Log POP HOME	0.384	0.039	-0.035	-0.020	0.830	-0.0216	1							
ENR_TER HOST	0.152	-0.040	-0.043	0.234	-0.007	0.1132	0.0047	1						
ENR_TER HOME	-0.079	-0.048	0.000	-0.006	0.079	0.0105	-0.2222	0.0436	1					
PA_SH HOST	-0.049	-0.034	0.013	0.080	-0.001	0.0512	0.0037	0.336	0.0581	1				
PA_SH HOME	-0.112	-0.036	0.029	-0.002	0.088	0.0101	-0.0432	0.0556	0.4155	0.044	1			
HTX_SH HOST	-0.031	0.089	-0.020	-0.149	0.006	-0.2482	0.0036	-0.0682	-0.0155	-0.011	-0.012	1		
HTX_SH HOME	-0.050	0.078	-0.008	0.006	-0.045	0.0038	-0.1549	-0.0111	0.0346	-0.005	0.056	-0.020	1	
TDIST	0.009	0.167	0.061	0.277	0.336	0.2283	0.2222	0.2019	0.1623	0.079	0.111	0.033	0.068	1

Table 62: Descriptive statistics for host and home country determinants of R&D internationalisation – an extended model

Variable	Obs	Mean	Std. Dev.	Min	Max
Log RDij	910	2.252	2.871	-4.605	8.775
Log distance	910	7.380	1.094	4.088	9.320
Common language	910	0.089	0.285	0.000	1.000
Common border	910	0.129	0.335	0.000	1.000
Log RGDP HOST	910	12.298	1.676	8.727	16.228
Log RGDP HOME	910	12.944	1.580	9.041	16.228
Log population HOST	910	16.615	1.245	14.108	19.526
Log population HOME	910	16.759	1.563	12.601	21.001
Tertiary enrolment rate HOST	910	61.425	13.027	24.500	93.800
Tertiary enrolment rate HOME	910	62.587	16.533	9.940	96.100
Share patent applications residents HOST	910	495.287	405.310	3.082	2391.667
Share patent applications residents HOME	910	485.970	361.089	3.550	2875.000
Share high-tech exports HOST	910	4.464	3.331	0.244	16.188
Share high-tech exports HOME	910	4.835	3.728	0.142	32.762
Technology distance	910	0.644	0.170	0.102	0.935

APPENDIX 4 DRIVERS OF R&D INTERNATIONALISATION (CAST STUDIES)

Selected project profiles

May 2011 - Daimler AG (Germany) - Automotive OEM investment in China

German automobile manufacturer Mercedes-Benz is to expand its research and development team in China to further strengthen its R&D capabilities in the country. The company plans to expand the team to around 500 engineers.

March 2011 - Alstom (France) - Industrial Machinery, Equipment & Tools investment in China

Alstom Grid, a subsidiary of France-based Alstom, has opened a new technology centre in Shanghai, China. The facility, located in the Caoheijing Pujiang High-Tech Park, will be used to research, develop and test ultra high voltage alternating and direct current transmission equipment.

November 2010 - picoChip (UK) - Software & IT services investment in China

picoChip Designs, a UK-based supplier of semiconductors and software for femtocells, has announced plans to double the size of its development centre in Beijing, China.

April 2011 - Nokia (Finland) - Communications investment in China

Finland-based Nokia is to enlarge its R&D team in Beijing, China. The Beijing team will become the development team for the Nokia series 30 and series 40 mobile handsets. The team will be enlarged by October 2012.

May 2011 - Sony Ericsson (Sweden) - Communications investment in China

Joint venture company Sony Ericsson is increasing its investment in its Beijing R&D centre, in China. The company will start the operation of its new building from July 2011 and boost its R&D employees from 2000 to 3000 people. In the future, more than 50% of the development of products and solutions will be carried out in the country.

April 2011 - NXP Semiconductors (Netherlands) - Semiconductors investment in China

Netherlands-based semiconductor components manufacturer NXP has established a new China Automotive Technical Centre in Shanghai to focus on R&D, system innovation, and customer application support. The new facility will act as a regional hub for technical excellence in automotive systems and applications.

October 2010 - Vestas Wind Systems (Denmark) - Engines & Turbines investment in China

Denmark-based wind energy company Vestas has opened a new research and development centre in Beijing, China. The centre will focus on high voltage engineering, aerodynamics, material development and software development. The company will invest $50m into the centre until 2015 and employ 200 engineers by 2012. The centre is the first of its kind to be opened by an international investor in the country.

