Sector Reports Internationalisation of business R&D investments by country

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

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Internationalisation of business expenditures on R&D and analysis of their economic impact (BERD Flows)

Implementing

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for the provision of Services in the Field of Research Evaluation and Research Policy Analysis ([1] 2010/S 172-262618) - Lot 2: Data collection and performance indicators to monitor European research policy

4.3. Internationalisation of business R&D investments by sector

This annex provides an overview of the current status of the internationalisation of business R&D at the sector level. In order to better to better understand what drives foreign R&D investments, the study carried out 7 sector studies and 4 special topic studies. This annex includes the cases themselves as referred to in the text of the main analysis report. The approach here combines the metrics used in the first chapters with a more qualitative analysis of factors and actors behind the numbers. The presentation serves as an introduction and a complement to chapter 5 which carries out a formal analysis and also reports on the special analytic topics. Here is an overview of the briefs found in this annex.

Sector cases

1. R&D internationalization in chemicals, excluding pharma (NACE 20)
2. R&D internationalization in pharmaceuticals (NACE 21)
3. R&D internationalization in computer, electronic and optical products (NACE 26)
4. R&D internationalization in electrical equipment (NACE 27)
5. R&D internationalization in machinery and equipment (NACE 28)
6. R&D internationalization in motor vehicles, etc. (NACE 29)
7. R&D internationalization in computer programming, consultancy, information services and related activities (NACE 58.2 and 62-63)

Special analytic topics

1. The financial crisis and BERD Flows
2. The effects of tax credit policy on Inward BERD for selected OECD host countries.

Special data topics

1. R&D Internationalization, Global Innovation Collaboration and Foreign Ownership: Using the Community Innovation Survey
2. R&D Internationalization: Using supplementary data on FDI (FT Markets)

The paper version of this report is furthermore complemented by a number of interactive online maps featuring the sector level. These maps can be customized by readers according to their interest, for example, by changing the indicators or the countries displayed, is available at the project homepage:

http://www.ait.ac.at/departments/internationalisation-of-business-investments-in-rd-and-analysis-of-their-economic-impact/

https://public.tableau.com/profile/georg.zahradnik#!/vizhome/BERD_Flows/Amounts

https://public.tableau.com/profile/georg.zahradnik#!/vizhome/BERD_Flows/Indicators

R&D internationalization in the chemical industry less pharma (NACE 20) BERD Flows: Submitted under subtask 4.3. (Drivers of foreign R&D investments)

Introduction

This is a digest of R&D internationalization of the manufacture of "Chemicals and chemical product less Pharma" (NACE 20). Based primarily on the inward-flows of BERD data and domestic BERD data (1999-2013), it integrates also a number of secondary data (see Responsiveness score in section 4 and data in the Annex). The sectoral case study is organized in three sections: the first one introduces the core data and the approach; the second section provides a synthetic picture of the chemical industry mainly based on BERD database and two other data sources, R&D Investment Scoreboard and European R&D survey. The third section presents the patterns of Inward R&D and of its weight on *Total BERD* activity in the sector across time and country. The last section is an analysis of the underlying drivers that can help to explain the observed patterns of R&D internationalization. The Annexes include several tables: the full data for Inward, Total BERD, the missing data and two tables on secondary data.

1. Data and approach

The core-data, as described in deliverable D.3.2., consists of the following:

- Total BERD, which is the total R&D expenditure of firms in a specific country or sector;
- Inward BERD, which is the R&D expenditure of foreign-owned firms in a specific country or sector.

These data are limited by the extent of missing-values, especially for certain countries. An average more than 2/3 (73%) of the 34 countries do not provide values in any given year. The coverage is variable, particularly after 2007 when coverage in even-years is minimal. Annex 2 presents the coverage.

Data for *Outward BERD*, which is the R&D expenditure of foreign affiliates of domestic firms in a specific host country or sector are not used here, as outward-BERD data are, since 2009, no longer available for most countries. Exceptions include the US and Japan. A separate case-study will present what can be learnt from the extant data on outward BERD. The secondary data that are used includes standard GDP data, labour-costs, GBOARD, educational levels, patents, the size of the sector and domestic R&D in general. [1]

The document is primarily based on presenting figures from the core and secondary data sources. The major analytical step is taken to gauge the impact of the main drivers of inward R&D in the sector, applying the responsiveness score method developed at IRCRES (Cerulli, 2015). The approach, based on iterated random coefficient regression, assumes that individual units react ('responsiveness') to individual factors differently. It allows to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, GBAORD, Domestic R&D, level of education), conditional on the other factors at play. The approach is further explained in the fourth section.

3. The European Chemical Industry and BERD

A number of characteristics and tendencies can be used to introduce the sector (see box).

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[1] See the annex for a detailed description of the data used.

Box 1. 1. R&D internationalization in chemicals, excluding pharma (NACE 20)

The chemicals industry represents around 7% of EU industrial production.

- Increasing international competition, pressure to increase resource efficiency, and new regulations drives R&D and innovation in the chemical industry.
- Chemicals are patent intensive relative to the key enabling technologies.
- Greenfield investment has been strong (ranging between 35€ Billion and 60€ Billion per year since 2010) as firms attempt tap into local R&D resources.
- Key challenges: undergoing rapid structural change.
- Future technology: Industrial (white) biotechnology (industrial processing and production of chemicals and related materials).

In this light, the chemical industry is a medium high R&D intensive sector. The R&D growth of EU companies outperform their US counterparts in medium-high tech sectors, however performance is mixed in different sectors. The R&D intensity of the top European chemicals companies is 2.1% in 2015, while it is 3.4% for the chemical US companies and 3.6% for the Japanese ones. Between 2014 and 2015, R&D growth of the chemical industry was slow (1.9%), together with Aerospace & Defense (1.5%) and Industrial Engineering (2.0%).

Table 1. Top 10 Global enterprises in the chemical industry

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

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

The R&D of the chemical industry makes up 3% of the activity among the 608 top R&D companies in Europe. R&D activity of these companies decreased 0.8% between 2014 and 2015, while in the same industry the R&D of the top US 829 companies grew of 1.3% (Scoreboard 2015). Among the first top R&D investors, the US companies from Chemicals sector are Dupont, Monsanto and Dow Chemicals, following BASF (Germany). European countries with the highest number of chemical companies among the top 1000 R&D investors are: DE (13), UK (11), BE (3), FI (3), and SE (3).

Several general tendencies are observable. The migration of the petrochemical and basic chemical sectors out of Europe - mainly in the Middle East, but increasingly also in China- in the past decade has led to an important change in the European chemical industry: companies are increasingly focusing on the high- tech and high-margin specialty and fine chemicals segments. Companies which make basic chemicals and plastics are vulnerable to emerging competition from shale-gas-fueled production in US. The European industry is looking seriously at reducing its raw material dependency on oil. BASF, for example, is researching into the production of succinic acid from biomass. Notwithstanding the changes, the export strength of German chemical industry remained untouched.

Table: The global chemicals export share by country in % and in billions euro is the following (2010):

	Export share %	Billion euro
Germany	11.5	144
US	10.5	129
Belgium	7.9	97
France	5.6	69
China	4.7	60
Netherlands	4.7	58
UK	4.6	57
Switzerland	4.6	56
Japan	4.6	55

Between 2000 and 2010 the China market share increased by 16 percentage points. In ten years European Union gradually lost its top place in world chemical sales to China and the rest of Asia. The EU contribution to the world chemical sales dropped from 30.9% in 2004 to 17.0% in 2014 (European Chemical Industry Council, 2015). The total value of sales in the European Union has been continuously growing, but world chemical sales have outpaced that rate of growth, increasing by 22 times in value terms in 2014 compared to 2004. China's share of world chemical market sales swelled to 34.4% in 2014, from 9.3% share in 2004.

German chemical companies reduced energy needs by 40% in ten years, turnover and labor productivity increased from 177,000 to 412,000 Euro per employee. As productivity rose, the number of employee numbers fell however, at an average annual reduction of 2.1% in Europe. The European chemical industry revenue by country in 2010, in billions of Euro, was: Germany 180, France 115, Italy 75, UK 65, Netherlands 52, Spain 50 (Eurostat, 2011).

In terms of chemical patent registration share, Germany has the third world place (17%) after USA and Japan, followed by countries are France, Korea, China, India, UK. Academic and non-academic institutions (such as Max Planck Society; Fraunhofer Society) support this large patent activity through R&D and training in the chemistry sector. The industry is the second strongest R&D sector in Germany, after the automotive sector (see the case study in this report), with an R&D intensity of 5.5%.

Germany's chemical industry is number one in Europe, it employs around half a million trained staff, business and research institute invest substantially in R&D; there are around 2000 chemical companies, 90% are SMEs with less than 500 employees. Around 100 companies produce 75% of total chemical revenue in the Country. The big players are BASF, Bayer, Henkel, Evonik, Linde, Merck.

Leading international chemical firms choose to locate in Germany because of its highly qualified workforce, the excellent research environment, logistics and the presence of world class infrastructures such as chemical parks. Moreover, investment projects receive financial assistance through different instruments regardless of country provenance; KfW (the State owned development bank) is particularly active, both in early and later stage investment. R&D project funding is available through a number of incentive programs at the national and regional levels, focused on reducing the operating cost of R&D projects.

BASF is a giant chemical company, with 70 billion of euro sales in 2015, i.e. 21% more than the second largest firm in sales, China's Sinopec. Its portfolio is structured into five segments: Chemicals, Performance Products, Functional Materials & Solutions, Agricultural Solutions and Oil & Gas. The chemical industry consists of the Petrochemicals, Monomers and Intermediates Divisions. BASF has strong partnership with Gazprom, Monsanto, Petronas, Shell, Sinopec, Statoil, Total and Yara. Their customers are found in a large number of industries: chemical and plastics, energy and resources, consumer goods, transportation, agriculture, construction, electronics, health and nutrition.

The company is located in the following different world regions (% of income from operations):

- Europe (excl. Germany): 37%
- Germany: 30%
- North America 21%
- Asia Pacific: 6%
- South America, Africa, Middle East: 6%

In North America BASF focuses on innovation, attractive market segments and cross-business initiatives. Sales at companies headquartered in North America grew by 1% year-on-year. The sales increase was essentially due to positive currency effects in all divisions, which more than compensated for raw material cost and price drops in the chemicals business. In Asia Pacific the BASF regional strategy is to raise the proportion of sales coming from local production. The continuing expansion of the Innovation Campus Asia Pacific in Shanghai, China, strengthens the presence of this region within the BASF global Research Verbund. To improve profitability in Asia Pacific, the company intensified measures to increase efficiency. Gross domestic product shrank in South America as a consequence of the recession in Brazil and the deteriorating economic environment in other countries in the region. BASF sales declined slightly under these conditions. Sales decreased in the chemicals business, but rose in the crop protection business and in the Oil & Gas segment. Companies in Africa and in the Middle East showed considerable sales growth, driven by volumes and currencies.

Belgium

A relevant European country in chemicals industry is Belgium. The Belgian chemicals industry is one of the most diversified and integrated chemical clusters in the world. Eleven of the top-15 global chemical groups have production facilities in Belgium and the Belgian cluster (especially in Antwerp Port) is the biggest in the world after Houston. The share of the chemical industry in the total Belgian economy is twice the size of the average share of this industry in the European Union and even bigger than in the traditional chemicals country, Germany. All together the Chemical sub-sectors in Belgium represented a turnover of 45 billion of euro in 2009 and an added value of more than 10 billion of euro. The sector employs 91,500 people and employment in the chemicals industry stayed stable during the past twenty years. The number of jobs in the overall industry fell in the same period, with the consequence that the chemicals industry's share rose, from 13.6% in 1990 to 17.4% in 2009. Furthermore, one direct job in chemicals generates 1.6 indirect jobs in other sectors.

3.1. Chemical Inward R&D (in Euros)

Table 1 presents reported *Inward R&D* (in Euro) by host-country and by year, pre and post crisis. Here the values are presented for odd-years where data is systematically more complete (see also annex). Due to the lack of data (see the annex for missing values), we are not able to study the pre and post crisis variation for all of the countries considered.

Table 1 illustrates that in most cases there have be an increase in the R&D investments of MNE's operating in the Chemical sector (excluding pharma). In Europe, only Belgium, UK and Norway have experienced a decrease of R&D foreign investments. Both North American Countries (Canada and US), have recorded an increase inward BERD; while Canada records a slightly decrease in 2013, United States shows an upward trend also in the last year considered.

But, notwithstanding, the important role in the economy, the investments in the sector have decreased in the last years. It is interesting to notice that the Chemical industry of Belgium shows an opposite trend with respect to the Pharmaceutical industry. While the latter have recorded, in the same period, the highest increase of R&D foreign investments in Europe, the former has experienced a decrease of approximately 32%.

Table 1. Inward R&D in Chemical and chemicals products (Nace 20) before and after 2008 and for last available year: Millions Euro regions and selected countriess

Region and Country	Annual Average		Latest available year
	Pre-2008 [a]	Post-2008	2013
Row Labels	**period1-**	**period2-**	**Latest**
Eastern Asia		**132**	**151**
Japan**		132	151
Eastern Europe	**8**	**32**	**34**
Bulgaria*		1	1
Czech Republic	8	19	21
Hungary		5	3
Poland		6	8
Slovakia		1	1
Northern America	**1191**	**1218**	**1258**
Canada	64	96	66
United States of America	1127	1122	1192
Northern Europe	**633**	**407**	**497**
Denmark		64	64
Estonia		2	2
Finland*		60	65
Ireland	26		0
Norway	92	37	34
Sweden	161		0
United Kingdom	354	245	332
Southern Europe	**3**	**221**	**245**
Italy		145	148
Portugal	3	0	0
Slovenia		2	2
Spain		75	94
Western Europe	**1393**	**1649**	**1930**
Austria	101	134	116
Belgium	320	208	222
France	415	490	577
Germany	557	612	808
Netherlands		204	207
Grand Total	**3228**	**3658**	**4115**

Czech Republic is the country where, in the aftermath of the economic crisis, there has been the larger increase of the inward investments in the chemical sector. In addition, with respect to the pharmaceuticals the increase seems continuous over time. The case of Belgium attracts particular attention (see above). In fact, the chemical industry plays a pivotal role in the country, with a share in total economy nearly two time larger than the EU27 average. In addition, 13 of the top 20 chemical companies have production sites in Belgium and the country is in the first position for sales per capita in the world.

The table below (table 2) reveals more about the evolution of inward investments in R&D. It describes the relation between total R&D expenditure and the inward share, expressed as a percentage of total BERD in the industry. For Czech Republic there have been a significant increase of the inward share. Both domestic and inward BERD have increased in the considered time period, but the growth rate of the latter has been almost the double of the former (+ 47% of domestic, +110% inward).

Table 2. Inward BERD as a percentage of total BERD in the chemical industry

		2007		2009		2011		2013
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	142	71.1%	172	75.6%	215	73.0%	189	61.4%
Belgium	387	69.3%	277	63.5%	350	64.9%	307	72.3%
Canada		:	186	41.9%	220	65.0%		:
Czech Rep.	25	16.7%	34	20.8%	41	43.9%	43	48.8%
Denmark	:	:	208	:	239	:	270	23.7%
Finland	:	:	115	47.8%	129	50.4%	128	:
France		:	1,031	39.1%	833	:	944	61.1%
Germany	3,148	17.4%	3,198	12.5%	3,297	19.1%	3,347	24.1%
Greece		:		:	16	:	13	:
Hungary	11	:	13	:	12	58.3%	14	21.4%
Ireland	173	:	31	:	50	:	50	:
Italy	366	:	338	:	339	41.6%	364	40.7%
Japan	5,098	:	5,794	:	6,706	2.0%	5,799	:
Netherlands	820	:	1,668	11.3%	1,108	19.5%	1,046	19.8%
Norway	117	78.6%		:		:		:
Poland	15	:	16	31.3%	31	19.4%		:
Portugal	16	18.8%	19	:	18	:	24	:
Romania	4	:	15	:	22	:	1	:
Slovakia	3	:	3	33.3%	4	:	5	8.3%
Slovenia	13	:	14	:	53	1.9%	38	10.5%
Spain	242	:	238	23.9%	242	30.2%	239	39.3%
Sweden	132	121.2%*		:		:		:
UK		:	306	:	327	48.0%	425	78.1%
USA	5,615	20.5%	6,017	18.2%	6,735	16.0%		:

The inward share in Belgium has increased over time, but this is mainly due to a decrease of domestic BERD. Anyway, the country has among the most internationalized Chemical R&D activity in the word. The other most internationalized Countries for their R&D activities in the chemical sector are UK, Norway, Austria.