Source: FDI Intelligence from Financial Times Ltd (fDi Markets database), Project Profiles

Table 63: Inward and outward BERD to China

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	av. growth 2003-07, %
Outward BERD to China, billion EUR[1)]												
Japan				0.037	0.053	0.073	0.101	0.110				31.3
USA	0.548	n.a.*)	0.682	0.499	0.462	0.537	0.604	0.856	1.031			14.4
Sweden		0.034		0.061		0.083		0.133				21.3
Italy				0.0003								
aggregated	0.548	0.034	0.682	0.598	0.515	0.693	0.706	1.099	1.031			16.4
as % of total outward BERD of the respective country												
Japan				1.6	2.3	3.2	4,18	5.2				
USA	2.5	n.a.*)	3.1	2.5	2.2	2.4	2.6	3.4	4.1			
Sweden		1.2		2.7		3.2		4.0				
Italy				0.1								
Inward BERD China, billion RMB												av. growth
R&D expenditure of all business enterprises in China												2004-08, %
R&D expenditure of all business enterprises(domestic and foreign)[2)]	53.7	63.0	78.8	96.0	131.4	167.4	213.5	267.9	338.2	4248.6		26.7
Industrial enterprises above designated size [3)]												
Intramural expenditure on R&D of all enterprises					110.5				307.3	377.7		29.2
Intramural expenditure on R&D of domestic enterprises					80.5				224.9			
Intramural expenditure on R&D of foreign-owned enterprises [4)]					30.0				82.4	99.7		28.8
Large and medium-sized industrial enterprises [5)]												
Intramural expenditure on R&D of all enterprises	35.3	44.2	56.0	72.1	95.5	125.0	163.0	211.3	268.1	321.2	401.5	29.5
Intramural expenditure on R&D of domestic enterprises					69.7		118.6	149.7	195.2	234.5	296.7	29.4
Intramural expenditure on R&D of foreign-owned enterprises [6)]					25.8		44.4	61.5	72.9	86.7	104.8	29.7
Enterprises with funds from HK, Macao and Taiwan [7)]					7.4		14.6	18.3	22.4	31.2	35.7	31.7
out of this: wholly foreign-owned					3.2		7.0	8.1	10.2	14.2	16.0	33.6
Foreign Funded Enterprises [7)]					18.3		29.9	43.2	50.6	55.4	69.1	28.9
out of this: wholly foreign-owned					5.9		11.0	14.7	16.5	20.3	26.5	29.2
Intramural expenditure on R&D of all *wholly foreign-owned* enterprises					9.1		18.0	22.8	26.7	34.6	42.5	30.8
Intramural expenditure on R&D of foreign-owned enterprises as % of all enterprises					27.0		27.3	29.1	27.2	27.0	26.1	
Exchange rate RMB/EUR, annual average [8)]			8.01	9.36	10.29	10.20	10.02	10.42	10.22	9.53	8.98	

Note: * withheld to avoid disclosing operations of individual companies (UNCTAD, 2005, p. 129.

Sources: 1) OECD, AIT calculations.- 2) China Statistic Yearbook on S&T (MOST), OECD.- 3) annual business revenue from principal activity of five million RMB (about 500 million euro) and above ; China Statistic Yearbook on S&T (MOST); data for 2004 identical with industrial census 2004, enterprises above a designated size, China Economic Census Yearbook 2004, Secondary Industry, p.180.- 4) Foreign funded enterprises plus enterprises with funds from Hong Kong, Macao and Taiwan.- 5) China Statistical Yearbook, Basic Statistics on Science and Technology Activities of Large and Medium-sized Industrial Enterprises and Basic Statistics on R&D Activities of Large and Medium-sized Industrial Enterprises by Registration Status; 2004: China Economic Census Yearbook 2004, Secondary Industry, medium and large enterprises, p.195.- 6) Comprises enterprises with funds from Hong Kong, Macao and Taiwan plus foreign funded enterprises.- 7) Joint Ventures, cooperative enterprises, wholly foreign-owned enterprises and share-holding corporations.- 8) China Statistical Yearbook 2010, Table 6-2.

Correlation matrices – impacts on host country (R&D levels)

Table 64: Correlation matrix for the impact on the scale of R&D expenditure– overall sample

	LnFORRD	Size	Gr size	Openness	GR RGDP pc	Cont MHT	GBAORD in RGDP
LnFORRD	1						
Size	-0.135	1					
Gr size	-0.058	0.107	1				
Openness	-0.064	-0.236	0.103	1			
GR RGDP pc	-0.363	0.219	0.162	0.012	1		
Cont MHT	0.152	-0.015	-0.020	-0.123	-0.274	1	
GBAORD in RGDP	0.076	0.105	-0.009	-0.126	0.119	-0.123	1

Table 65: Correlation matrix for the impact on the scale of R&D expenditure – EU countries only

	LnFORRD	Size	Gr size	Openness	GR RGDP pc	Cont MHT	GBAORD in RGDP
LnFORRD	1						
Size	-0.117	1					
Gr size	-0.074	0.104	1				
Openness	-0.029	-0.248	0.119	1			
GR RGDP pc	-0.376	0.208	0.189	-0.039	1		
Cont MHT	0.330	0.000	-0.049	-0.056	-0.029	1	
GBAORD in RGDP	-0.046	0.173	0.003	-0.144	0.190	0.069	1