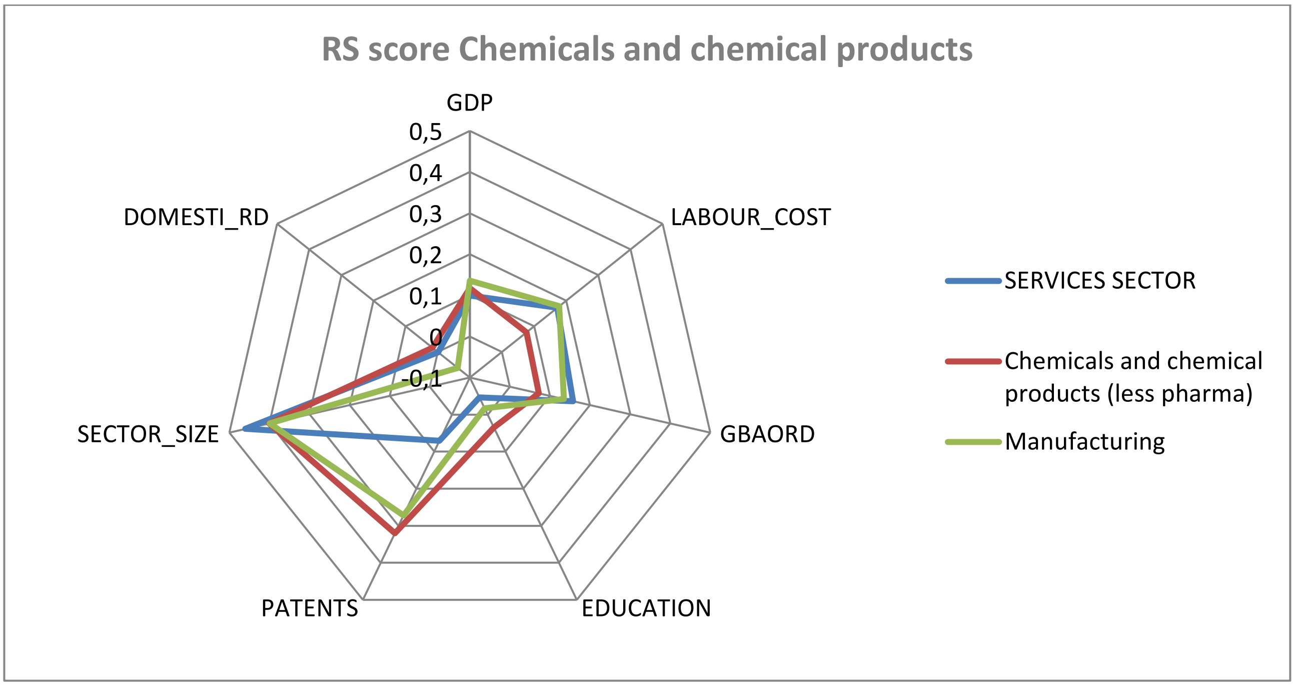
For Norway, due to missing data, we are not able to see the evolution of the inward performance over time. In United Kingdom, there have been an important increase of inward share, from 2011 to 2013, mainly due to an important decrease of domestic investments. In Austria, both domestic and inward BERD have increased from 2007 to 2013. However, in the last years inward have decreased of 26% and, consequently, “inward share” have drop from 73% in 2011 to 61% in 2013.

Contrary to the trends recorded in the Pharmaceutical industry, the chemical sector of Germany has experienced an important increase of inward investments and a parallel decrease of domestic R&D investments.

4. R&D main drivers using the Responsiveness score (R-Score) Analysis

An important contribution of the project is to use newly adapted empirical methods (see Chapter3) to better understand the factors that contribute to increased inward R&D investments. This section presents the main findings regarding the drivers of inward R&D in the chemical sector. As introduced above, the analysis is based on the idea that inward R&D may respond differently to a given change of a series of factors. Particularly, we expected a set of generic drivers– GDP, GBAORD, Patenting, Education, Domestic R&D, Labour costs – to influence the level of R&D investments.[2]

We use the Responsiveness score method to identify the main drivers of the inward investments in R&D. This methodology (based on iterated random coefficient regression) allows us to measure and to rank the change of the outcome(external R&D in a given Country) when a given factor changes conditional on all other factors.[3]



The responsiveness score measures the effect of an increase in an individual factor (such as patenting activity) on the inward R&D investments of foreign firms above and beyond that caused by the other driving factors under consideration (such as government R&D). The above figure illustrates the responsiveness scores of the different factors in the chemical industry, as compared to two benchmark sectors, specifically, total Manufacturing and total Services. The most important drivers are “Patenting” and “Sectoral size”. “Patenting” and “education” and “Domestic R&D” record higher values in the chemical industry than in the baseline industries.

[2] See the annex 2 for further explication on the data used.

[3] See more on the annex

Annex 2. Database description

Data on” GDP”, “Total sectors production”, accounting for the size of each sectors, and “Labour cost per sector” are taken from STAN Database (OECD). The database includes annual measures of output, labour input, investment and international trade. The current version of STAN is based on the International Standard Industrial Classification of all economic activities, Revision 3 (ISIC Rev. 3) and covers all activities (including services).

In order to measure the influence that Government support for research and development activities may have on Inward investments R&D, we use the GBAORD index, accounting for Government budget appropriations or outlays for research and development. GBAORD include all appropriations (government spending) given to R & D in central (or federal) government budgets. The source of data is OECD. Science Technology and Innovation (STI) indicators.

“Patents Application” is used as a proxy of the innovation capabilities of countries. Data are taken from World Bank, World Development Indicators. As to capture the capability innovation of the country we have add to the number of patent applications of resident the patent applications of non-resident.

In order to capture the influence that skills and education may have on Inward R&D we use the indicator “Tertiary graduates in mathematics science and technology per 1000 inhabitants aged 20-29 years”.

The data source is Eurostat, and the years observed go from 2001 to 2012. The levels and fields of education and training used follow the 1997 version of the International Standard Classification of Education (ISCED97) and the Eurostat Manual of fields of education and training (1999). Data on Foreign direct investment inflow are taken from OECD, FDI Statistics according to Benchmark definition 4th edition (BMD4).

ANNEX. 1 Table. 3 Total BERD investments in R&D in the chemical sector

Total BERD	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	79				94	93	96	108	124	142		172		215		189
Belgium	588	597	600	648	471	490	471	482	397	387	296	277	291	350	316	307
Bulgaria					0	1	1	1	1	1		1	2	2	1	1
Canada	73	151	163	162	155	150	111	112	112			186	258	220		
Switzerland											359				421	
Czech Republic	20	18	18	16	16	19	19	20	23	25	29	34	38	41	38	43
Germany	3543	3605	3718	3643	3450	3290	3177	2973	3418	3148	3226	3198	3124	3297	3496	3347
Denmark	75	80		132	81	165	160	165	140	0		208	212	239	282	270
Estonia	0	1			3		2	2		3	3	3	3	2	4	2
Spain				139	179	189	213	220	256	242	285	238	249	242	235	239
Finland				0	0	0	0	0	0	0	149	115	122	129	106	128
France	1113	1136	1189	1286	1301	1357	1394	1325	1291		1136	1031	1080	833	905	944
HR											2	2	2	2	2	2
Hungary	5	4	5	7	10	10	7	8	9	11	12	13	11	12	8	14
Ireland	22	24	22	20	19	19	20	33	103	173		31	30	50		50
Italy	315	292	352	340	385	336	353	373	365	366	356	338	363	339	354	364
Japan	6487	7407	8844	8017	7357	6799	6183	6389	5959	5098	5418	5794	6400	6706	7287	5799
Netherlands	519	499	499	467	470	545	746	742	799	820	836	834	685	554	501	523
Norway	43	40	59	80	96	75	90	97	95	117			112			
Poland	40	32	31	11	22	7	9	10	12	15	23	16	25	31	34	
Portugal	6	7	9	11	12	14	13	11	13	16	17	19	30	18	25	24
Romania							3	5	6	4	17	15	14	22	1	1
Sweden	82	106	131	127	119	126	154	177	178	132						
Slovenia	7	9	5	7	7	5	6	9	12	13	14	14	20	20	20	19
South Korea	244	279	457	505	560	542	599	787	962	1006	811	821	1132	1513	1578	1827
United Kingdom	1017	1090	1118	991	953	893	921	919	990		316	306	374	327	324	425
United States	8263	7805	8797	8659	6814	6103	6220	6556	5916	5615	6880	6017	6504	6735	7067	

ANNEX. 1 Table.4 Total inward BERD in the chemical sector

Total inward	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria							55			101		130		157		116
Belgium			385	416	354	364	330	327	249	268		176		227		222
Canada	44	119	98	84	75	86	60	48	60	57	72	78	170	143	85	66
Switzerland																
Czech Republic	2	1	2	6	5	8	7	7	10	10	15	17	17	18	20	21
Germany						505		620		547		400		629		808
Denmark																64
Spain												57		73		94
Finland												55		65		
France	279			332	392	393		443	416	408		403				
Italy														141		148
Japan													142	132	151	
Netherlands											200	189	189	216	193	207
Norway										92				40		34
Poland												5		6		8
Sweden	68	80	115	173	158	163		160		160						
United Kingdom	333	211	359	402	377			344	399	364	437			157		332
United States	1239	1396	1514	1607	1308	1284	1000	947	978	1151	1102	1097	1076	1077	1259	1192

A.3. Inward R&D. Summary statistics with tally of missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Missing values	Total	Percent Missing
A1999	6	302	542	1	1396	A1999	28	34,0	82,35
A2000	6	412	561	2	1514	A2000	28	34,0	82,35
A2001	7	431	542	6	1607	A2001	27	34,0	79,41
A2002	7	381	437	5	1308	A2002	27	34,0	79,41
A2003	7	400	429	8	1284	A2003	27	34,0	79,41
A2004	5	290	417	7	1000	A2004	29	34,0	85,29
A2005	9	325	313	7	947	A2005	25	34,0	73,53
A2006	6	352	350	10	978	A2006	28	34,0	82,35
A2007	11	287	337	3	1151	A2007	23	34,0	67,65
A2008	5	365	443	15	1102	A2008	29	34,0	85,29
A2009	16	163	282	0	1097	A2009	18	34,0	52,94
A2010	5	319	429	17	1076	A2010	29	34,0	85,29
A2011	21	147	257	0	1077	A2011	13	34,0	38,24
A2012	5	342	517	20	1259	A2012	29	34,0	85,29
A2013	22	177	307	0	1192	A2013	12	34,0	35,29

A. Manufacture of chemicals and chemical products

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
EU	Total	77.4	91.7	:	:	:	:	:	:	:
	Inward	91.82	118.4	113.7	:	:	:	:	:	:
Austria	Total	102.8	137	121	9.9	8.9	8.8	9.3	9.3	9
	Inward	106.7	157.8	142.4	12.6	10.3	8.8	9.8	10.2	9.7
Belgium	Total	:	150.2	157.9	:	:	:	:	:	:
	Inward	:	178.4	183.1	:	:	0	:	:	0
Bulgaria	Total	9.8	16	20.3	0.4	0.4	0.2	0.7	0.6	0.6
	Inward	15.4	28.6	43.7	0.2	0.6	:	0.3	1	:
Croatia	Total	:	22	17.3	:	1.3	1.5	:	1.5	1.5
	Inward	:	22.4	30.1	:	2.4	1.9	:	2.8	3
Cyprus	Total	36.7	36.5	33.5	2.1	1.6	:	3.1	3	:
	Inward	:	:	:	:	:	:	:	:	:
Czech Rep.	Total	30.3	42.5	37.4	3.8	3.3	4	2.7	2.8	3
	Inward	43.4	54.6	52	2.7	2.4	3.1	2.2	2.4	2.5
Denmark	Total	117.2	103.3	119.1	:	:	14.9	:	:	12.2
	Inward	132.2	83.4	99.4	:	:	13.5	:	:	11
Estonia	Total	23.7	43.8	32.6	4.5	1.5	3.2	3.2	3.7	0
	Inward	23.2	42.9	28.6	4.7	1.2	3.7	3.2	3.2	0
Finland	Total	92.8	:	:	9	:	:	8.9	:	:
	Inward	104.7	148.2	:	7.2	6.1	:	7.9	7.3	:
France	Total	74.3	100	90.6	12.4	:	13.2	7.6	:	8.5
	Inward	73.6	122.8	95.3	10	:	10.5	6.1	:	7.3
Germany	Total	91.1	110.7	105	12.2	10.7	11.8	7	7.3	7.5
	Inward	97	123.5	113.4	5.5	5.8	7.4	4.9	6.5	7.3
Greece	Total	:	:	53.7	:	:	0.7	:	:	0.9
	Inward	:	:	82.1	:	:	0	:	:	0
Hungary	Total	33.3	44.3	53.5	1.7	1.5	1.7	2.6	1.8	2.9
	Inward	61.3	51.7	70.3	0.9	1.9	0.7	4.1	1.8	1.4
Ireland	Total	117.4	171.8	:	:	:	:	:	:	:
	Inward	111	176.9	:	:	:	:	:	:	:
Italy	Total	66.9	84.6	87.9	:	3.6	3.8	4	4.3	4.9
	Inward	93.3	120	117.4	:	3.6	3.8	4.3	4.1	4.6
Latvia	Total	15.9	14.5	13	0	:	:	0	:	:
	Inward	10.1	13.8	16.3	0	:	:	0	:	:
Lithuania	Total	23.5	74.1	19.2	:	:	:	:	:	:
	Inward	58.7	135.9	33.4	:	:	:	:	:	:
Luxembourg	Total	:	67.9	74.1	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Malta	Total	31.9	32.7	28.7	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Netherlands	Total	132.3	176.8	166	13.9	7	7.1	13.5	12.2	11.3
	Inward	147	190.4	201.4	4.7	4.2	3.8	6.8	7.9	6.8
Norway	Total	125.2	148.2	163	9.8	5.9	6.9	10.1	7.4	9.1
	Inward	:	157.1	159.4	:	6.1	5.7	:	8.2	7
Poland	Total	32.3	46.4	42.2	0.7	0.9	1	1.1	1.5	1.5
	Inward	46.9	55.9	51.4	0.5	0.5	0.7	1	1.2	1.3
Portugal	Total	47.4	57.2	49.8	0.1	0.1	0.1	1.8	2.5	2.8
	Inward	68	76.4	57.4	0	0	0	1.1	1.9	2.9
Romania	Total	15.7	25	19.6	0.1	0	0.1	0.1	0.1	0.1
	Inward	16.7	26.2	25.4	0.2	0.1	0.2	0.2	0.2	0.3
Slovakia	Total	16.4	34.7	25.8	2.6	1.1	1.1	1.2	1.2	1
	Inward	17.6	42	28.1	0.9	:	0.5	0.5	:	0.3
Slovenia	Total	37.4	52.2	51.6	5.4	5.6	5.6	6	7.2	6.4
	Inward	46.4	60.9	69.8	:	:	1.2	:	:	2.3
Spain	Total	69.7	94.2	82.3	4	3.1	3.6	5.8	5.7	5.8
	Inward	91.5	118.7	110.6	3.3	2.2	2.8	4.9	4.1	4.5
Sweden	Total	89.4	114.5	126	:	:	:	:	:	:
	Inward	106.9	140.4	149.3	:	:	:	:	:	:
UK	Total	90.3	91.2	94.6	:	3	4.2	2.8	3.1	4.5
	Inward	94	105.2	105	:	2.5	3.7	3.4	2.8	4.1

Source: Eurostat

Annex. **RESPONSIVENESS SCORES DEFINITION AND ESTIMATION.**

In this section we provide a technical presentation of the Random Coefficient Regression (RCR) used to compute Countries' responsiveness scores. The basic econometrics of this model can be found in Wooldridge (2002, pp. 638-642) whose this section is a concise account with slight modifications. The application of RCR in this work follow this simple protocol:

1. Define *y*, the outcome variable, "Inward R&D investments from 1998 to 2013".
2. Define a set of *Q* factors thought of as affecting *y*, and indicate the generic factor with x_j.
3. Define a RCR linking *y* to the various x_j, and extract a Country-specific *responsiveness effect* of *y* to the all set of factors x_j, with *j*=1, ..., *Q*.
4. For the generic Country *i* and factor *j*, indicate this effect as b_{ij} and collect all of them in a matrix **B**. Finally, aggregate by Country (row) and by factor (column) the b_{ij} getting synthetic Country and factor responsiveness measures.

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

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

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

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

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

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

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

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

If all variables are standardized, partial effects are *beta coefficients* so that they are independent of the unit of measurement and can be compared and summed.

Once matrix **B** is known, we can define for each region *i* the Total Country Responsiveness (TCR) and the Mean Country Responsiveness (MCR) as:

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

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

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

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

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

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

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

By repeating this procedure for each Country *i* and factor *j*, we can finally obtain $\hat{\mathbf{B}}$, the estimation of matrix **B**.

When a longitudinal dataset is available, the estimation of **B** can be obtained either by using random-effect or fixed-effects estimation of this panel regression:

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

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

R&D internationalization in pharmaceuticals (NACE 21) BERD Flows: Submitted under subtask 4.3. (Drivers of foreign R&D investments)

Introduction

This is a digest of R&D internationalization of the manufacture of basic pharmaceutical products and pharmaceutical preparations (NACE 21, the 'pharmaceutical industry'). Based primarily on the inward-flows of BERD data and domestic BERD data (1999-2013), it integrates also a number of secondary data (see Responsiveness score in section 4 and data in the Annex). The sectoral case study is organized in three sections: the first introduces the core data and the approach; the second section provides a synthetic picture of the pharmaceutical industry mainly based on BERD and two data sources, R&D Investment Scoreboard and European R&D survey. The third section presents the patterns of Inward R&D and of its weight on *Total BERD* activity in the sector across time and country. The last section is an analysis of the underlying drivers that can help to explain the observed patterns of R&D internationalization. The Annexes include several tables: the full data for *Inward and Total BERD*, the missing data and two tables on secondary data.

Data and approach

The core-data, as described in deliverable D.3.2., consists of the following:

- Total BERD, which is the total R&D expenditure of firms in a specific country or sector;
- Inward BERD, which is the R&D expenditure of foreign-owned firms in a specific country or sector.

These data are limited by the extent of missing-values, especially for certain countries. An average 2/3 (66%) of the 34 countries do not provide values in any given year. The coverage is variable, particularly after 2007 when coverage in even-years is minimal. Annex 2 presents the coverage.

Data for *Outward BERD*, which is the R&D expenditure of foreign affiliates of domestic firms in a specific host country or sector, are not used here as outward-BERD data are, since 2009, no longer available for most countries. Exceptions include US and Japan. A separate case-study will present what can be learnt from the extant data on outward BERD. The secondary data that are used include standard GDP data, labour-costs, GBOARD, educational levels, patents, the size of the sector and domestic R&D in general.[1]

The document is primarily based on presenting figures from the core and secondary data sources. The major analytical step is taken to gauge the impact of the main drivers of inward R&D in the sector, applying the responsiveness score method developed at IRCRES (Cerulli, 2015). The approach, based on iterated random coefficient regression, assumes that individual units react ('responsiveness') to individual factors differently. It allows to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, GBAORD, Domestic R&D, level of education), conditional on the other factors at play. The approach is further explained in the fourth section.

[1] See the annex for a detailed description of the data used.

3. The European pharmaceutical industry and BERD

A number of characteristics and tendencies can be used to introduce the sector (see box).

Box 1. R&D internationalization in the pharmaceuticals industry (NACE 21)

The pharmaceutical sector is one of the most technologically concentrated.

- Some companies focused purely on pharmaceuticals but others specialized in medical technologies (Johnson & Johnson) or chemistry (Bayer) and some with substantial patenting activity in biotechnology (Roche).
- The US appears to be the most attractive region of the world for the R&D investment for health related sectors, especially biopharma.
- Pharmaceuticals companies dominate the ranking of M&As over the past eight years (Pfizer, Merck, Roche and Novartis). But any firms access specialized R&D in the pharmaceutical industry by acquiring smaller biotech companies via M&A to further diversify their portfolio of biopharmaceutical innovations or to acquire a promising pipeline drug.
- Key challenges: medicines, therapies, diagnostics, and vaccines.
- Future technology: genomics (genome sequencing, gene editing), monoclonal antibodies (the basis of many new drugs), drugs capable of fighting antibiotic-resistant infections, anti-viral drugs (for HIV, HepC etc.), regenerative medicine (stem cells etc.) and cancer immunotherapy.

In this light, the pharmaceutical and biotechnology industry is among the highest R&D intensive sectors (OECD, 2011), where knowledge generation plays a key role in a context of global competition. Companies in these sectors dominate the top places in the world ranking of R&D industrial investors. The first 9 top world pharmaceutical companies by R&D investments (Scoreboard, 2015) are:

- Novartis Switzerland
- Roche Switzerland
- Johnson & Johnson US
- Pfizer US
- Merck US
- Sanofi Aventis France
- AstraZeneca UK
- Glaxo Smith Kline UK
- Bayer Germany

Switzerland, with its strong position in pharmaceutical industry, is the only OECD countries for which the amount of outward investment in R&D is higher than inward. The largest part of this outward BERD is directed to US. Novartis is among the top 5 R&D investors in the world. Most of the top 100 companies showing a relevant R&D increase in the last two years are in the pharmaceutical industry. Pfizer (US) in 2014 climbed to the 10th place from the 15th one; Bayer improved 20 places (now ranked 29th). The rank change between 2004 and 2015 of top world pharmaceutical companies is the following:

- Novartis up 15 places
- Roche up 11 places
- Johnson & Johnson up 4 places
- Pfizer down 8 places
- Merck up 17 places
- Sanofi Aventis down 3 places
- AstraZeneca down 1 place

- Glaxo Smith Kline down 16 places
- Bayer up 31 places

In the pharmaceutical industry, companies operating in biotechnology increased R&D by 21.3% whereas the traditional pharmaceutical companies increased it by 4.8%. In some case the big changes in R&D over the last ten years are the result of mergers & acquisitions policies (M&As). In fact, in terms of total value of the deals, pharmaceuticals companies dominate the ranking of M&As over the past eight years (Pfizer, Merck, Roche and Novartis). In the pharmaceutical sector, many companies access specialized R&D by acquiring smaller biotech companies via M&A to diversify their portfolio of biopharmaceutical innovations or to acquire a promising pipeline drug. Main *Merger and Acquisition* activities concerning top R&D investor pharmaceutical companies are presented in the following table.

Company	Total value M&A deals € bn.	N. of cross border M&A activities	Total n. of deals	Total value of FDI €bn. (n. of FDI projects)
Pfizer	64,89	4	19	0
Merck US	47.84	1	5	2,7 (49)
Roche	45,89	22	22	3,7 (46)
Novartis	38,1	7	10	2,7 (61)
Sanofi Aventis	18,43	14	17	3,8 (54)
Glaxo-Smith-Klein	14,91	15	17	3,3 (62)
Bayer	12,44	2	5	4 (124)

Source: *Zephir database,* Bureau van Dijk and *fDi Markets database,* the *Financial Times*.

Looking at the patent portfolios of the world's top R&D investors, US appear to have the highest degrees of internationalization in health related inventions (pharma and biotech), i.e. patent families are developed by inventors located outside the world region. The country distribution of patents filed by the world's top R&D investors is a good proxy for the location of companies' innovation activities.

The pharmaceutical industry recovered in 2014 from the 2013 sluggish performance in both the US and the EU: the R&D investment performance of pharma and biotech companies is better in 2014 both in the US (10.7%) and the EU (6.5%), than in 2013 (0.4% and 0.9% respectively) (source: R&D Scoreboard, 2015). Pharma companies based in Japan showed an inverse trend: poor performance in 2014 (-1.0%) compared to the good performance in 2013 (9.3%). R&D intensity in biotechnology is 18% in Europe vis-à-vis 23,1% in US and in pharmaceutical is 13,1% in Europe vis-à-vis 15, 2% in US.

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

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

In Europe the pharmaceutical and biotech companies counted among the top European 1000 R&D investors are 105 (R&D Scoreboard, 2014) mostly present in UK (30), France (17) and Germany (17). Their R&D investment grew in the last three years, respectively 0.4% (UK), 3.9% (France) and 2.3% (Germany). In terms of performance the European pharmaceutical and biotech companies show the highest labor productivity (averaged and compared to the other sectors): €158.7 thousands value added per employee. Important differences between R&D intensity (R&D/Value added) and productivity (Value added per employee) are anyway present among the main companies in this sector: from R&D intensity of UCB 47,8% (Belgium) to 19,9% of Novo Nordisk (Denmark) and 19% of Bayer (Germany) and from labor productivity of Novo Nordisk €207.1 thousands (Denmark) to €62,6 thousands of Actavis (Ireland).

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

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

3.1. Pharmaceutical Inward R&D (in Euros)

Table 1 presents reported Inward R&D (in Euros) by host-country and by year, pre and post crisis. Here the values are presented for odd-years where data is systematically more complete (see also annex). There are only few cases in which the BERD Inward increased in the aftermath of the economic crisis: United States, Belgium and Czech Republic. Conversely, in all the other observed countries we see an opposite tendency.

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

Table 1. Inward R&D in Pharmaceuticals (Nace 21) before and after 2008 and for last available year: Millions Euro regions and selected countries

Region and Country	Annual Average		Latest available year
	Pre-2008 [a]	Post-2008	2013
Eastern Asia	**..**	**1450**	**1327**
Japan**	..	1450	1327
Eastern Europe	**22**	**163**	**169**
Czech Republic	22	30	26
Hungary	..	103	104
Poland	..	22	29
Romania	..	4	5
Slovakia	..	5	5
Northern America	**8772**	**12187**	**14645**
Canada	446	206	149
United States of America	8326	11981	14496
Northern Europe	**3554**	**1571**	**2657**
Estonia	..	1	1
Finland*	34	32	38
Ireland	257		0
Norway	0	24	24
Sweden	1190		0
United Kingdom	2073	1514	2594
Southern Europe	**13**	**462**	**398**
Italy	..	275	247
Portugal	13	0	0
Spain	..	187	151
Western Europe	**3396**	**3303**	**3672**
Austria	261	197	264
Belgium	774	1270	1582
France	753	593	531
Germany	1607	924	854
Netherlands	..	319	234
Switzerland**	..	..	207
Grand Total	**15757**	**19137**	**22868**

latest year=*2011, **

Unfortunately, due to the shortage of data, for some Countries it is not possible to study the "before and after" variation.

Table 2 allows additional analysis on the evolution on the inward investments in R&D. As already seen, the pharmaceutical industries of United States, Belgium and Czech Republic are the only ones that have experienced an increase of the inward investments in R&D. However, these three countries show different patterns in the evolution of their total BERD investments and in the level of internationalization. In the Czech Republic, the growth of inward BERD investments is not continuous over time but seems have stagnated in recent years. This fact has implied a decrease in the inward share of the total BERD investments. From 2011 both total and inward BERD start a falling trend. Conversely, Belgium shows a significant increase of total BERD at the same time that it is experiencing an increase in the internationalization of R&D activities in the pharmaceutical sector.

In contrast, the United States, demonstrates a divergence between inward share and total BERD investments. While the former decreases, from 2007 to 2011, the latter increases (from 30% to 33.4%). In all other observed countries, the opposite tendency is observed. Germany records the most pronounced decrease of inward investments in R&D. The increase of 23% is entirely ascribable to an increase of domestic R&D.

Table 2. Inward BERD as a percentage of total BERD in the pharmaceutical industry

		2007		**2009**		**2011**		**2013**
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	280	93.2%	193	91.7%	170	88.2%	285	92.6%
Belgium	1,249	76.5%	1,145	83.4%	1,428	89.2%	1,944	81.4%
Canada		:	423	58.6%	368	60.3%	372	40.1%
Czech Rep.	40	87.5%	45	86.7%	44	59.1%	38	68.4%
Denmark	:	:	879	:	894	:	1,110	:
Finland	:	:	109	23.9%	117	32.5%	120	:
France		:	854	76.7%	839	:	805	66.0%
Germany	3,312	52.7%	3,896	21.9%	4,070	26.2%	4,075	21.0%
Greece		:		:	60	:	59	:
Hungary	166	:	189	:	193	52.3%	202	51.5%
Ireland	147	:	240	:	127	:	165	:
Italy	474	:	534	:	578	52.4%	544	45.4%
Japan	7,752	:	9,158	:	11,084	13.1%	11,083	:
Netherlands	471	:	816	49.1%	700	45.9%	488	48.0%
Norway	63	:	52	:	92	:	49	49.0%
Poland	34	:	37	45.9%	41	48.8%	52	55.8%
Portugal	62	21.0%	68	1.5%	87	:	85	:
Romania	16	:	2	20.8%	9	55.6%	9	55.6%
Slovakia	7	:		:	13	:	2	104.2%
Slovenia	111	:	135	:	299	:	322	:
Spain	617	:	664	37.2%	636	25.6%	568	26.6%
Sweden	1,102	81.9%	595	:	858	:	805	:
UK		:	461	:	609	71.3%	539	481.3%*
USA	34,749	30.1%	32,217	32.4%	33,009	33.4%	:	:

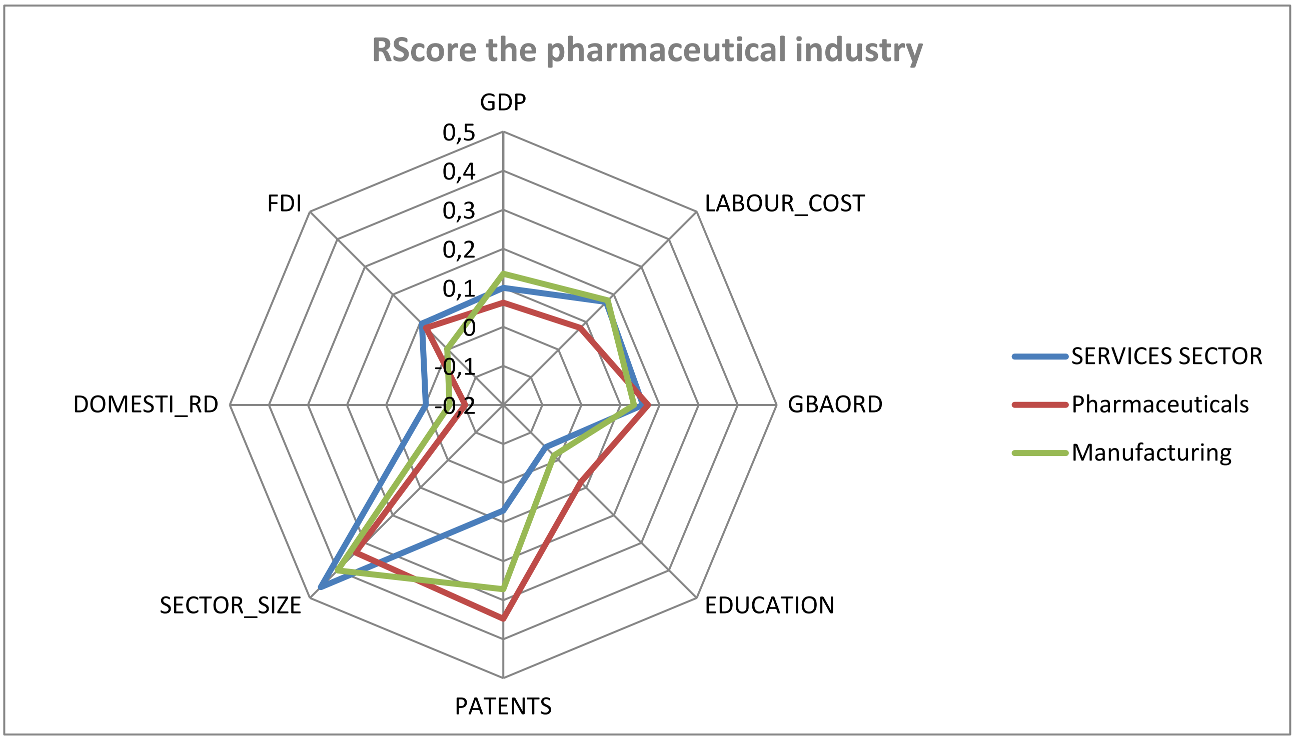
Notes: for UK data are not consistent.

4. R&D Main drivers using Responsiveness score.

An important contribution of the project is to use newly adapted empirical methods (see Chapter3) to better understand the factors that contribute to increased inward R&D investments. This section presents the main findings regarding the drivers of inward R&D in the pharmaceutical sector. As introduced above, the analysis is based on the idea that inward R&D may respond differently to a given change of a series of factors. Particularly, we expected a set of generic drivers – GDP, GBAORD, Patent, Education, Domestic R&D value, Labour cost- to influence the level of R&D investments.[2]

We use the Responsiveness score method to identify the main drivers of the inward investments in R&D. This methodology (based on iterated random coefficient regression) allows us to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes conditional to all other factors.

Figure 1. Responsiveness score. The pharmaceutical industry



The responsiveness score measures the effect of an increase in an individual factor (such as patenting activity) on the inward R&D investments of foreign firms above and beyond that caused by the other driving factors under consideration (such as government R&D). The figure above illustrates the responsiveness scores of the different factors in the pharmaceutical sector compared to two benchmark sectors, specifically, total Manufacturing and total Services. All the drivers seem to have the same influence on the inflow of R&D inward investments in the three sectors. "Patenting" records higher values in the Pharmaceutical sector than in the others considered. As we can see, the two most important drivers for the Pharmaceutical industry are, as we have explained above, "Patenting" and "Sectoral size". An increase in one of these two drivers may determine an increase in the inward investments in R&D of foreign company much more pronounced than the one caused by an increase of the other factors considered.

[2] See the annex 2 for further explication on the data used.

ANNEX. 1

Table.3 Total BERD investments in R&D in the Pharmaceutical sector.

country/Total	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	124				143	145	164	212	277	280		193		170		285
Belgium	500	587	581	706	704	778	939	921	1125	1249	1139	1145	1143	1428	1870	1944
Canada	340	371	514	597	785	726	759	869	939			423	489	368	391	372
Switzerland			1178				2309				2915				3152	
Czech Republic	6	8	13	14	21	19	30	28	145	40	43	45	42	44	44	38
Germany	1974	2090	2238	2277	2490	3059	3143	3390	3648	3312	3414	3896	3737	4070	4092	4075
Denmark	478	532		693	710	714	814	960	1044	0		879	948	894	1038	1110
Espana				320	403	461	479	544	606	617	647	664	629	636	587	568
France	2250	2458	2401	2517	2796	2993	3062	3096	3311		1052	854	833	839	807	805
Hungary	45	51	67	86	94	87	116	161	192	166	198	189	203	193	214	202
Ireland	83	82	64	71	131	190	250	267	207	147		240	236	127		165
Italy	493	490	515	514	486	483	367	390	340	474	480	534	557	578	577	544
Japan	4652	5683	7502	7462	8180	6747	6745	7673	8013	7752	8498	9158	10977	11084	12744	11083
Netherlands	327	419	396	401	382	455	505	544	551	471	447	408	382	350	257	244
Norway	54	67	65	56	60	54	65	60	71	63	60	52	62	92	52	49
Poland	16	22	20	25	29	29	26	34	32	34	53	37	39	41	62	52
Portugal	11	8	10	12	17	21	32	44	53	62	86	68	78	87	89	85
Sweden	926	1067	1346	1456	1566	1540	1211	909	974	1102		595		858		805
Slovenia	34	39	43	55	66	83	105	76	105	111	138	135	160	135	164	161
Slovakia				7						7			11	13	9	2
South Korea	52	132	133	237	216	181	220	275	382	469	395	389	482	560	722	745
United Kingdom	3309	3848	4670	4872	5024	4526	4773	4942	5793		447	461	533	609	622	539
United States	11299	11923	13851	11319	15014	14229	25305	28003	30982	34749	32724	32217	37275	33009	37474	

Table 4. Total inward R&D investments in the Pharmaceutical sector.

Country Inward	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria							120			261		177		150		264
Belgium			498	606	566	622	739	745	849	956		955		1274		1582
Canada	248	255	431	480	552	462	468	463	479	414	206	248	289	222	158	149
Switzerland															207	
Czech Republic	1	1	6	6	10	8	25	24	28	35	39	39	11	26	31	26
Germany						1581		1494		1747		852		1066		854
Espana												247		163		151
Finland	25	26	31	31				34	41			26		38		
France	498			615	705	793		720	746	747		655				
Hungary														101		104
Ireland		78		62				257								
Italy														303		247
Japan													967	1450	1327	
Netherlands											441	401	372	321	251	234
Poland												17		20		29
Portugal										13		1		0		0
Romania												1		5		5
Sweden	249	1326	1595	1463	1387	1373		1296		902						
United Kingdom	1135	1618	1555	2086	2026			1919	2149	2226	2018			434		2594
United States	5692	5809	6435	6838	6740	7519	6976	7001	9269	10457	8601	10428	11607	11019	13987	14496

Annex 2. Database description

Data on" GDP", "Total sectors production", accounting for the size of each sectors, and "Labour cost per sector" are taken from STAN Database (OECD). The database includes annual measures of output, labour input, investment and international trade. The current version of STAN is based on the International Standard Industrial Classification of all economic activities, Revision 3 (ISIC Rev. 3) and covers all activities (including services).