Table 66: Correlation matrix for the impact on the scale of R&D expenditure – EU-15

	LnFORRD	Size	Gr size	Openness	GR RGDP pc	Cont MHT	GBAORD in RGDP
LnFORRD	1						
Size	0.007	1					
Gr size	0.017	0.030	1				
Openness	-0.098	-0.272	0.219	1			
GR RGDP pc	-0.011	-0.030	0.000	0.026	1		
Cont MHT	0.429	-0.069	-0.107	-0.041	-0.107	1	
GBAORD in RGDP	0.063	0.096	0.017	-0.173	-0.292	-0.084	1

Table 67: Correlation matrix for the impact on the scale of R&D expenditure – EU-12

	LnFORRD	Size	Gr size	Openness	GR RGDP pc	Cont MHT	GBAORD in RGDP
LnFORRD	1						
Size	0.128	1					
Gr size	0.155	0.054	1				
Openness	-0.008	-0.341	-0.118	1			
GR RGDP pc	0.043	0.037	0.051	0.042	1		
Cont MHT	0.414	0.114	0.016	-0.274	-0.108	1	
GBAORD RGDP	0.246	0.113	-0.149	-0.069	0.103	0.347	1

Descriptive statistics – impacts on host country (R&D level)

Table 68: Descriptive statistics for the impact on the scale of R&D expenditure – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMRD	614	4.058	2.581	-6.215	10.191
Log FORRD	614	3.029	2.352	-2.526	9.235
Size	614	1.146	0.890	0.008	5.099
Size growth	614	-1.231	5.857	-31.213	30.432
Openness	614	179.288	371.634	9.962	4551.289
Real GDP per capita growth	614	3.023	4.008	-6.675	18.396
Contribution MHT to manuf	614	2.080	4.319	-5.507	15.255
Share of GBAORD in RGDP	614	0.714	0.194	0.341	1.102

Table 69: Descriptive statistics for the impact on the scale of R&D expenditure – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMRD	523	3.505	2.216	-6.215	9.351
Log FORRD	523	2.889	2.256	-2.303	7.843
Size	523	1.192	0.921	0.015	5.099
Size growth	523	-1.274	6.099	-31.213	30.432
Openness	523	192.441	378.779	23.041	4551.289
Real GDP per capita growth	523	3.690	3.783	-2.570	18.396
Contribution MHT to manuf	523	1.117	2.397	-5.507	7.244
Share of GBAORD in RGDP	523	0.706	0.189	0.341	1.102

Table 70: Descriptive statistics for the impact on the scale of R&D expenditure – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMRD	368	4.419	1.697	-0.511	9.351
Log FORRD	368	3.661	1.921	-2.303	7.843
Size	368	1.039	0.826	0.015	5.099
Size growth	368	-2.100	5.145	-31.213	30.432
Openness	368	206.801	446.298	23.041	4551.289
Real GDP per capita growth	368	2.036	1.093	-0.351	4.895
Contribution MHT to manuf	368	1.015	2.533	-5.507	7.244
Share of GBAORD in RGDP	368	0.661	0.161	0.372	0.979

Table 71: Descriptive statistics for the impact on the scale of R&D expenditure – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMRD	155	1.334	1.743	-6.215	4.665
Log FORRD	155	1.057	1.911	-2.303	5.619
Size	155	1.554	1.029	0.061	4.957
Size growth	155	0.689	7.583	-22.701	24.192
Openness	155	158.347	99.912	27.167	796.599
Real GDP per capita growth	155	7.616	4.858	-2.570	18.396
Contribution MHT to manuf	155	1.359	2.024	-4.575	3.711
Share of GBAORD in RGDP	155	0.812	0.206	0.341	1.102

Correlation matrices – impacts on host country (R&D intensities)

Table 72: Correlation matrix for the impact on domestic R&D intensities – overall sample

	R&D intf	Size	Gr size	Openness	GR RGDP pc	Cont MHT
R&D intf	1					
Size	-0.110	1				
Gr size	0.029	0.119	1			
Openness	0.055	-0.258	-0.102	1		
GR RGDP pc	-0.119	0.158	0.161	0.240	1	
Cont MHT	0.011	-0.020	-0.023	-0.152	-0.099	1

Table 73: Correlation matrix for the impact on domestic R&D intensities – EU countries only

	R&D intf	Size	Gr size	Openness	GR RGDP pc	Cont MHT
R&D intf	1					
Size	-0.112	1				
Gr size	0.035	0.119	1			
Openness	0.058	-0.279	-0.108	1		
GR RGDP pc	-0.118	0.141	0.191	0.215	1	
Cont MHT	-0.021	0.051	0.017	-0.011	0.238	1