In order to measure the influence that Government support for research and development activities may have on Inward investments R&D, we use the GBAORD index, accounting for Government budget appropriations or outlays for research and development. GBAORD include all appropriations (government spending) given to R&D in central (or federal) government budgets. The source of data is OECD. Science Technology and Innovation (STI) indicators.

"Patents Application" is used as a proxy of the innovation capabilities of Countries. Data are taken from World Bank, World Development Indicators. As to capture the capability innovation of the Country we have add to the number of patent applications of resident the patent applications of non-resident.

In order to capture the influence that skills and education may have on Inward R&D we use the indicator "Tertiary graduates in mathematics, science and technology per 1000 inhabitants aged 20-29 years".

The data source is Eurostat, and the years observed go from 2001 to 2012. The levels and fields of education and training used follow the 1997 version of the International Standard Classification of Education (ISCED97) and the Eurostat Manual of fields of education and training (1999).

A.2. Inward R&D. Summary statistics with tally of missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Missing values	Total	Percent Missing
A1999	8	1139	1993	1	5809	A1999	26	34,0	76,47
A2000	7	1507	2269	6	6435	A2000	27	34,0	79,41
A2001	9	1354	2172	6	6838	A2001	25	34,0	73,53
A2002	7	1712	2311	10	6740	A2002	27	34,0	79,41
A2003	7	1765	2593	8	7519	A2003	27	34,0	79,41
A2004	5	1666	2982	25	6976	A2004	29	34,0	85,29
A2005	10	1395	2068	24	7001	A2005	24	34,0	70,59
A2006	7	1937	3311	28	9269	A2006	27	34,0	79,41
A2007	11	1614	3020	0	10457	A2007	23	34,0	67,65
A2008	5	2261	3631	39	8601	A2008	29	34,0	85,29
A2009	15	936	2645	0	10428	A2009	19	34,0	55,88
A2010	5	2649	5020	11	11607	A2010	29	34,0	85,29
A2011	17	976	2629	0	11019	A2011	17	34,0	50
A2012	6	2660	5569	31	13987	A2012	28	34,0	82,35
A2013	20	1065	3228	0	14496	A2013	14	34	41,18

ANNEX 3.

A.1 Manufacture of basic pharmaceutical products and pharmaceutical preparations

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
EU	Total	54.2	67.7	67.2	:	:	:	:	:	:
	Inward	61.9	75.5	75.0	:	:	:	:	:	:
Austria	Total	73.6	108.2	103.6	31.1	24.7	28.3	19.3	20.7	21.9
	Inward	86.7	146.7	130.9	40.5	28.1	33.7	24.5	26.1	27.8
Belgium	Total	:	91.7	104.2	:	:	:	:	:	:
	Inward	:	101.8	102.6	:	:	0	:	:	0
Bulgaria	Total	8.8	12.7	16.4	2.2	0.6	2.1	2.5	1	1.9
	Inward	10.5	17.4	22	:	:	:	:	:	:
Croatia	Total	:	20	31.5	:	1.4	0.8	:	1	1
	Inward	:	:	:	:	:	:	:	:	:
Cyprus	Total	57	:	:	5.9	:	:	13.6	:	:
	Inward	:	:	:	:	:	:	:	:	:
Czech Rep.	Total	14.2	20	34	7.9	5.8	4	3.4	3.5	4.2
	Inward	12.9	18.1	42.4	6	4.1	2.6	2	2	3
Denmark	Total	89.4	81.6	84	:	:	19.8	:	:	18.1
	Inward	87.5	87.6	91.6	:	:	18.9	:	:	16.7
Estonia	Total	15.6	30.7	27.3	3.1	0.8	1.4	3.4	1.7	0
	Inward	15.7	32.1	27.6	1.8	0.6	0.8	2.1	0.7	0
Finland	Total	72.3	52.4	65.1	:	140.7	112.6	:	32.4	37.5
	Inward	84.6	83.9	108.2	33.8	28.4	36.4	25.5	19.7	29.4
France	Total	60.1	74.2	69.9	43.1	:	42.6	22.2	:	24.9
	Inward	72.1	83	86.7	28.7	:	44.5	17.4	:	29.5
Germany	Total	60.3	79.2	75.1	18.8	15.2	15.7	10.4	10.4	10.1
	Inward	87	99.8	92.6	13.8	18.8	20.7	10.6	14.3	15.3
Greece	Total	:	:	48.6	:	:	5.3	:	:	3.7
	Inward	:	:	92.4	:	:	0	:	:	0
Hungary	Total	26.4	32.2	32.9	2.8	3.2	3	2.1	2.7	3.4
	Inward	28.6	34.7	36.2	2.6	2.6	2.8	1.8	2.3	3.3
Ireland	Total	160	163.5	:	:	:	:	:	:	:
	Inward	171.7	183.2	:	:	:	:	:	:	:
Italy	Total	51.4	63	61.5	:	20.4	20.2	10.9	12.5	14.2
	Inward	64.9	86.7	81.9	:	17.2	19.6	12	14.2	13.6
Latvia	Total	28.5	40.4	35.8	0.1	:	:	1.2	:	:
	Inward	17.2	23.6	:	0	:	:	0	:	:
Lithuania	Total	14.6	19.3	22.6	:	:	:	:	:	:
	Inward	20.1	12.2	32	:	:	:	:	:	:
Luxembourg	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Malta	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Netherlands	Total	98.2	108.7	110.2	16.7	19.3	22.3	15.7	19.2	24.4
	Inward	167.9	116.7	105.8	10.1	14.8	17.1	21	20.6	21.9
Norway	Total	:	118.2	131.6	:	18.3	17.3	:	19	18.5
	Inward	:	115.9	132	:	17.3	18.5	:	16.5	17.8
Poland	Total	20.4	25.7	26.8	1.8	2.1	2.6	1.8	2.2	2.7
	Inward	21.7	27.1	29	0.2	0.2	0.5	0.2	0.3	0.5
Portugal	Total	27.8	35.7	35.3	0.1	0.5	0	2.3	4	3.8
	Inward	32.5	39.1	36.4	0	0.1	0	1.1	2.7	3.1
Romania	Total	16.3	15.4	15.5	1.6	0.2	0	0.6	0.5	0
	Inward	19.3	16.5	15.4	2.3	0.4	0	1	0.8	0
Slovakia	Total	15.4	28.2	36.3	0.2	0.5	0.6	0.2	0.5	0.7
	Inward	15.9	32.4	42.7	0.2	0.2	0.2	0.1	0.2	0.1
Slovenia	Total	20.3	32.1	:	30.9	21.8	23.5	12.9	16.5	:
	Inward	19.5	24.8	:	:	:	13.8	:	:	:
Spain	Total	53.3	50.3	50.2	12.8	13.6	12.8	13	13.4	13.2
	Inward	60.5	54.2	62.8	10.4	10.5	9	9.7	9.8	10.3
Sweden	Total	88.2	:	127.8	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
UK	Total	66.1	77.5	68	:	10.2	12.8	9.5	8.9	8.5
	Inward	81.2	:	97.4	:	11	15.1	12.2	:	10.9

Annex. **RESPONSIVENESS SCORES DEFINITION AND ESTIMATION.**

In this section we provide a technical presentation of the Random Coefficient Regression (RCR) used to compute Countries' responsiveness scores. The basic econometrics of this model can be found in Wooldridge (2002, pp. 638-642) whose this section is a concise account with slight modifications. The application of RCR in this work follow this simple protocol:

1. Define y, the outcome variable, "Inward R&D investments from 1998 to 2013".
2. Define a set of Q factors thought of as affecting y, and indicate the generic factor with x_j.
3. Define a RCR linking y to the various x_j, and extract a Country-specific *responsiveness effect* of y to the all set of factors x_j, with j=1, ..., Q.
4. For the generic Country i and factor j, indicate this effect as b_{ij} and collect all of them in a matrix **B**. Finally, aggregate by Country (row) and by factor (column) the b_{ij} getting synthetic Country and factor responsiveness measures.

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

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

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

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

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

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

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

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

If all variables are standardized, partial effects are *beta coefficients* so that they are independent of the unit of measurement and can be compared and summed.

Once matrix **B** is known, we can define for each region *i* the Total Country Responsiveness (TCR) and the Mean Country Responsiveness (MCR) as:

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

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

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

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

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

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

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

By repeating this procedure for each Country *i* and factor *j*, we can finally obtain $\hat{\mathbf{B}}$, the estimation of matrix **B**.

When a longitudinal dataset is available, the estimation of **B** can be obtained either by using random-effect or fixed-effects estimation of this panel regression:

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

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

R&D internationalization in computer, electronic and optical products (NACE 26)

Submitted under subtask 4.3. (Drivers of foreign R&D investments)

Version 1:

1. Introduction

This case study presents a digest of R&D internationalization of the manufacture of computer, electronic and optical products (NACE 26). The main objective is to identify some of the key drivers of inward R&D in the electronics industry. Based primarily on statistics on total BERD flows and inward-BERD flows (excludes domestic BERD), the study integrates productivity data from the Foreign affiliates statistics (FATS) together with several other indicators to investigate the underlying determinants that explain the observed patterns of R&D internationalization. Statistics for outward BERD are presented in a separate case study. Certain limitations in the data are briefly presented.

2. The *computer, electronic and optical products industry*

A number of characteristics and tendencies can be used to introduce the sector (see box).

Box 1. R&D internationalization in computer, electronic and optical products (NACE 26)

In May 2013, Europe adopted an electronics strategy covering micro and nanoelectronics.

- The computer, electronic and optical products industries drive innovation and provide key-enabling technologies.
- Rapid technological change is driving the consolidation of electronics industry.
- Technology hardware and electronic equipment sectors appear to engage more in greenfield FDI to benefit from local R&D resources.
- Key challenges: developing more capable semiconductor chips.
- Future technology: nanoelectronics (semiconductor components and highly miniaturised electronics) and Photonics (conversion of sunlight into electricity, photodiodes, LEDs and lasers).

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

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

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

Table 1. Top 10 Global enterprises in technology hardware and equipment.

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

Source: EU R&D scoreboard 2015.

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

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

Key technological trends in this sector include recent developments in compound semiconductor devices, nanotechnology, micro-sensors & actuators, advanced robotics (involving ICT and new materials), and additive manufacturing (3D printing). Two electronic firms Samsung and LG involves nanotechnology and nanocrystal/quantum dot ultra-high definition TV screens.

3. Inward R&D in computer, electronic and optical products.

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

Table 2. Inward BERD as a percentage of total BERD in computer, electronic and optical products.

		2009		**2011**		**2013**
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	527	67.4%	524	66.4%	616	64.4%
Belgium	453	50.8%	425	51.5%	478	52.3%
Canada	1,608	20.0%	1,777	18.4%	1,728	28.4%
Czech Rep.	50	52.0%	47	40.4%	59	50.8%
Denmark	351	:	326	:	386	24.6%
Finland	2,635	5.5%	2,510	4.2%	1,781	:
France	3,373	27.9%	3,193	:	3,669	41.5%
Germany	5,815	14.1%	6,563	20.6%	7,342	21.8%
Greece		:	23	:	15	:
Hungary	56	:	66	69.7%	55	78.2%
Ireland	155	:	153	:	103	:
Italy	1,272	:	1,444	21.3%	1,296	20.8%
Japan	24,215	:	28,321	1.7%	22,463	:
Netherlands	796	17.0%	1,152	12.9%	1,306	12.3%
Norway	215	:	214	21.0%	209	25.8%
Poland	21	9.5%	32	6.3%	35	11.4%
Portugal	21	:	26	:	24	:
Romania	5	50.0%	5	8.3%	15	:
Slovakia	1	:	3	33.3%	4	25.0%
Slovenia	39	:	118	6.8%	80	8.3%

Spain	241	16.6%	208	11.5%	176	13.1%
Sweden	1,751	:	2,105	:	2,026	:
UK	1,093	:	1,126	50.9%	1,202	91.5%
USA	40,461	7.7%	45,046	6.8%		:

Source: BERD flows database.

Notes

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

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

Table 3 shows the average value (in millions of Euros) for the years 2009 and 2011 and for the most recent year 2013. Little change is detected during these three years except in France and Germany where some growth is detected and in Japan where there were some notable declines.

Table 3. Inward R&D computer, electronic and optical products after 2008.

Region and Country	Annual Average Post 2008	Latest available year
Japan**	491	306
Eastern Europe	75	78
Czech Republic	25	30
Hungary	45	43
Poland	3	4
Romania*	2	1
Slovakia	1	1
Northern America	3575	3883
Canada	380	490
USA	3195	3393
Northern Europe	1108	1355
Denmark	95	95
Estonia*	1	1
Finland*	126	105
Norway	50	54
UK	837	1100
Southern Europe	326	301
Italy	289	270
Slovenia	8	8
Spain	29	23

Western Europe	3236	4531
Austria	367	397
Belgium	233	250
France	1232	1523
Germany	1257	1597
Netherlands	148	160
Switzerland**	..	604
Grand Total	8810	10454

Table A3 shows apparent labour productivity, BERD intensity (share of BERD in value added) and the share of R&D employment for 2009, 2011 and 2013. Foreign ownership plays a central role here as total BERD is distinguished from inward BERD. Apparent labour productivity of inward BERD appears consistently higher in the larger countries such as France, Germany, Italy and the UK. A similar pattern is observed for BERD intensity and the share of R&D employment. Ireland appears to have the highest apparent labour productivity, perhaps because of the strong presence of Apple, but it could also be due to transfer pricing. Several small countries show the opposite trend, where total labour productivity is higher in the domestic industry. Results appear mixed as to whether any significant catching up took place over the last decade.

4. *Inward R&D in motor vehicles* using responsiveness scores

This section explores the impact of drivers of inward R&D in the automotive industry. Here we apply an (iterated random coefficient regression) analysis based on a method developed by IRCRES. Following Woodridge (2002), the approach calculates unit responsiveness scores. This approach assumes that individual units react ('responsiveness') to the individual factors differently. The approach allows us to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, etc.), conditional on the other factors at play. (See Cerulli (2015))

Figure 1 illustrates the responsiveness scores for the automotive industry against a benchmark for manufacturing and for the service sectors. It illustrates that size-effects (GDP and the size of the sectors) are factors that are fairly consistent for all sectors in consideration. Here labour costs and government budgetary appropriations for R&D (GBAORD) are average in computer, electronic and optical products. Here the educational level and patenting activity plays an instrumental role in relation to inward R&D in this sector. Details are presented in Annex A.5.

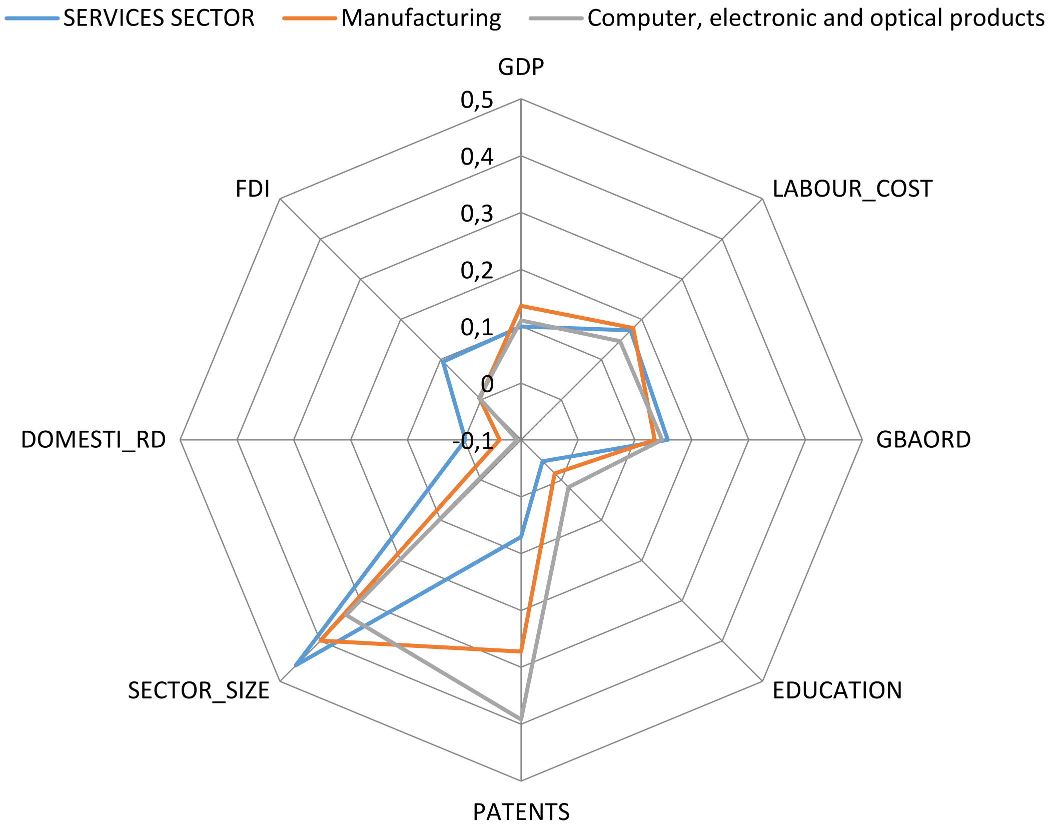
5. Overview of the computer, electronic and optical products industry.

- The share of BERD performed abroad has remained relatively stable within Europe since 2008, with some modest gains in France, Germany and the Netherlands. While research remains concentrated near the home bases of lead firms, internationalization has focused more on production facilities abroad, particularly in east Asia.
- There is no main player in the European computer, electronic and optical products industry as several countries have headquarters in Europe. Germany, Italy, France, Italy, the Netherlands, Sweden and the United Kingdom have research programmes cantered in Europe. Europe depends heavily on the United States and east Asia, which means that research networks will play an important role in transferring technology and fostering innovation
- The level of economic development explains large national differences in the R&D intensity, especially in the computer, electronic and optical products industry. Here the relatively backward countries contribute relatively low-value added activities to the global value chain. There is some indication that technological upgrading is taking place in east Asia and there may be significant

catching-up taking place in eastern Europe though from a low level. Apparent labour productivity more than doubled between 2009 and 2013 in Bulgaria, Czech Republic, and Slovakia (and possibility Slovenia)

- Labor productivity (both in terms of value added and production output) appears to be higher in the countries with inward FDI, except for new small countries where it appears higher in the domestic economy.

Figure 1: Computer, electronic and optical products Inward R&D main drivers using Responsiveness Scores



Annex

Table A.1. *Total BERD and inward BERD in computer, electronic and optical products*

Total BERD	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Austria										882		872		1013
Belgium									472	683	409	644	457	728
Bulgaria										3	5	1	6	6
Canada	357	112	285	249	226	289	283	236	290	1930	1864	2104	2566	2218
Croatia									1	2	2	2	1	2
Czech Rep.						34	47	39	40	76	66	66	67	89
Denmark										351	341	326	380	481
Estonia									2	4	3	4	2	3
Finland									2726	2781	2585	2615	1906	1781
France									3288	4314	3091	3193	3456	5192
Germany									6475	6633	5995	7918	7392	8939
Greece												23		15
Hungary									41	56	53	112	56	98
Ireland										155	152	153		103
Israel											1015	1071	1019	
Italy									1198	1272	1379	1751	1368	1566
Japan									24702	24215	25555	28812	29187	22463
Latvia									2	1	2	1	2	3
Lithuania									3	4	5	5	6	6
Malta									4	4	3	3	4	3
Netherlands									974	931	1258	1301	1410	1466
Norway									228	215	190	259	221	263
Poland									22	23	38	34	38	39
Portugal									30	21	19	26	26	24
Romania									8	11	5	6	21	15
Slovakia									2	1	2	4	4	5
Slovenia									44	39	39	126	38	96
South Korea									7883	7561	10773	12129	14903	16544
Spain									273	281	232	232	180	199
Sweden										1751		2105		2026
Switzerland									718				1471	
UK									1509	1093	964	1699	1204	2302
USA									2883	43582	49095	48117	54055	3393

Inward BERD	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria										355		348		397
Belgium										230		219		250
Canada	357	112	285	249	226	289	283	236	290	322	308	327	635	490
Czech Rep.						34	47	39	40	26	19	19	18	30
Denmark														95
Estonia										1		1		
Finland										146		105		
France										941				1523
Germany										818		1355		1597
Hungary												46		43
Italy												307		270
Japan											329	491	306	
Netherlands									116	135	136	149	164	160
Norway												45		54
Poland										2		2		4
Romania										6		1		0
Slovakia										0		1		1
Slovenia												8		16
Spain										40		24		23
Switzerland													604	
UK												573		1100
USA									2883	3121	3930	3071	3411	3393

BERD Flows Database

Table A.2. Inward BERD with summary statistics and missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable Missing values	Total	% Missing
A2000	1	357	.	357	357	33	34	97.06
A2001	1	112	.	112	112	33	34	97.06
A2002	1	285	.	285	285	33	34	97.06
A2003	1	249	.	249	249	33	34	97.06
A2004	1	226	.	226	226	33	34	97.06
A2005	2	162	180.3122	34	289	32	34	94.12
A2006	2	165	166.8772	47	283	32	34	94.12
A2007	2	138	139.3	39	236	32	34	94.12
A2008	4	832	1371.166	40	2883	30	34	88.24
A2009	15	410	806.4007	0	3121	19	34	55.88
A2010	5	944	1673.873	19	3930	29	34	85.29
A2011	20	355	715.6253	0	3071	14	34	41.18
A2012	6	856	1274.675	18	3411	28	34	82.35
A2013	19	497	865.3257	0	3393	15	34	44.12

Table A3: Labour productivity and BERD intensity in the computer, electronic and optical products industry

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
EU	Total	54.2	67.7	67.2	:	:	:	:	:	:
	Inward	61.9	75.5	75.0	:	:	:	:	:	:
Austria	Total	73.6	108.2	103.6	31.1	24.7	28.3	19.3	20.7	21.9
	Inward	86.7	146.7	130.9	40.5	28.1	33.7	24.5	26.1	27.8
Belgium	Total	:	91.7	104.2	:	:	:	:	:	:
	Inward	:	101.8	102.6	:	:	0	:	:	0
Bulgaria	Total	8.8	12.7	16.4	2.2	0.6	2.1	2.5	1	1.9
	Inward	10.5	17.4	22	:	:	:	:	:	:
Croatia	Total	:	20	31.5	:	1.4	0.8	:	1	1
	Inward	:	:	:	:	:	:	:	:	:
Cyprus	Total	57	:	:	5.9	:	:	13.6	:	:
	Inward	:	:	:	:	:	:	:	:	:
Czech Rep.	Total	14.2	20	34	7.9	5.8	4	3.4	3.5	4.2
	Inward	12.9	18.1	42.4	6	4.1	2.6	2	2	3
Denmark	Total	89.4	81.6	84	:	:	19.8	:	:	18.1
	Inward	87.5	87.6	91.6	:	:	18.9	:	:	16.7
Estonia	Total	15.6	30.7	27.3	3.1	0.8	1.4	3.4	1.7	0
	Inward	15.7	32.1	27.6	1.8	0.6	0.8	2.1	0.7	0
Finland	Total	72.3	52.4	65.1	:	140.7	112.6	:	32.4	37.5
	Inward	84.6	83.9	108.2	33.8	28.4	36.4	25.5	19.7	29.4
France	Total	60.1	74.2	69.9	43.1	:	42.6	22.2	:	24.9
	Inward	72.1	83	86.7	28.7	:	44.5	17.4	:	29.5
Germany	Total	60.3	79.2	75.1	18.8	15.2	15.7	10.4	10.4	10.1
	Inward	87	99.8	92.6	13.8	18.8	20.7	10.6	14.3	15.3
Greece	Total	:	:	48.6	:	:	5.3	:	:	3.7
	Inward	:	:	92.4	:	:	0	:	:	0
Hungary	Total	26.4	32.2	32.9	2.8	3.2	3	2.1	2.7	3.4
	Inward	28.6	34.7	36.2	2.6	2.6	2.8	1.8	2.3	3.3
Ireland	Total	160	163.5	:	:	:	:	:	:	:
	Inward	171.7	183.2	:	:	:	:	:	:	:
Italy	Total	51.4	63	61.5	:	20.4	20.2	10.9	12.5	14.2
	Inward	64.9	86.7	81.9	:	17.2	19.6	12	14.2	13.6
Latvia	Total	28.5	40.4	35.8	0.1	:	:	1.2	:	:
	Inward	17.2	23.6	:	0	:	:	0	:	:
Lithuania	Total	14.6	19.3	22.6	:	:	:	:	:	:
	Inward	20.1	12.2	32	:	:	:	:	:	:
Netherlands	Total	98.2	108.7	110.2	16.7	19.3	22.3	15.7	19.2	24.4
	Inward	167.9	116.7	105.8	10.1	14.8	17.1	21	20.6	21.9
Norway	Total	:	118.2	131.6	:	18.3	17.3	:	19	18.5
	Inward	:	115.9	132	:	17.3	18.5	:	16.5	17.8
Poland	Total	20.4	25.7	26.8	1.8	2.1	2.6	1.8	2.2	2.7
	Inward	21.7	27.1	29	0.2	0.2	0.5	0.2	0.3	0.5
Portugal	Total	27.8	35.7	35.3	0.1	0.5	0	2.3	4	3.8
	Inward	32.5	39.1	36.4	0	0.1	0	1.1	2.7	3.1
Romania	Total	16.3	15.4	15.5	1.6	0.2	0	0.6	0.5	0
	Inward	19.3	16.5	15.4	2.3	0.4	0	1	0.8	0
Slovakia	Total	15.4	28.2	36.3	0.2	0.5	0.6	0.2	0.5	0.7
	Inward	15.9	32.4	42.7	0.2	0.2	0.2	0.1	0.2	0.1
Slovenia	Total	20.3	32.1	:	30.9	21.8	23.5	12.9	16.5	:
	Inward	19.5	24.8	:	:	:	13.8	:	:	:
Spain	Total	53.3	50.3	50.2	12.8	13.6	12.8	13	13.4	13.2
	Inward	60.5	54.2	62.8	10.4	10.5	9	9.7	9.8	10.3
Sweden	Total	88.2	:	127.8	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
UK	Total	66.1	77.5	68	:	10.2	12.8	9.5	8.9	8.5
	Inward	81.2	:	97.4	:	11	15.1	12.2	:	10.9

Source: Eurostat

R&D internationalization in the manufacture of electrical equipment (NACE 27)

Submitted under subtask 4.3. (Drivers of foreign R&D investments)

Version 4:

1. Introduction

This case study presents a digest of R&D internationalization of the manufacture of electrical equipment (NACE 27). The main objective is to identify some of the key drivers of inward R&D in the electrical equipment industry. Based primarily on statistics on total BERD flows and inward-BERD flows (excludes domestic BERD), the study integrates productivity data from the Foreign affiliates statistics (FATS) together with several other indicators to investigate the underlying determinants that explain the observed patterns of R&D internationalization. Statistics for outward BERD are presented in a separate case study. Certain limitations in the data are briefly presented.

2. The electrical equipment industry

The electrical equipment industry is classified as a medium-high technology industry based on its R&D intensity. Some multinational firms such as Samsung could easily be classified in computer, electronic and optical products (NACE 26), especially when you consider their smart phones, smart televisions and other related products that BERD intensity in Samsung is approximately twice that of Apple. Robert Bosch, for example, could be classified in electrical equipment, but its core activity is automotive. There are some important differences in the Industry Classification Benchmark (ICB) system and the Statistical classification of economic activities in the European Community (NACE). The Institute for Prospective Technological Studies (IPTS) uses the former to compile the EU R&D Scoreboard and Eurostat uses the latter to compile the BERD statistics. The main difference is that consumer electronics are identified separately from electronic office equipment and are considered to be electrical goods.

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

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

Table 1. Top 10 Global enterprises producing consumer electronic and electrical equipment.

World Rank	Name	Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)
2	SAMSUNG ELECTRONICS	**South Korea**	12,187.0	7.9	13.1	154,500.7
24	SIEMENS	**Germany**	4,377.0	6.1	2.1	71,920.0
33	GENERAL ELECTRIC	**US**	3,486.5	2.8	1.1	122,386.1
47	TOSHIBA	**Japan**	2,407.9	5.3	1.0	45,442.3
51	HITACHI	**Japan**	2,285.9	3.4	-5.2	66,737.2
70	PHILIPS	**Netherlands**	1,693.0	7.9	2.4	21,391.0
75	HONEYWELL	**US**	1,558.4	4.7	0.1	33,198.2
94	HON HAI PRECISION INDUSTRY	**Taiwan**	1,269.9	1.2	4.5	109,520.9
95	MITSUBISHI ELECTRIC	**Japan**	1,226.4	4.2	1.6	29,515.0
112	FUJIFILM	**Japan**	1,100.2	6.5	-1.8	17,018.0

Source: EU R&D scoreboard 2015.

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

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

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

3. Inward R&D in electrical equipment industry

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

Table 2. Inward BERD as a percentage of total BERD in electrical machinery and apparatus

		2007		2009		2011		2013
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	647	74.5%	826	71.4%	736	59.9%	688	56.5%
Belgium	128	74.2%	197	86.3%	222	64.0%	137	41.6%
Canada		:	103	54.4%	105	42.9%	102	54.9%
Czech Rep.	38	39.5%	40	67.5%	66	59.1%	72	61.1%
Denmark	67	6.0%	52	:	79	:	67	14.9%
Finland	147	59.2%	212	68.4%	260	67.3%	300	:
France		:	838	20.3%	649	:	660	30.5%
Germany	1,343	30.6%	1,333	29.6%	1,602	53.1%	2,130	30.3%
Hungary	16	93.8%	21	:	22	81.8%	28	82.1%
Ireland	112	:	17	:	13	:	34	:
Italy	205	:	381	:	461	36.9%	483	34.2%
Japan	6,698	3.3%	2,629	:	3,120	1.7%	2,709	:
Netherlands	67	:	1,114	2.3%	962	2.2%	1,040	2.1%
Norway	77	22.1%	46	:	48	35.4%	60	38.3%
Poland	29	37.9%	32	20.8%	52	80.8%	78	62.8%
Portugal	12	58.3%	27	:	44	:	35	:
Romania	15	:	6	20.8%	17	11.8%	5	16.7%
Slovakia	3	66.7%	6	66.7%	18	38.9%	12	33.3%
Slovenia	24	8.3%	42	:	201	24.9%	174	46.0%
Spain	170	:	211	22.3%	195	42.1%	190	53.2%
Sweden	180	23.9%	214	:	268	:	329	:
UK	285	83.2%	154	:	175	57.7%	189	105.8%
USA	1,976	16.4%	2,390	17.1%	2,583	18.2%		:

Source: BERD flows database

Notes:

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

From a longer period viewpoint, covering the period just before the financial crisis and the one afterwards, inward BERD appears to have increased by about 25% between the two periods in western Europe and roughly doubled in eastern and southern Europe, although from a low level. Table 3 shows the average value (in millions of Euros) both before and after 2008 and 2013. This is put in contrast to the large increases observed in the US and the very large declines observed for Japan. Inward flows to Northern Europe declined, possibly because of missing or irregular data.

Table 3. Inward R&D in the motor-vehicles industry before and after 2008: Regional presentation for a selection of countries.

Region and Country	Annual Average		Latest available year
	Pre-2008 [a]	Post-2008	2013
Japan	**152**	**54**	**26**
Eastern Europe	**56**	**101**	**123**
Bulgaria	0	1	1
Czech Republic	12	37	44
Hungary	31	21	23
Poland	11	36	49
Romania	0	2	2
Slovakia	2	5	4
Northern America	**354**	**577**	**749**
Canada	43	52	56
USA	311	524	693
Northern Europe	**489**	**342**	**410**
Denmark	4	10	10
Estonia*	0	2	2
Finland*	87	160	175
Ireland	53		0
Norway	17	20	23
Sweden	105		0
UK	223	151	200
Southern Europe	**122**	**272**	**306**
Italy		168	165
Portugal	4	0	0
Slovenia	2	28	40
Spain	116	77	101
Israel	**5**	**6**	**0**
Western Europe	**996**	**1435**	**1314**
Austria	255	473	389
Belgium	74	123	57
France	275	186	201
Germany	392	630	645
Netherlands		23	22
Grand Total	**2173**	**2787**	**2928**

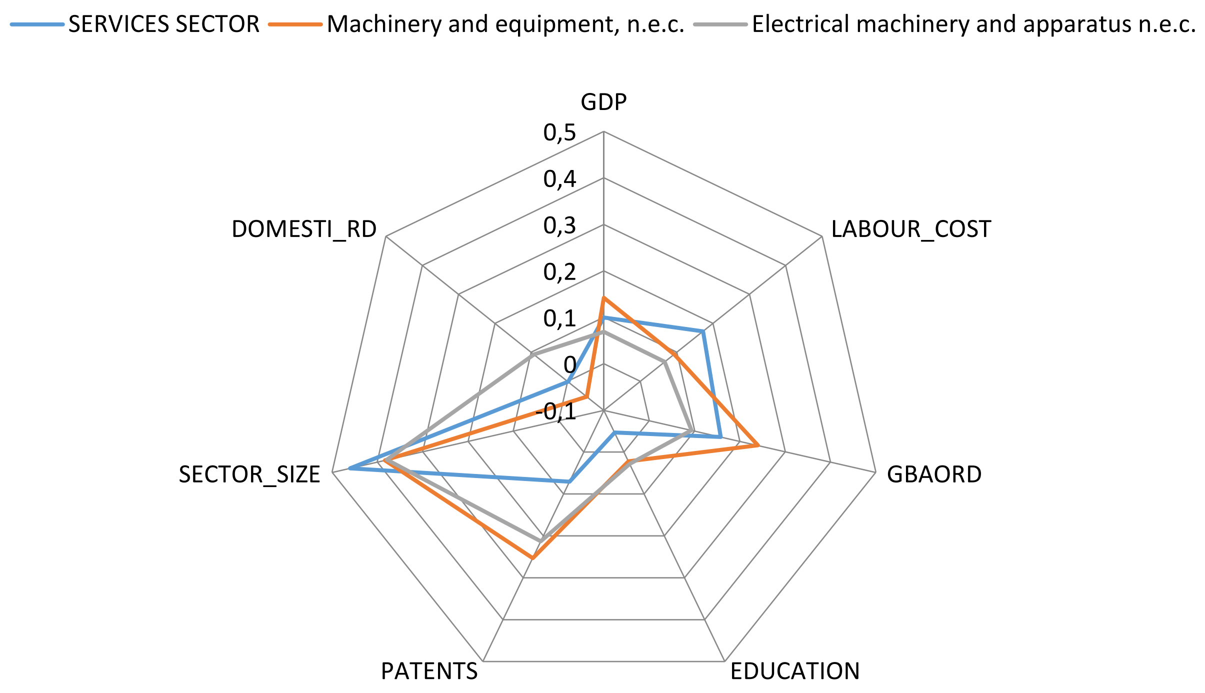
Table A3 shows apparent labour productivity, BERD intensity (share of BERD in value added) and the share of R&D employment for 2009, 2011 and 2013. Foreign ownership plays a central role here as total BERD is distinguished from inward BERD. Apparent labour productivity of inward BERD appears higher than for total BERD for Europe as a whole. This includes Germany, Italy and the UK, but the results tend in the opposite direction in France and the Netherlands. Labour productivity also appears to have risen in the east European catching-up economies across all three periods, but the larger west European countries experienced mixed results from 2011 to 2013. The Nordic countries were an exception to this trend with labour productivity growth continuing in the third period. The share of BERD also tended to increase over the three periods, but the share of R&D employment does not rise in all countries in the third period. Although not the highest in terms of BERD intensity, Norway observes the highest apparent labour productivity. There appears to have been some significant catching up that took place over the last decade.