Table 74: Correlation matrix for the impact on domestic R&D intensities – EU-15

	R&D intf	Size	Gr size	Openness	GR RGDP pc	Cont MHT
R&D intf	1					
Size	-0.124	1				
Gr size	0.081	0.075	1			
Openness	0.109	-0.364	-0.176	1		
GR RGDP pc	-0.132	-0.074	0.033	0.078	1	
Cont MHT	-0.001	-0.148	-0.166	-0.014	-0.011	1

Table 75: Correlation matrix for the impact on domestic R&D intensities – EU-12

	R&D intf	Size	Gr size	Openness	GR RGDP pc	Cont MHT
R&D intf	1					
Size	-0.163	1				
Gr size	0.076	0.109	1			
Openness	0.010	-0.295	-0.107	1		
GR RGDP pc	-0.037	0.010	0.192	0.203	1	
Cont MHT	0.277	0.225	0.136	-0.145	0.117	1

Descriptive statistics – impacts on host country (R&D intensity)

Table 76: Descriptive statistics for the impact on domestic R&D intensities – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Domestic R&D intensity	429	9.479	37.794	0	531.773
Foreign R&D intensity	429	4.967	8.181	0	69.217
Size	429	1.170	0.885	0.028	4.686
Size growth	429	-0.202	5.382	-35.399	23.590
Openness	429	116.038	109.626	13.007	994.021
Real GDP per capita growth	429	3.620	1.828	0.656	10.522
Contribution MHT sectors	429	2.250	4.451	-5.507	15.255

Table 77: Descriptive statistics for the impact on domestic R&D intensities – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Domestic R&D intensity	346	5.578	10.385	0	68.478
Foreign R&D intensity	346	4.055	6.151	0	38.970
Size	346	1.244	0.922	0.028	4.686
Size growth	346	-0.240	5.570	-35.399	23.590
Openness	346	126.532	112.530	23.041	994.021
Real GDP per capita growth	346	3.850	1.951	0.656	10.522
Contribution MHT sectors	346	1.046	1.883	-5.507	3.711

Table 78: Descriptive statistics for the impact on domestic R&D intensities – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Domestic R&D intensity	221	7.300	12.167	0	68.478
Foreign R&D intensity	221	5.218	7.052	0.023	38.970
Size	221	1.093	0.835	0.028	3.773
Size growth	221	-0.647	3.796	-10.782	20.000
Openness	221	113.785	127.741	23.041	994.021
Real GDP per capita growth	221	2.834	1.108	0.656	6.016
Contribution MHT sectors	221	0.559	1.945	-5.507	2.241

Table 79: Descriptive statistics for the impact on domestic R&D intensities – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Domestic R&D intensity	125	2.533	4.774	0	39.212
Foreign R&D intensity	125	1.999	3.222	0	17.761
Size	125	1.510	1.007	0.107	4.686
Size growth	125	0.481	7.741	-35.399	23.590
Openness	125	149.067	74.024	35.241	577.583
Real GDP per capita growth	125	5.646	1.824	3.167	10.522
Contribution MHT sectors	125	1.908	1.408	-0.054	3.711

Correlation matrices – impacts on host country (domestic labour productivity)

Table 80: Correlation matrix for the impact on domestic labour productivity – whole sample

	Log RDf	Size growth	Openness	Investment rate	Log RGDP pc	Share graduates
Log RDf	1					
Size growth	-0.045	1				
Openness	-0.077	0.134	1			
Investment rate	-0.224	0.060	0.181	1		
Log RGDP pc	0.554	-0.126	0.086	-0.283	1	
Share graduates	-0.024	-0.012	-0.095	-0.004	0.148	1

Table 81: Correlation matrix for the impact on domestic labour productivity – EU countries only

	Log RDf	Size growth	Openness	Investment rate	Log RGDP pc	Share graduates
Log RDf	1					
Size growth	-0.039	1				
Openness	-0.038	0.148	1			
Investment rate	-0.214	0.057	0.205	1		
Log RGDP pc	0.547	-0.136	0.102	-0.264	1	
Share graduates	0.014	-0.014	-0.106	-0.024	0.202	1

Table 82: Correlation matrix for the impact on domestic labour productivity – EU-15

	Log RDf	Size growth	Openness	Investment rate	Log RGDP pc	Share graduates
Log RDf	1					
Size growth	0.008	1				
Openness	-0.109	0.242	1			
Investment rate	-0.091	0.013	0.270	1		
Log RGDP pc	0.025	-0.014	0.139	-0.131	1	
Share graduates	-0.076	-0.093	-0.141	-0.016	0.305	1

Table 83: Correlation matrix for the impact on domestic labour productivity – EU-12

	Log RDf	Size growth	Openness	Investment rate	Log RGDP pc	Share graduates
Log RDf	1					
Size growth	0.110	1				
Openness	0.008	-0.004	1			
Investment rate	-0.131	0.049	-0.133	1		
Log RGDP pc	0.210	-0.003	-0.020	-0.115	1	
Share graduates	-0.054	0.129	0.007	0.061	0.041	1