4. *Inward R&D in motor vehicles* using responsiveness scores

This section explores the impact of drivers of inward R&D in the automotive industry. Here we apply an (iterated random coefficient regression) analysis based on a method developed by IRCRES. Following Woodridge (2002), the approach calculates unit responsiveness scores. This approach assumes that individual units react ('responsiveness') to the individual factors differently. The approach allows us to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, etc.), conditional on the other factors at play. (See Cerulli (2015))

Figure 1 illustrates the responsiveness scores for the automotive industry against a benchmark for manufacturing and for the service sectors. It illustrates that size-effects (GDP and the size of the sectors) are factors that are fairly consistent for all sectors in consideration. The figure shows machinery and equipment is broadly similar to the manufacture of electrical equipment. Domestic factors tend to predominate in this sector. Details are presented in Annex A.5.

Figure 1: Electrical machinery and apparatus Inward R&D main drivers using Responsiveness Scores



5. Overview of the electrical equipment industries

There are several characteristics of the industry that are noteworthy and that can help to shape internationalisation of R&D going forward. The box indicates some fo these.

Box 1. R&D internationalization in electrical equipment (NACE 27)

Europe has the largest electrical engineering market, followed by the USA and Japan.

- EU firms tend to have higher than average R&D intensity, but a relatively lower degree of concentration.
- Electrical Equipment sector has the highest patent propensity, about ten times larger than that of the pharmaceuticals, which indicates it is a key enabling technology, but the sector is driven mainly by Asia.
- Greenfield investment has been strong as firms attempt tap into local R&D resources, particularly in Asia.
- Key challenges: development of smart technologies.
- Future technology: Imaging physics, including all pictorial communication, and Dynamo-electric machines.

In this light the case study highlights the following:

- The share of BERD performed has increased in the European Union over the last decade. Internationalization of electrical equipment R&D has focused mostly on development, while research remains concentrated near the home bases of lead firms. But inward BERD is generally higher than domestic BERD in virtually all countries.

- France, Germany, Netherlands and the UK are key players in the European electrical equipment industry. These four countries make up about 60% total European BERD. There was not much
- The level of economic development explains large national differences in the R&D intensity. There was little activity within east Europe with the exception of Slovenia and possibly Poland. There appears to have been some significant catching up that took place over the last decade.
- Labor productivity (both in terms of value added and production output) appears to be higher in the countries with inward FDI, except for the Netherlands (mainly because of Phillips).
- European firms account for about half of global R&D in the industry, not including China or Taiwan. There appears to have been some significant catching up that took place over the last decade in east Asia. The rapid decline BERD in the Japanese electrical equipment industry likely reflects the factors influencing the technology upgrading and catch-up of East Asia. China, Taiwan and India will play an increasingly important role in the contribution of R&D activities.

Annex

Table A.1. *Total BERD in the electrical industry (NACE 27)*

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	97				133	136	144	166	195	647		826		736		688
Belgium	72	79	91	91	148	115	117	115	111	128	218	197	202	222	139	137
Bulgaria	0	0			0	0	0	0	1	1	1	1	2		4	3
Canada	81	108	170	237	132	98	79	84	86			103	116	105	102	102
Croatia											2	3	2	2	2	3
Czech Rep.	10	10	11	12	16	21	24	27	33	38	47	40	55	66	81	72
Denmark	50	68		89	112	119	117	94	175	67		52	72	79	74	67
Estonia				0		0	1	2	0	0	0	1	2	4	4	2
Finland						105	123	123	118	147	210	212	233	260	289	300
France	645	690	678	681	755	810	850	811	974		711	838	634	649	667	660
Germany	930	1021	1021	1158	1111	1080	1132	1146	1247	1343	1496	1333	1345	1602	1732	2130
Greece	5	7	6	4	3	3	4	5						11		7
Hungary	4	6	27	17	14	22	32	22	19	16	22	21	19	22	20	28
Iceland	3	0	0	0	0	1	1	0	1	1	0			1		
Ireland	39	37	13	12	60	93	95	34	73	112		17	17	13		34
Israel													117	165	173	
Italy	180	140	184	232	165	154	152	173	188	205	379	381	434	461	472	483
Japan	7649	8325	10757	9661	7962	7550	7513	7746	7533	6698	2628	2629	3275	3120	3324	2709
Latvia			0				0		0				0		4	
Lithuania					1	1	1	1	1	1	2	1	1	1	1	1
Luxembourg																3
Malta					1			2	2	3	1	0	0	0	0	1
Netherlands	71	74	62	67	63	71	73	66	69	67	1150	1114	856	962	957	1040
Norway	40	45	52	55	49	45	36	39	41	77	46	46	45	48	56	60
Poland	40	37	24	20	20	24	17	21	24	29	33	32	49	52	113	78
Portugal	10	11	13	14	11	7	5	2	7	12	25	27	34	44	38	35
Romania						10	8	12	13	15	8	6	6	17	7	5
Slovakia	3	1	4	2	2	2	2	2	3	3	20	6	17	18	17	12
Slovenia	7	7	10	12	14	14	16	17	21	24	31	42	48	201	47	174
South Korea	122	160	169	196	188	167	165	288	389	368	425	434	545	597	747	710
Spain				92	134	169	221	178	209	170	233	211	206	195	209	190
Sweden	82	88	113	129	149	164	160	153	173	180		214		268		329
UK	625	542	693	569	591	542	598	583	632	285	119	154	190	175	210	189
USA	4322	3962	3906	5561	2156	1833	2142	1948	1817	1976	2137	2390	2504	2583	2403	

Inward BERD in the electrical industry

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	:	:	:	:	:	28	27	:	:	482	:	590	:	441	:	389
Belgium	:	:	73	70	53	53	66	74	102	95	:	170	:	142	:	57
Bulgaria	:	:	:	:	:	:	:	0	:	:	:	:	:	:	:	1
Canada	40	47	86	133	57	49	44	41	39	40	38	56	56	45	41	56
Czech Republic	2	2	2	3	6	9	13	13	12	15	17	27	32	39	49	44
Denmark	:	:	:	:	:	:	:	:	:	4	:	:	:	:	:	10
Estonia	:	:	:	:	:	:	0	0	0	0	:	1	:	2	:	:
Finland	49	48	54	53	:	:	:	:	:	87	:	145	:	175	:	:
France	143	:	:	139	171	198	:	314	271	314	:	170	:	:	:	201
Germany	:	:	:	:	:	:	:	373	:	411	:	394	:	851	:	645
Hungary	:	:	:	:	:	61	14	16	16	15	:	:	:	18	:	23
Ireland	:	:	:	:	:	86	:	20	:	:	:	:	:	:	:	:
Israel	:	:	:	:	:	:	:	:	:	5	6	6	:	:	:	:
Italy	:	:	:	:	:	:	:	:	:	:	:	:	:	170	:	165
Japan	3	0	13	77	69	77	113	154	128	224	:	:	62	54	26	:
Netherlands	:	:	:	:	:	:	:	:	:	:	28	26	14	21	22	22
Norway	:	:	:	:	:	:	:	:	:	17	:	:	:	17	:	23
Poland	2	17	3	2	11	12	5	10	12	11	:	16	:	42	:	49
Portugal	:	:	:	:	:	:	:	1	:	7	:	0	:	0	:	0
Romania	:	:	:	:	:	:	0	:	0	0	:	3	:	2	:	2
Slovakia	:	:	:	:	:	:	:	1	2	2	:	4	:	7	:	4
Slovenia	:	:	:	:	:	:	:	:	1	2	:	:	:	17	:	40
Spain	:	:	:	:	:	109	108	122	:	:	:	47	:	82	:	101
Sweden	53	44	130	196	134	107	:	165	:	43	:	:	:	:	:	:
UK	93	64	107	135	129	:	:	209	158	237	275	:	:	101	:	200
USA	789	1121	891	977	402	297	:	:	307	325	331	409	473	471	601	693

BERD Flows Database

Table A.2. Inward BERD with summary statistics and missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Missing values	Total	Percent Missing
A1998	9	130	251	2	789	A1998	25	34	73.5
A1999	9	149	365	0	1121	A1999	25	34	73.5
A2000	9	151	281	2	891	A2000	25	34	73.5
A2001	10	179	287	2	977	A2001	24	34	70.6
A2002	9	115	121	6	402	A2002	25	34	73.5
A2003	12	91	83	9	297	A2003	22	34	64.7
A2004	11	35	42	0	113	A2004	23	34	67.7
A2005	17	89	117	0	373	A2005	17	34	50.0
A2006	14	75	105	0	307	A2006	20	34	58.8
A2007	22	106	152	0	482	A2007	12	34	35.3
A2008	6	116	146	6	331	A2008	28	34	82.4
A2009	16	129	181	0	590	A2009	18	34	52.9
A2010	5	127	194	14	473	A2010	29	34	85.3
A2011	20	135	216	0	851	A2011	14	34	41.2
A2012	5	148	254	22	601	A2012	29	34	85.3
A2013	21	130	203	0	693	A2013	13	34	38.2

Table A3: Labour productivity and BERD intensity in the electrical equipment Industry

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
EU	Total	51.8	58.2	58.4	:	:	:	:	:	:
	Inward	52.8	58.8	:	:	:	:	:	:	:
Austria	Total	76.3	86.4	85.4	24.8	18.8	17.8	13.4	12.9	13.4
	Inward	82.1	93.9	95.5	32.3	20.6	17.8	15.4	13.2	12.6
Belgium	Total	:	93.0	87.8	:	:	:	:	:	:
	Inward	:	108.8	108.9	:	:	0.0	:	:	0.0
Bulgaria	Total	9.4	10.7	12.2	0.4	:	0.6	:	:	0.6
	Inward	10.5	12.1	13.4	:	:	0.5	:	0.5	0.4
Croatia	Total	:	25.9	25.7	:	1.1	1.0	:	1.1	1.5
	Inward	:	:	33.6	:	:	0.8	:	:	1.0
Cyprus	Total	31.1	:	:	0.2	:	:	0.3	:	:
	Inward	:	:	:	:	:	:	:	:	:
Czech Rep.	Total	19.9	25.6	25.5	2.3	2.8	2.9	1.3	1.6	1.7
	Inward	22.1	29.5	29.4	2.1	2.5	2.8	1.0	1.3	1.6
Denmark	Total	75.9	64.1	65.3	:	:	3.7	:	:	2.9
	Inward	95.4	74.0	71.9	:	:	4.5	:	:	4.1
Estonia	Total	18.9	27.3	29.3	1.2	2.8	1.0	1.2	2.1	0.0
	Inward	19.9	29.3	31.6	1.3	2.3	1.3	1.0	2.2	0.0
Finland	Total	66.8	75.1	85.8	14.8	17.2	19.4	9.1	10.1	9.2
	Inward	83.8	97.1	106.7	16.4	18.9	22.3	11.4	12.3	8.7
France	Total	63.2	63.6	65.9	10.4	:	13.1	5.7	:	7.8
	Inward	60.8	73.7	69.8	6.6	:	7.8	4.2	:	5.2
Germany	Total	65.5	75.8	73.4	15.4	14.0	15.3	6.8	6.5	6.9
	Inward	83.8	86.8	77.8	6.9	13.1	10.0	5.2	12.2	7.1
Greece	Total	:	:	38.4	:	:	0.6	:	:	0.4
	Inward	:	:	:	:	:	:	:	:	:
Hungary	Total	18.3	21.5	21.7	2.9	2.7	3.4	1.2	1.2	1.5
	Inward	21.2	24.3	24.6	3.4	2.9	3.3	1.2	1.1	1.6
Ireland	Total	54.7	60.9	:	:	:	:	:	:	:
	Inward	74.1	70.3	:	:	:	:	:	:	:
Italy	Total	49.9	61.2	62.5	:	4.5	4.7	4.2	4.6	5.1
	Inward	69.0	79.9	77.9	:	5.7	5.8	4.6	5.2	5.5
Latvia	Total	11.3	17.6	20.4	:	:	:	:	:	:
	Inward	9.0	16.7	19.7	:	:	:	:	:	:
Lithuania	Total	7.9	15.1	15.5	:	:	:	:	:	:
	Inward	8.1	15.4	17.3	:	:	:	:	:	:
Luxembourg	Total	:	:	56.9	:	:	:	:	:	:
	Inward	:	66.1	:	:	:	:	:	:	:
Malta	Total	:	:	:	:	:	:	:	:	:
	Inward	6.8	:	:	:	:	:	:	:	:
Netherlands	Total	84.0	83.7	79.0	28.8	26.6	31.0	20.0	24.3	21.9
	Inward	77.7	:	76.9	6.1	:	4.6	7.2	8.6	7.7
Norway	Total	85.4	104.2	114.6	7.1	5.5	5.2	6.8	6.5	5.3
	Inward	:	119.7	129.3	:	5.0	5.8	:	4.7	5.4
Poland	Total	24.4	27.5	27.0	1.4	2.1	3.2	1.3	1.7	2.0
	Inward	31.6	30.6	31.0	1.1	2.6	3.0	0.8	1.9	2.0
Portugal	Total	38.2	40.2	35.2	0.1	0.0	0.0	1.8	2.7	3.2
	Inward	43.0	42.9	39.0	0.0	0.0	0.0	2.5	3.1	3.4
Romania	Total	11.6	13.4	14.8	0.7	0.4	0.4	0.5	0.2	0.3
	Inward	12.6	13.9	15.3	1.1	0.6	0.5	0.8	0.3	0.5
Slovakia	Total	12.1	18.6	21.3	2.2	2.8	3.0	0.8	1.3	1.2
	Inward	11.2	19.1	20.9	2.1	1.9	1.2	0.7	0.9	0.7
Slovenia	Total	25.4	33.3	34.4	10.1	12.4	13.2	4.1	5.9	5.9
	Inward	38.3	41.6	41.8	:	6.5	20.4	:	4.8	7.8
Spain	Total	59.0	54.2	56.9	4.9	5.2	5.8	4.9	5.1	7.2
	Inward	77.4	68.6	71.8	2.6	4.1	5.5	3.1	4.5	8.0
Sweden	Total	56.7	76.9	82.8	:	:	:	:	:	:
	Inward	73.7	98.3	:	:	:	:	:	:	:
UK	Total	52.0	52.3	65.9	:	3.5	3.4	2.7	2.6	3.8
	Inward	56.3	64.7	74.9	:	4.2	4.0	3.3	3.2	4.4

Source: Eurostat

R&D internationalization in machinery and equipment (NACE 28) BERD Flows: Submitted under subtask 4.3. (Drivers of foreign R&D investments)

Introduction

This is a digest of R&D internationalization of the manufacture of Machinery and equipment (NACE 28). Based primarily on the inward-flows of BERD data and domestic BERD data (1999-2013), it integrates also a number of secondary data (see Responsiveness score in section 4 and data in the Annex). The sectoral case study is organized in three sections: the first one introduces the core data and the approach; the second section provides a synthetic picture of the machinery and equipment industry mainly based on BERD and two data sources, R&D Investment Scoreboard and European R&D survey. The third section presents the patterns of Inward R&D and of its weight on Total BERD activity in the sector across time and country. The last section is an analysis of the underlying drivers that can help to explain the observed patterns of R&D internationalization. The Annexes include many tables: the full data for Inward and Total BERD, the missing data and two tables on secondary data.

1. Data and approach

The core-data, as described in deliverable D.3.2., consists of the following.

- Total BERD, which is the total R&D expenditure of firms in a specific country or sector;
- Inward BERD, which is the R&D expenditure of foreign-owned firms in a specific country or sector.

These data are limited by the extent of missing-values, especially for certain countries. An average more than half (60,5%) of the 34 countries do not provide values in any given year. The coverage is variable, particularly after 2007 when coverage in even-years is minimal. Annex 2 presents the coverage.

Data for *Outward BERD*, which is the R&D expenditure of foreign affiliates of domestic firms in a specific host country or sector are not used here, as outward-BERD data are, since 2009, no longer available for most countries. Exceptions include the US and Japan. A separate case-study will present what can be learnt from the extant data on outward BERD.

The secondary data that are used includes standard GDP data, labour-costs, GBOARD, educational levels, patents, the size of the sector and domestic R&D in general. [1]

The document is primarily based on presenting figures from the core and secondary data sources. The major analytical step is taken to gauge the impact of the main drivers of inward R&D in the sector, applying the responsiveness score method developed at IRCRES (Cerulli, 2015). The approach, based on iterated random coefficient regression, assumes that individual units react ('responsiveness') to individual factors differently. It allows to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, GBAORD, Domestic R&D, level of education), conditional on the other factors at play. The approach is further explained in the fourth section.

[1] See the annex for a detailed description of the data used.

3. The European Machinery industry and BERD

A number of characteristics and tendencies can be used to introduce the sector (see box).

Box 1. R&D internationalization in machinery and equipment NACE 28 for selected countries

With a 36% share of the world market, Europe is expected to growth 3.8% on average over 10 years.

- Upstream and downstream linkages contribute to the innovativeness of the industry and often depend on own R&D capabilities. The industry requires a stable, predictable, and coherent regulatory environment that embraces 'smart' principles.
- Europe is the leading supplier of this leading edge technology.
- Greenfield investment increased quite markedly after the financial collapse, while there was considerable variation in cross-border M&As.
- Key challenges: The convergence of electronics, electrical and mechanical technologies. Precision machining and specific high-speed processing technologies.
- Future technology: electronics and increasing use of ICT technologies (especially software) that come from different subsystems of the supply chain.