Descriptive statistics – impacts on host country (domestic labour productivity)

Table 84: Descriptive statistics for the impact on domestic labour productivity – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	303	11.542	0.762	9.189	15.237
Log RDf	303	2.490	2.036	-2.303	7.843
Size growth	303	0.268	5.239	-16.880	23.896
Openness	303	130.824	104.450	23.041	973.209
Investment rate	303	5.695	3.041	0.159	22.603
Log real GDP	303	9.653	0.634	8.728	10.609
Share graduates	303	0.143	0.044	0.069	0.240
Dummy: MT	303	0.528	0.500	0	1
Dummy: HT	303	0.135	0.343	0	1

Table 85: Descriptive statistics for the impact on domestic labour productivity – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	290	11.502	0.754	9.189	15.237
Log RDf	290	2.502	2.068	-2.303	7.843
Size growth	290	0.117	5.194	-16.880	23.896
Openness	290	129.250	101.476	23.041	973.209
Investment rate	290	5.751	2.996	0.159	22.603
Log real GDP	290	9.617	0.624	8.728	10.609
Share graduates	290	0.145	0.045	0.069	0.240
Dummy: MT	290	0.528	0.500	0	1
Dummy: HT	290	0.134	0.342	0	1

Table 86: Descriptive statistics for the impact on domestic labour productivity – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	167	11.932	0.587	10.010	15.237
Log RDf	167	3.332	1.825	-2.303	7.843
Size growth	167	-0.679	3.831	-11.084	20.000
Openness	167	114.021	116.154	23.041	973.209
Investment rate	167	4.881	2.528	0.159	22.603
Log real GDP	167	10.098	0.327	9.614	10.609
Share graduates	167	0.156	0.043	0.108	0.240
Dummy: MT	167	0.509	0.501	0	1
Dummy: HT	167	0.102	0.303	0	1

Table 87: Descriptive statistics for the impact on domestic labour productivity – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	123	10.919	0.529	9.189	12.970
Log RDf	123	1.375	1.837	-2.303	5.619
Size growth	123	1.198	6.473	-16.880	23.896
Openness	123	149.926	72.709	35.241	577.583
Investment rate	123	6.932	3.183	0.223	18.065
Log real GDP	123	8.964	0.171	8.728	9.250
Share graduates	123	0.130	0.043	0.069	0.201
Dummy: MT	123	0.553	0.499	0	1
Dummy: HT	123	0.179	0.385	0	1

Correlation matrices – impacts on host country (domestic and foreign labour productivity)

Table 88: Correlation matrix for the impact of foreign labour productivity on domestic labour productivity – whole sample

	Log FORLP	Size growth	Openness	Investment rate	Log RGDP	Share graduates
Log FORLP	1					
Size growth	0.073	1				
Openness	-0.172	-0.077	1			
Investment rate	-0.376	0.120	-0.063	1		
Log RGDP	0.460	-0.115	-0.177	-0.276	1	
Share graduates	0.277	-0.027	0.027	-0.151	0.029	1

Table 89: Correlation matrix for the impact of foreign labour productivity on domestic labour productivity – EU countries only

	Log FORLP	Size growth	Openness	Investment rate	Log RGDP	Share graduates
Log FORLP	1					
Size growth	0.059	1				
Openness	-0.169	-0.082	1			
Investment rate	-0.380	0.132	-0.055	1		
Log RGDP	0.473	-0.111	-0.182	-0.287	1	
Share graduates	0.307	-0.005	0.025	-0.168	0.018	1

Table 90: Correlation matrix for the impact of foreign labour productivity on domestic labour productivity – EU-15

	Log FORLP	Size growth	Openness	Investment rate	Log RGDP	Share graduates
Log FORLP	1					
Size growth	0.105	1				
Openness	-0.071	-0.111	1			
Investment rate	-0.338	0.150	-0.195	1		
Log RGDP	0.029	-0.016	-0.128	0.074	1	
Share graduates	0.210	-0.099	0.012	-0.298	-0.404	1

Table 91: Correlation matrix for the impact of foreign labour productivity on domestic labour productivity – EU-12

	Log FORLP	Size growth	Openness	Investment rate	Log RGDP	Share graduates
Log FORLP	1					
Size growth	0.306	1				
Openness	-0.174	-0.100	1			
Investment rate	-0.122	0.051	-0.051	1		
Log RGDP	-0.024	0.044	-0.187	-0.382	1	
Share graduates	0.069	0.194	0.146	0.189	-0.262	1

Descriptive statistics – impacts on host country (domestic and foreign labour productivity)

Table 92: Descriptive statistics for the impact of foreign labour productivity on domestic labour productivity – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	457	11.664	0.834	9.189	15.520
Log FORLP	457	12.281	0.727	10.221	15.695
Size growth	457	-0.321	5.672	-35.399	23.896
Openness	457	137.787	146.843	21.574	2081.039
Investment rate	457	5.395	3.433	-0.774	33.334
Log RGDP	457	12.297	1.110	10.522	14.505
Share graduates	457	0.148	0.045	0.069	0.240
Dummy: MT	457	0.514	0.500	0	1
Dummy: HT	457	0.149	0.356	0	1