The Industrial Machinery & Equipment industry consists of companies engaged in the manufacturing of basic power and hand tools, hardware, small-scale machinery and other industrial components. This was the largest EU-28 manufacturing sector in 2012 in terms of value added and employment.

- N. of enterprises 93.0 (thousands)
- N of persons employed 2 920.0 (thousands)
- Turnover 632.000 (million EUR)
- Value added 191.000 (million EUR)

Source : EU 28, 2012 Eurostat, *Statistics explained.*

Table 1. Top 10 Global enterprises producing machinery and equipment (Industrial Engineering)

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

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

In this light, the machinery and equipment industry is a medium-high R&D intensity sector, where EU generally outperform than US: R&D intensity is 2,9% in US and 3,2% in EU. But the R&D growth of the EU based companies of the secotr has been negative in the last year (-4.1%), largely explained by the figures of the largest R&D investors in this sector Volvo (Sweden) (-4.4%) and Alstom (France) (-59.5%). Companies based in US have had a low, but positive R&D growth (0,8%), while companies based in Japan registered the highest one-year growth rate, 12,4%. The R&D shares of the sector by main world regions and its R&D intensity is the following

Country	R&D share	R&D intensity
US	3%	2,90%
EU	2%	3,20%
Japan	6%	2,80%
China	3%	

Source: *The 2015 EU Industrial R&D Investment Scoreboard*, European Commission, JRC/DG RTD.

The number of companies within the EU 1000 top R&D investors and by the top 5 countries

	Tot EU	DE	UK	SE	IT	FI
Industrial Engineering	101	37	12	10	8	7

The R&D and sales 2014 growth in the sector was positive for Germany, but negative for France and UK:

	Germany		**France**		**UK**	
	R&D	Sales	R&D	Sales	R&D	Sales
Industrial Eng.	12.7	3.2	-49.0	-0.9	4.2	-3.7

The industry is highly diversified, with the largest companies that have very different productive profiles. The Volvo Group is one of the world's leading manufacturers of trucks, buses, construction equipment and marine and industrial engines. With its headquarters in Gothenburg (Sweden) it employs about 100,000 people and has production facilities in 18 countries. The Volvo Group has an established and strong position in Europe, North America, and South America, but it has also established a global industrial structure with manufacturing as well as sales and distribution channels on all continents.

ABB (Switzerland), which is the result of a merger between a Swedish and a Swiss conglomerate, is a global leader in power and automation technologies. As a result, some important production and research facilities remain in Scandinavia. Each year it dedicates around 1.33 billion of euro to fund research and development activities driven by 8,500 technologists in four divisions and seven corporate research centers. The research centers collaborate with leading universities around the world, such as MIT, Carnegie Mellon, the University of Cambridge, the Royal Institute of Technology Stockholm and the Federal Institutes of Technology in Zurich and Lausanne. Process Automation division provide customers with products and solutions for instrumentation, automation and optimization of industrial processes; the Discrete Automation and Motion division provides products, solutions and related services that increase industrial productivity and energy efficiency; the Robotics one is a leading supplier of industrial robots, modular manufacturing systems and service.

Isuzu (Japan) is a world manufacturer of commercial vehicles, light commercial vehicles and diesel engines, it is a global corporation leading the automotive industry. Komatsu is a Japanese company, the world's second largest manufacturer of construction equipment and mining equipment after Caterpillar. It has manufacturing operations in Japan, Asia, Americas and Europe.

The R&D Scoreboard defines “high performers” companies which satisfy the following conditions:

- an R&D intensity superior to 10%;
- a compound annual growth rate of R&D above 10% on the period 2005-2013;
- an average net sales growth above 10% on the period 2005-2013 and;
- a positive operating profits in 2013.

Among these high performers we find five European companies operating in the machinery and equipment sector (see the table below).

Company	Country	Position	R&D intensity	R&D growth	Net sale growth
Exagon	Sweden	93	11	27	11
Wartsila	Finland	110	5	7	15
Class	Germany	121	5	16	7
Kone	Finland	227	1	16	5
Weir	UK	457	1	22	14

Source: *The 2015 EU Industrial R&D Investment Scoreboard*, European Commission, JRC/DG RTD.

3.1. Machinery and equipment Inward R&D (in Euros)

Table 1 presents reported Inward R&D (in Euro) by host-country and by year, pre and post crisis. Here the values are presented for odd-years where data is systematically more complete (see also annex). It is only in the case of the United Kingdom, where there seems to have been a decrease of inward BERD in the aftermath of the economic crisis. However, this tendency appears to have changed in the most recent year (2013).

The Eastern European countries, taken as a group, have experienced the most important increase of inward BERD. In particular, Hungary and Czech Republic are the two success-stories in the “machinery and equipment” sector. In the first case there has been an increase of foreign investments of approximately 180%, while in the second case an increase of 125%. The growth seems to be continuous over time, and in both countries, it reaches a pick in the last year considered (2013).

Table 1. Inward R&D in the Machinery and Equipment Industry (Nace 28) before and after 2008 and for last available year: Millions Euro regions and selected countries

Region and Country	Annual Average		Latest available year
	Pre-2008 [a]	Post-2008	2013
Eastern Asia	**19**	**119**	**268**
Japan**	19	119	268
Eastern Europe	**52**	**121**	**168**
Bulgaria	0	1	2
Czech Republic	28	63	90
Hungary	12	34	42
Poland	10	14	22
Romania	0	1	2
Slovakia	2	7	10
Northern America	**1415**	**1922**	**2082**
Canada	64	74	67
United States of America	1351	1848	2015
Northern Europe	**1191**	**1036**	**1290**
Denmark	59	319	319
Estonia	1	2	3
Finland*	87	97	93
Norway	32	42	51
United Kingdom	648	576	824
Southern Europe	**404**	**400**	**430**
Italy	310	358	385
Slovenia	7	7	5
Spain	78	35	40
Western Europe	**1523**	**2502**	**3160**
Austria	189	362	446
Belgium	122	170	213
France	383	541	582
Germany	830	1268	1718
Netherlands		161	201
Grand Total	**4603**	**6099**	**7398**

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

Table 2 allows for more analysis on the internationalization of R&D activities in the Machinery and Equipment sector. Among all the observed countries, Belgium has the most internationalized R&D activities, followed by Denmark and Hungary. Conversely, Netherlands has the most "closed" R&D activities for the machinery and equipment sector. Among the top European economies, Germany is the best performer in terms of internationalization of R&D activities in the sector.

Table 2. Inward BERD as a percentage of total BERD in machinery and equipment

		2007		2009		2011		2013
	Total	Inward Share	Total	Inward Share	Total	Inward Share	Total	Inward Share
Austria	553	49.7%	545	48.1%	680	55.7%	890	50.1%
Belgium	254	62.2%	193	67.9%	240	69.2%	303	70.3%
Canada		:	399	20.3%	452	:	466	14.4%
Czech Rep.	101	43.6%	86	51.2%	119	47.1%	165	54.5%
Denmark	191	30.9%	622	:	689	:	454	70.3%
Finland	370	27.3%	349	28.9%	399	23.3%	504	:
France		:	932	53.6%	1,026	:	1,035	56.2%
Germany	4,763	18.5%	4,498	13.6%	4,902	30.0%	5,388	31.9%
Greece		:		:	7	:	7	:
Hungary	31	64.5%	14	:	39	66.7%	54	77.8%
Ireland	43	:	48	:	30	:	4	:
Italy	911	37.1%	1,080	:	1,168	28.3%	1,372	28.1%
Japan	7,256	0.1%	8,381	:	9,888	1.2%	9,622	:
Netherlands	580	:	1,030	6.5%	1,632	13.2%	1,910	10.5%
Norway	236	13.6%	90	:	117	28.2%	160	31.9%
Poland	42	26.2%	29	31.0%	42	26.2%	52	42.3%
Portugal	28	42.9%	15	:	16	:	19	:
Romania	14	:	6	16.7%	2	20.8%	5	16.7%
Slovakia	8	20.8%	6	33.3%	13	69.2%	14	71.4%
Slovenia	27	33.3%	15	53.3%	81	29.6%	39	25.6%
Spain	335	18.8%	244	11.5%	224	17.0%	218	18.3%
Sweden	792	51.3%	534	:	668	:	739	:
UK	1,506	55.4%	706	:	730	44.9%	883	93.3%
USA	7,198	19.7%	6,551	26.0%	10,567	17.3%		:

Notes:

France and Italy have both experienced an increase in total and inward BERD, however, for Italy the percentage of inward over total BERD has decreased from 2007 (37%) to 2013 (28%).

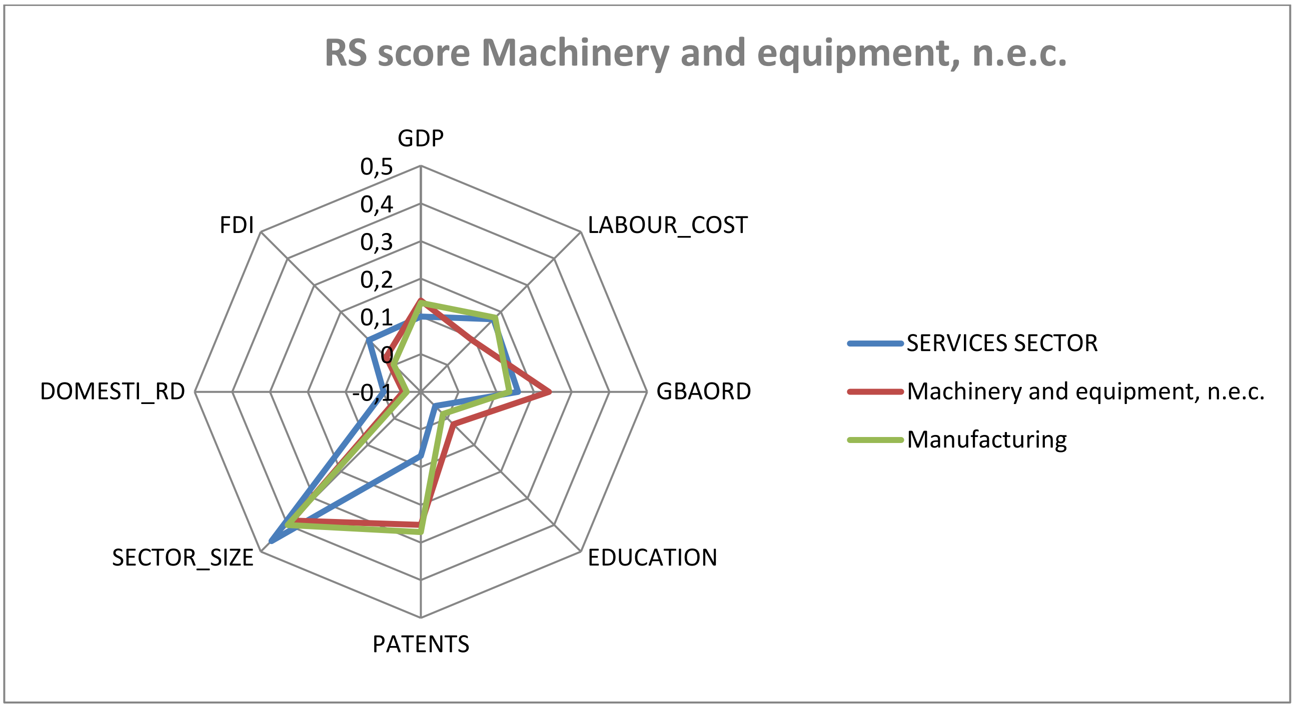
4. R&D Main drivers using Responsiveness score.

An important contribution of the project is to use newly adapted empirical methods (see Chapter3) to better understand the factors that contribute to increased inward R&D investments. This section presents the main findings regarding the drivers of inward R&D in the machinery sector. As introduced above, the analysis is based on the idea that inward R&D may respond differently to a given change of a series of factor. Particularly, we expected a set of generic factors – GDP, GBAORD, Patent, Education, Domestic R&D value, Labour cost- to influence the level of R&D investments.[2]

We use the Responsiveness score method to identify the main drivers of the inward investments in R&D. This methodology (based on iterated random coefficient regression) allows us to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes conditional to all other factors.

[2] See the annex 2 for further explication on the data used.

Figure. Responsiveness score. The machinery and equipment industry



The responsiveness score measures the effect of an increase in an individual factor (such as patenting activity) on the inward R&D investments of foreign firms above and beyond that caused by the other driving factors under consideration (such as government R&D). The figure above illustrates the responsiveness scores of the different factors in the machinery and equipment industry compared to two benchmark sectors, specifically, total Manufacturing and total Services. The drivers that have greatest relative effect (the r-score) on the inflow of R&D investments are “Patent” and “Sectoral size”. An increase in one of these drivers may determine an increase in the inward investments in R&D of foreign company more pronounced than the one caused by an increase of the other factors considered. Inward investments in R&D seems have almost the same response to the drivers for the Manufacturing sector and for machinery and equipment. “Labour cost” seems to be less important for investments in “Machinery and equipment” than for “Manufacturing”, while the opposite is true for “GBAORD” and “education”.

ANNEX. 1 Table. 3 Total BERD investments in R&D in the Machinery and equipment sector

Total BERD	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	186				352	367	388	429	483	553		545		680		890
Belgium	158	160	189	182	169	176	206	216	243	254	215	193	217	240	296	303
Bulgaria	1	1			0	1	1	1	4	3	3	3	8	6	11	13
Canada	138	175	251	258	320	303	294	335	362			399	390	452	450	466
Switzerland			1290								826				1293	
Czech Republic	39	34	39	37	43	45	49	73	85	101	101	86	99	119	153	165
Germany	3503	3403	3552	3763	3820	3760	3811	4130	4255	4763	4671	4498	4597	4902	5183	5388
Denmark	248	255		317	277	274	297	291	312	191		622	632	689	643	454
Spain				186	231	233	273	307	303	335	235	244	216	224	227	218
Finland				307	271	258	273	283	317	370	400	349	347	399	471	504
France	810	831	921	969	991	1049	1077	1111	1180		802	932	953	1026	1087	1035
Hungary	10	7	6	7	7	8	13	13	16	31	20	14	30	39	49	54
Ireland	21	22	21	20	30	49	38	48	46	43		48	47	30		4
Italy	426	425	458	566	812	801	798	849	935	911	1062	1080	1063	1168	1295	1372
Japan	5544	6688	8883	7502	7955	7005	7372	7819	7876	7256	7485	8381	9159	9888	10596	9622
Netherlands	263	339	440	535	480	502	503	490	584	580	632	515	729	816	937	955
Norway	76	72	88	112	121	139	134	127	198	236	128	90	94	117	136	160
Poland	63	77	57	47	18	22	21	37	32	42	32	29	31	42	69	52
Portugal	9	12	13	14	15	16	15	15	22	28	16	15	14	16	21	19
Romania						11	14	19	12	14	10	6	6	2	7	5
Sweden	543	564	633	599	557	549	599	677	795	792		534		668		739
Slovenia	10	13	12	17	21	15	14	19	22	27	14	15	21	15	14	19
Slovakia	23	4	9	3	2	2	3	4	4	8	8	6	10	13	15	14
South Korea	279	195	272	435	553	545	569	666	878	1273	976	904	1199	1338	1880	1833
United Kingdom	946	975	1154	1155	1208	1025	1121	1092	1183	1506	3770	706	725	730	957	883
United States	5455	5902	7124	7151	6799	5573	5289	6857	7843	7198	6870	6551	7510	10567	11094	

ANNEX. 1 Table. 3 Total inward BERD investments in R&D in the Machinery and equipment sector

Inward BERD	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria						102	148			275		262		379		446
Belgium			83	79	99	101	96	106	146	158		131		166		213
Canada	39	55	77	71	63	60	56	56	64	76	72	81	44		70	67
Czech Republic	1	1	6	10	13	15	14	24	35	44	41	44	43	56	81	90
Germany				566		731		879		881		613		1472		1718
Denmark										59						319
Spain						63	106	108		63		28		38		40
Finland	26	38	43	57				73	81	101		101		93		
France	308			287	290	365		374	419	409		500				
Hungary						7	7	9	8	20				26		42
Ireland		7		9		12		30								
Italy				192	337	284	295	308	330	338				330		385
Japan	274	82	57	36	29	26	28	22	22	8			106	119	268	
Netherland											67			216		201
Norway										32				33		51
Poland	2	21	9	2	2	2	3	16	10	11		9		11		22
Portugal								6		12		0		0		0
Sweden	172	136	254	587	168	287		339		406						
Slovenia						5	7		8	9		8		8		5
Slovakia						1	1	2	2	4		2		9		10
United Kingdom	213	203	331	519	501			461	544	834	568			328		824
United States	604	843	1893		1778	1390	1317	1247	1395	1415	1746	1703	1915	1825	2049	2015

Annex 3. Inward R&D. Summary statistics with tally of missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Missing values	Total	Percent Missing
A1998	9	182	198	1	604	A1998	25	34	73,53
A1999	10	139	256	0	843	A1999	24	34	70,6
A2000	9	306	606	6	1893	A2000	25	34	73,5
A2001	12	201	230	2	587	A2001	22	34	64,7
A2002	10	328	535	2	1778	A2002	24	34	70,6
A2003	18	192	354	0	1390	A2003	16	34	47,1
A2004	15	139	336	0	1317	A2004	19	34	55,9
A2005	20	203	332	0	1247	A2005	14	34	41,2
A2006	15	204	372	0	1395	A2006	19	34	55,9
A2007	23	224	363	0	1415	A2007	11	34	32,4
A2008	5	499	731	41	1746	A2008	29	34	85,3
A2009	16	222	436	0	1703	A2009	18	34	52,9
A2010	5	454	818	43	1915	A2010	29	34	85,3
A2011	20	256	495	0	1825	A2011	14	34	41,2
A2012	6	490	768	70	2049	A2012	28	34	82,4
A2013	22	320	549	0	2015	A2013	12	34	35,3

Database description

Data on ”GDP”, “Total sectors production”, accounting for the size of each sectors, and “Labour cost per sector” are taken from STAN Database (OECD). The database includes annual measures of output, labour input, investment and international trade. The current version of STAN is based on the International Standard Industrial Classification of all economic activities, Revision 3 (ISIC Rev. 3) and covers all activities (including services).