Table 93: Descriptive statistics for the impact of foreign labour productivity on domestic labour productivity – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	435	11.627	0.836	9.189	15.520
Log FORLP	435	12.261	0.735	10.221	15.695
Size growth	435	-0.476	5.643	-35.399	23.896
Openness	435	138.224	147.622	21.574	2081.039
Investment rate	435	5.435	3.429	-0.774	33.334
Log RGDP	435	12.312	1.135	10.522	14.505
Share graduates	435	0.150	0.046	0.069	0.240
Dummy: MT	435	0.510	0.500	0	1
Dummy: HT	435	0.152	0.359	0	1

Table 94: Descriptive statistics for the impact of foreign labour productivity on domestic labour productivity – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	288	11.946	0.646	10.010	15.288
Log FORLP	288	12.581	0.597	11.363	15.695
Size growth	288	-1.062	4.095	-14.329	21.029
Openness	288	123.778	114.752	21.574	973.209
Investment rate	288	4.605	2.529	-0.774	22.603
Log RGDP	288	12.942	0.841	11.921	14.505
Share graduates	288	0.160	0.044	0.096	0.240
Dummy: MT	288	0.517	0.501	0	1
Dummy: HT	288	0.128	0.335	0	1

Table 95: Descriptive statistics for the impact of foreign labour productivity on domestic labour productivity – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMLP	147	11.002	0.815	9.189	15.520
Log FORLP	147	11.635	0.555	10.221	13.310
Size growth	147	0.672	7.727	-35.399	23.896
Openness	147	166.526	194.104	35.241	2081.039
Investment rate	147	7.059	4.286	0.223	33.334
Log RGDP	147	11.078	0.352	10.522	11.584
Share graduates	147	0.131	0.043	0.069	0.201
Dummy: MT	147	0.497	0.502	0	1
Dummy: HT	147	0.197	0.399	0	1

Correlation matrices – impacts on host country (domestic employment)

Table 96: Correlation matrix for the impact on domestic employment – whole sample

	Log RDf	Openness	Investment rate	Real GDP gr	MHT manuf
Log RDf	1				
Openness	-0.070	1			
Investment rate	-0.354	-0.033	1		
Real GDP gr	-0.256	0.067	0.293	1	
MHT manuf	0.374	-0.105	-0.163	-0.056	1

Table 97: Correlation matrix for the impact on domestic employment – EU countries only

	Log RDf	Openness	Investment rate	Real GDP gr	MHT manuf
Log RDf	1				
Openness	-0.006	1			
Investment rate	-0.340	-0.062	1		
Real GDP gr	-0.225	0.040	0.271	1	
MHT manuf	0.352	-0.079	-0.143	-0.028	1

Table 98: Correlation matrix for the impact on domestic employment – EU-15

	Log RDf	Openness	Investment rate	Real GDP gr	MHT manuf
Log RDf	1				
Openness	0.050	1			
Investment rate	-0.093	-0.171	1		
Real GDP gr	0.039	-0.048	-0.069	1	
MHT manuf	0.313	-0.003	-0.099	-0.033	1

Table 99: Correlation matrix for the impact on domestic employment – EU-12

	Log RDf	Openness	Investment rate	Real GDP gr	MHT manuf
Log RDf	1				
Openness	0.182	1			
Investment rate	-0.058	-0.112	1		
Real GDP gr	0.217	0.002	0.134	1	
MHT manuf	0.509	-0.219	-0.145	0.080	1

Descriptive statistics - impacts on host country (domestic employment)

Table 100: Descriptive statistics for the impact on domestic employment – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EMPd	288	11.539	1.388	7.487	14.458
Log RDf	288	2.946	2.260	-2.303	9.235
Openness	288	97.239	65.704	13.007	451.689
Investment rate	288	5.455	2.980	0.159	22.603
Real GDP growth rate	288	4.585	8.368	-14.849	37.901
MHT manuf	288	1.179	2.109	-5.507	7.244

Table 101: Descriptive statistics for the impact on domestic employment – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EMPd	267	11.374	1.297	7.487	13.806
Log RDf	267	2.708	2.124	-2.303	7.843
Openness	267	100.867	65.961	23.041	451.689
Investment rate	267	5.605	3.023	0.159	22.603
Real GDP growth	267	5.091	8.340	-14.849	37.901
MHT manuf	267	1.076	2.157	-5.507	7.244

Table 102: Descriptive statistics for the impact on domestic employment – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EMPd	175	11.612	1.374	7.487	13.806
Log RDf	175	3.562	1.852	-2.303	7.843
Openness	175	86.722	64.105	23.041	451.689
Investment rate	175	4.600	2.406	0.159	22.603
Real GDP growth	175	1.533	4.786	-14.849	16.617
MHT manuf	175	0.951	2.387	-5.507	7.244

Table 103: Descriptive statistics for the impact on domestic employment – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EMPd	92	10.921	0.994	8.171	13.007
Log RDf	92	1.082	1.597	-2.303	5.010
Openness	92	127.773	61.184	27.167	297.806
Investment rate	92	7.516	3.163	2.462	18.065
Real GDP growth	92	11.858	9.428	-10.921	37.901
MHT manuf	92	1.312	1.618	-1.602	3.711

Correlation matrices – impacts on host country (domestic and foreign employment)

Table 104: Correlation matrix for the impact of foreign employment on domestic employment – whole sample

	Log FOREMPL	Openness	R&D intensity	Investment rate	Contribution MHT
Log FOREMPL	1				
Openness	-0.421	1			
R&D intensity	0.054	0.187	1		
Investment rate	-0.034	0.056	-0.006	1	
Contribution MHT	0.492	-0.086	0.160	-0.105	1

Table 105: Correlation matrix for the impact of foreign employment on domestic employment – EU countries only

	Log FOREMPL	Openness	R&D intensity	Investment rate	Contribution MHT
Log FOREMPL	1				
Openness	-0.374	1			
R&D intensity	-0.001	0.307	1		
Investment rate	-0.025	0.134	-0.026	1	
Contribution MHT	0.359	0.033	0.092	-0.095	1

Table 106: Correlation matrix for the impact of foreign employment on domestic employment – EU-15

	Log FOREMPL	Openness	R&D intensity	Investment rate	Contribution MHT
Log FOREMPL	1				
Openness	-0.377	1			
R&D intensity	0.000	0.372	1		
Investment rate	-0.057	0.199	0.059	1	
Contribution MHT	0.499	0.032	0.121	-0.139	1

Table 107: Correlation matrix for the impact of foreign employment on domestic employment – EU-12

	Log FOREMPL	Openness	R&D intensity	Investment rate	Contribution MHT
Log FOREMPL	1				
Openness	-0.377	1			
R&D intensity	0.007	0.167	1		
Investment rate	0.063	-0.175	0.008	1	
Contribution MHT	0.005	0.009	0.254	-0.072	1

Descriptive statistics - impacts on host country (domestic and foreign employment)

Table 108: Descriptive statistics for the impact of foreign employment on domestic employment – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMEMPL	637	11.022	1.599	5.220	14.805
Log FOREMPL	637	16.688	1.325	9.616	19.631
Openness	637	126.838	157.025	12.902	3014.479
R&D intensity	637	6.017	9.122	0	51.244
Investment rate	637	5.132	3.496	-0.774	47.097
Contribution MHT	637	0.193	3.366	-7.462	6.532

Table 109: Descriptive statistics for the impact of foreign employment on domestic employment – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMEMPL	568	10.909	1.474	6.155	13.806
Log FOREMPL	568	16.628	1.215	12.211	19.078
Openness	568	126.410	108.436	23.041	994.021
R&D intensity	568	5.533	8.520	0	51.244
Investment rate	568	5.261	3.579	-0.774	47.097
Contribution MHT	568	-0.042	2.739	-5.372	4.409

Table 110: Descriptive statistics for the impact of foreign employment on domestic employment – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMEMPL	406	11.086	1.513	7.369	13.806
Log FOREMPL	406	16.609	1.277	12.445	19.078
Openness	406	121.190	119.750	23.041	994.021
R&D intensity	406	7.042	9.522	0.050	51.244
Investment rate	406	4.696	3.487	-0.774	47.097
Contribution MHT	406	-0.377	2.703	-5.372	4.409

Table 111: Descriptive statistics for the impact of foreign employment on domestic employment – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log DOMEMPL	162	10.465	1.274	6.155	13.007
Log FOREMPL	162	16.678	1.042	12.211	18.432
Openness	162	139.493	71.390	27.167	577.583
R&D intensity	162	1.749	2.721	0	12.150
Investment rate	162	6.677	3.420	0.223	28.133
Contribution MHT	162	0.799	2.656	-4.556	3.403

Correlation matrices – impacts on host country (domestic patenting activity)

Table 112: Correlation matrix for the impact on host country patenting activity – whole sample

	FORRD int	DOMRD int	Size	Size growth	FDI int	Openness	GR RGDP pc	Cont MHT
FORRDint	1							
DOMRDint	0.605	1						
Size	-0.342	-0.409	1					
Size growth	-0.078	-0.056	0.161	1				
FDI int	0.236	0.174	-0.123	-0.009	1			
Openness	0.285	0.145	-0.331	-0.056	0.180	1		
GR RGDP pc	-0.177	-0.239	0.190	0.162	0.043	0.175	1	
Cont MHT	0.052	0.130	0.005	0.080	-0.158	-0.095	-0.099	1

Table 113: Correlation matrix for the impact on host country patenting activity – EU countries only

	FORRD int	DOMRD int	Size	Size gowthr	FDI int	Openness	GR RGDP pc	Cont MHT
FORRDint	1							
DOMRDint	0.614	1						
Size	-0.300	-0.375	1					
Size growth	-0.077	-0.065	0.167	1				
FDI int	0.263	0.227	-0.133	-0.008	1			
Openness	0.345	0.185	-0.359	-0.064	0.177	1		
GR RGDP pc	-0.131	-0.164	0.158	0.191	-0.046	0.100	1	
Cont MHT	0.037	0.037	-0.025	0.154	-0.053	0.089	0.323	1

Table 114: Correlation matrix for the impact on host country patenting activity – EU-15

	FORRDint	DOMRDint	Size	Size growth	FDI int	Openness	GR RGDP pc	Cont MHT
FORRDint	1							
DOMRDint	0.623	1						
Size	-0.348	-0.456	1					
Size growth	-0.116	-0.088	0.257	1				
FDI int	0.292	0.268	-0.244	-0.148	1			
Openness	0.532	0.331	-0.360	-0.229	0.228	1		
GR RGDP pc	-0.047	0.006	-0.007	-0.205	0.070	-0.050	1	
Cont MHT	0.097	0.121	-0.275	-0.105	-0.028	0.126	-0.374	1

Table 115: Correlation matrix for the impact on host country patenting activity – EU-12

	FORRD int	DOMRD int	Size	Size growth	FDI int	Openness	GR RGDP pc	Cont MHT
FORRDint	1							
DOMRDint	0.279	1						
Size	-0.213	-0.275	1					
Size growth	0.056	0.087	0.116	1				
FDI int	0.229	0.079	0.056	0.114	1			
Openness	0.145	0.060	-0.514	-0.098	-0.032	1		
GR RGDP pc	0.174	0.042	0.139	0.116	-0.288	-0.098	1	
Cont MHT	0.294	0.233	0.228	0.269	-0.232	-0.266	0.522	1

Descriptive statistics - impacts on host country (domestic patenting activity)

Table 116: Descriptive statistics for the impact on host country patenting activity – whole sample

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EPO applications	251	4.140	2.310	-1.966	9.178
Foreign R&D intensity	251	5.022	6.511	0	38.970
Domestic R&D intensity	251	8.064	12.768	0	69.062
Size	251	1.282	0.984	0.028	4.686
Size growth	251	-0.715	5.948	-36.198	24.192
Inward FDI intensity	251	18.267	19.409	0.058	254.021
Openness	251	119.300	104.797	13.007	994.021
Real GDP per capita growth	251	3.262	4.282	-6.675	13.543
Contribution of MHT sectors	251	1.763	3.387	-5.507	15.255

Table 117: Descriptive statistics for the impact on host country patenting activity – EU countries only

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EPO applications	208	3.657	2.082	-1.966	7.468
Foreign R&D intensity	208	4.614	6.490	0	38.970
Domestic R&D intensity	208	6.829	11.698	0	68.478
Size	208	1.341	1.029	0.028	4.686
Size growth	208	-0.773	6.169	-36.198	24.192
Inward FDI intensity	208	19.734	20.536	0.208	254.021
Openness	208	128.452	104.300	30.197	994.021
Real GDP per capita growth	208	4.138	3.883	-2.570	13.543
Contribution of MHT sectors	208	1.244	1.885	-5.507	3.711

Table 118: Descriptive statistics for the impact on host country patenting activity – EU-15

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EPO applications	116	5.178	1.230	2.769	7.468
Foreign R&D intensity	116	6.259	7.707	0.058	38.970
Domestic R&D intensity	116	9.844	14.222	0	68.478
Size	116	1.219	0.918	0.028	3.773
Size growth	116	-1.902	2.993	-9.398	8.245
Inward FDI intensity	116	19.173	25.793	0.208	254.021
Openness	116	105.832	114.997	30.197	994.021
Real GDP per capita growth	116	2.054	1.039	-0.351	4.466
Contribution of MHT sectors	116	0.738	2.053	-5.507	2.241

Table 119: Descriptive statistics for the impact on host country patenting activity – EU-12

Variable	Obs	Mean	Std. Dev.	Min	Max
Log EPO applications	92	1.740	1.132	-1.966	4.118
Foreign R&D intensity	92	2.539	3.597	0	17.761
Domestic R&D intensity	92	3.028	5.428	0	39.212
Size	92	1.494	1.141	0.107	4.686
Size growth	92	0.651	8.461	-36.198	24.192
Inward FDI intensity	92	20.441	10.847	1.040	53.762
Openness	92	156.972	80.987	35.241	577.583
Real GDP per capita growth	92	6.766	4.519	-2.570	13.543
Contribution of MHT sectors	92	1.882	1.421	-0.054	3.711