In order to measure the influence that Government support for research and development activities may have on Inward investments R&D, we use the GBAORD index, accounting for Government budget appropriations or outlays for research and development. GBAORD include all appropriations (government spending) given to R & D in central (or federal) government budgets. The source of data is OECD. Science Technology and Innovation (STI) indicators.

“Patents Application” is used as a proxy of the innovation capabilities of Countries. Data are taken from World Bank, World Development Indicators. As to capture the capability innovation of the Country we have add to the number of patent applications of resident the patent applications of non-resident.

In order to capture the influence that skills and education may have on Inward R&D we use the indicator “Tertiary graduates in mathematics science and technology per 1000 inhabitants aged 20-29 years”.

The data source is Eurostat, and the years observed go from 2001 to 2012. The levels and fields of education and training used follow the 1997 version of the International Standard Classification of Education (ISCED97) and the Eurostat Manual of fields of education and training (1999).

Data on Foreign direct investment inflow are taken from OECD, FDI Statistics according to Benchmark definition 4th edition (BMD4)

A. Manufacture of machinery and equipment

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
EU	Total	51.7	66.0	65.3	:	:	:	:	:	:
	Inward	61.2	77.9	73.5	:	:	:	:	:	:
Austria	Total	70.5	92.0	85.8	10.6	10.1	13.1	7.5	9.1	9.6
	Inward	73.1	106.8	94.1	14.1	12.8	16.1	8.9	10.9	10.8
Belgium	Total	:	93.2	91.7	:	:	:	:	:	:
	Inward	:	115.5	114.6	:	:	0.0	:	:	0.0
Bulgaria	Total	6.9	10.5	11.3	0.8	0.9	1.9	0.9	1.0	1.1
	Inward	9.8	14.1	13.9	0.4	0.5	1.9	0.3	0.3	0.4
Croatia	Total	:	20.4	19.8	:	0.2	1.3	:	0.2	0.4
	Inward	:	:	26.5	:	:	0.0	:	:	0.0
Cyprus	Total	37.7	46.6	38.0	2.0	0.6	:	1.6	0.6	:
	Inward	:	:	:	:	:	:	:	:	:
Czech Rep.	Total	22.1	25.9	26.6	3.2	3.9	5.0	1.7	2.3	2.8
	Inward	26.4	31.6	33.9	3.0	3.5	5.3	1.9	2.4	3.2
Denmark	Total	78.5	68.0	79.9	:	:	7.9	:	:	4.5
	Inward	93.5	84.1	81.0	:	:	15.5	:	:	6.9
Estonia	Total	16.2	26.8	27.1	0.8	0.5	2.9	0.9	1.3	0.0
	Inward	:	28.9	27.0	:	0.7	6.6	:	1.0	0.0
Finland	Total	61.8	78.6	75.1	10.2	8.5	12.5	6.5	6.8	7.8
	Inward	59.7	98.0	83.2	12.7	8.0	13.2	8.5	8.2	10.2
France	Total	58.7	69.6	69.1	7.6	:	8.7	5.2	:	5.6
	Inward	65.5	82.0	78.8	7.8	:	8.9	5.2	:	6.2
Germany	Total	58.4	74.6	73.5	11.9	9.8	11.1	5.0	5.1	5.5
	Inward	75.1	88.6	81.1	5.7	9.0	10.4	3.9	6.8	6.9
Greece	Total	:	:	29.9	:	:	0.2	:	:	0.2
	Inward	:	:	64.6	:	:	0.0	:	:	0.0
Hungary	Total	39.5	41.5	42.6	0.9	1.5	2.1	1.7	2.0	2.8
	Inward	57.3	54.8	56.5	0.7	1.2	1.9	1.4	1.5	2.6
Ireland	Total	78.3	90.8	:	:	:	:	:	:	:
	Inward	106.8	107.2	:	:	:	:	:	:	:
Italy	Total	49.5	65.1	68.4	:	3.9	4.4	4.4	4.8	5.6
	Inward	66.6	93.3	89.9	:	4.9	5.9	4.5	4.8	6.1
Latvia	Total	13.6	17.9	17.8	0.0	:	:	0.0	:	:
	Inward	18.9	:	22.6	0.0	:	:	0.0	:	:
Lithuania	Total	12.2	17.1	20.0	:	:	:	:	:	:
	Inward	13.7	21.9	24.2	:	:	:	:	:	:
Luxembourg	Total	:	:	93.0	:	:	:	:	:	:
	Inward	84.1	102.7	113.2	:	:	:	:	:	:
Malta	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Netherlands	Total	62.8	104.3	95.9	9.9	10.2	12.5	7.0	12.3	15.6
	Inward	75.8	91.2	92.2	4.3	10.1	8.2	4.6	10.7	10.7
Norway	Total	130.6	146.4	136.5	3.3	3.5	4.4	5.5	5.2	5.5
	Inward	:	207.5	164.2	:	1.9	2.9	:	3.2	3.6
Poland	Total	21.3	24.9	23.7	1.0	1.4	2.0	0.9	1.3	1.4
	Inward	32.1	35.6	27.8	0.7	0.9	2.3	0.5	0.7	0.8
Portugal	Total	26.6	27.9	34.3	0.1	0.1	0.1	1.3	1.1	1.3
	Inward	33.6	37.4	37.8	0.1	0.0	0.0	0.5	0.2	0.3
Romania	Total	10.7	19.8	16.4	0.2	0.1	0.2	0.2	0.1	0.2
	Inward	14.0	32.1	23.0	0.4	0.1	0.3	0.4	0.2	0.3
Slovakia	Total	15.4	22.0	24.4	1.0	1.4	1.5	0.6	1.0	1.2
	Inward	17.7	24.5	28.1	0.7	1.6	1.5	0.6	1.1	1.2
Slovenia	Total	24.4	33.6	32.1	3.9	7.2	4.3	1.5	4.8	4.2
	Inward	27.2	31.3	33.7	5.8	5.2	3.9	1.6	2.8	3.5
Spain	Total	51.7	57.6	58.6	4.1	3.8	3.9	5.2	5.4	5.3
	Inward	69.9	76.0	81.0	2.1	2.1	2.0	3.0	3.0	2.7
Sweden	Total	47.6	87.3	76.3	:	:	:	:	:	3.7
	Inward	56.8	88.3	85.7	:	:	:	:	:	4.5
UK	Total	59.5	79.3	73.9	:	4.6	6.0	3.8	3.1	
	Inward	69.1	108.4	94.9	:	3.8	5.3	4.8	3.5	

Source: Eurostat

Annex. **RESPONSIVENESS SCORES DEFINITION AND ESTIMATION.**

In this section we provide a technical presentation of the Random Coefficient Regression (RCR) used to compute Countries' responsiveness scores. The basic econometrics of this model can be found in Wooldridge (2002, pp. 638-642) whose this section is a concise account with slight modifications. The application of RCR in this work follow this simple protocol:

1. Define y, the outcome variable, "Inward R&D investments from 1998 to 2013".
2. Define a set of Q factors thought of as affecting y, and indicate the generic factor with x_j.
3. Define a RCR linking y to the various x_j, and extract a Country-specific *responsiveness effect* of y to the all set of factors x_j, with j=1, ..., Q.
4. For the generic Country i and factor j, indicate this effect as b_{ij} and collect all of them in a matrix **B**. Finally, aggregate by Country (row) and by factor (column) the b_{ij} getting synthetic Country and factor responsiveness measures.

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

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

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

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

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

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

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

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

If all variables are standardized, partial effects are *beta coefficients* so that they are independent of the unit of measurement and can be compared and summed.

Once matrix **B** is known, we can define for each region *i* the Total Country Responsiveness (TCR) and the Mean Country Responsiveness (MCR) as:

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

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

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

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

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

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

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

By repeating this procedure for each Country *i* and factor *j*, we can finally obtain $\hat{\mathbf{B}}$, the estimation of matrix **B**.

When a longitudinal dataset is available, the estimation of **B** can be obtained either by using random-effect or fixed-effects estimation of this panel regression:

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

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

R&D internationalization in motor vehicles (NACE 29)

Submitted under subtask 4.3. (Drivers of foreign R&D investments)

Version 4:

1. Introduction

This case study presents a digest of R&D internationalization of the manufacture of motor vehicles, trailers and semi-trailers, including the manufacture of parts and accessories for motor vehicles (NACE 29). The main objective is to identify some of the key drivers of inward R&D in the automotive industry. Based primarily on statistics on total BERD flows and inward-BERD flows (excludes domestic BERD), the study integrates productivity data from the Foreign affiliates statistics (FATS) together with several other indicators to investigate the underlying determinants that explain the observed patterns of R&D internationalization. Statistics for outward BERD are presented in a separate case study. Certain limitations in the data are briefly presented.

2. The automotive industry

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

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

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

Table 1. Top 10 Global enterprises producing motor vehicles

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

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

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

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

ICT companies are posing a potential threat to automotive industry, but also new opportunities. Advanced robotics and automation are also playing an increasingly important role in automobile production and in the way software is used in the automobile. Google is known to be developing advanced robotics (through its subsidiary Boston Dynamics) and self-driving cars, which are already being tested on public roads. Finally the re-emergence of the electric automobile has the potential to change the character of the market. But threats from the outside must be creditable to shake up the top 10 investors in new technology.

3. Inward R&D in motor vehicles

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

Table 2 also corroborates the relative importance of inward flowing R&D to the overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process. For example, Volkswagen, Daimler, Robert Bosch and BMW are among the top 5 European firms producing automobiles and all of them have their headquarters located in Germany. These firms may also have subsidiaries or joint ventures located in other countries, such as Austria, or may carry out assembly in countries such as the Czech Republic. The parent firm will be expected to carry out R&D abroad, which explains why size of the sector differs widely in these countries, as does the total R&D intensity. Italy also has production facilities, but it depends a great deal on the R&D facilities in the Detroit area (Fiat Chrysler)

Table 2. Inward BERD as a percentage of total BERD in the automotive industry

		2007		**2009**		**2011**		**2013**
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	*401*	86.0%	*369*	91.3%	*407*	90.7%	*463*	88.8%
Belgium	*123*	75.6%	*84*	73.8%	*113*	70.8%	*148*	72.3%
Canada		..	*158*	62.0%	*..*	..	*124*	46.8%
Czech Rep.	*290*[a]	44.1%	*134*	89.6%	*162*	92.6%	*250*	95.2%
France		..	*1,658*	46.4%	*1,918*	..	*1,908*	..
Germany	*13,519*	14.9%	*13,821*	15.8%	*16,312*	12.6%	*17,187*	17.9%
Hungary	*50*[a]	..	*61*	..	*70*	71.4%	*103*	75.7%
Italy	*966*	..	*993*	..	*1,298*	16.5%	*1,453*	18.2%
Japan	*15,008*	..	*18,840*	..	*24,606*	..	*23,435*	..
Netherlands	*139*	..	*124*	..	*284*	41.9%	*292*	39.7%
Norway	*40*	..	*30*	..	*27*	48.1%	*30*	63.3%
Poland	*27*	85.2%	*80*	97.5%	*44*	86.4%	*130*	93.1%
Portugal	*46*	65.2%	*63*	..	*35*	..	*24*	..
Romania	*35*	..	*43*	79.1%	*52*	78.8%	*42*	95.2%
Slovakia[b]	*0*	..	*20*	..	*24*	..	*85*	51.8%
Slovenia	*7*	..	*33*	..	*105*	..	*80*	16.3%
Spain	*254*	79.9%	*348*	48.9%	*357*	81.8%	*328*	82.6%
Sweden	*1,627*	47.8%	*..*	..	*1,053*	..	*..*	..
UK[b]	*1,134*	..	*1,083*	..	*1,493*	44.7%	*2,053*	..
USA	*11,699*	15.2%	*8,171*	14.0%	*..*	..	*..*	..

Source: BERD flows database

Notes: [a]Inward BERD exceeded Total BERD in 2007. [b]Data for Slovakia and UK appears faulty.

The table also indicates the general increase in total R&D in the European auto industry in 2013. The financial crisis of 2008 may of also had an impact on the growth of BERD in this industry. Both Germany and Japan show a general growth trend from 2007 to 2013 in total BERD. The most dramatic shift is in the consistent reduction in the US in total R&D in the sector from 2007. Here it is noted that the US total R&D in the US sector and the share of inward R&D both expand dramatically in the latest data

(2013). Data for the UK appears unreliable as inward BERD sometimes exceeds total BERD, and the share jumps around by wide margins every two years.

From a longer period viewpoint, covering the period just before the financial crisis and the one afterwards, inward BERD appears to have increased by about 12% between the two periods in western Europe and roughly doubled in Eastern Europe, although from a very low level. Table 1 shows the average value (in millions of Euros) for the years 2005 and 2007 and 2009 and 2011. Inward flows to Northern Europe declined, possibly because of some large cross-border acquisitions, particularly in Sweden and the UK. The US experienced a large decline from 2.6 to 1.75 billion euros after the financial crisis.

Table 3. Inward R&D in the motor-vehicles industry before and after 2008: Regional presentation for a selection of countries.

Region and Country	Annual Average		Latest available year
	Pre-2008 [a]	Post-2008	2013
Japan**	**2,799**		**2,837**
East Europe	**193**	**390**	**521**
Czech Rep.	132	169	238
Hungary	38	64	78
Poland	23	79	121
Romania	1	38	40
Slovakia		39	44
North America	**2,798**	**2,406**	**3,729**
Canada	225	75	58
USA	2,573	2,331	3,671
North Europe	**1,919**	**1,461**	**3,005**
Norway	11	16	19
Sweden**	816		778
UK	1,091	1,434	2,200
South Europe	**330**	**490**	**578**
Italy		239	264
Portugal**	18	0	30
Slovenia	0	7	13
Spain	312	244	271
West Europe	**2,817**	**3,824**	**4,562**
Austria	202	372	411
Belgium	74	83	107
France	654	812	854
Germany	1,887	2,439	3,074
Netherlands		118	116
Total	10,856	8,571	15,232

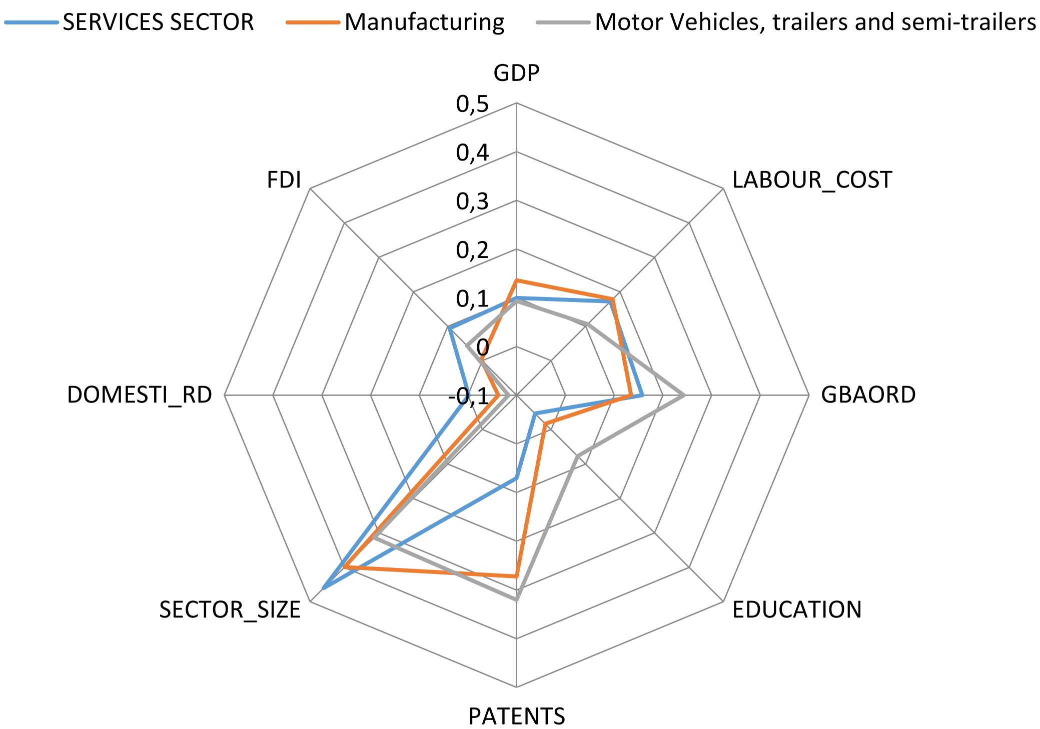
Table A3 shows apparent labour productivity, BERD intensity (share of BERD in value added) and the share of R&D employment for 2009, 2011 and 2013. Foreign ownership plays a central role here as total BERD is distinguished from inward BERD. Apparent labour productivity of total BERD appears higher in countries such as France, Germany, Italy and the UK where virtually all of the parent firms reside and productivity tends to be higher in firms with inward BERD. A similar pattern is observed for BERD intensity and the share of R&D employment, but as expected BERD intensity is higher in the three countries. Although not the highest in terms of BERD intensity, the UK observes the highest apparent labour productivity. Finally it should be noted that BERD intensity had increased in Austria and Slovenia. Results appear mixed as to whether any significant catching up took place over the last decade.

4. *Inward R&D in motor vehicles* using responsiveness scores

This section explores the impact of drivers of inward R&D in the automotive industry. Here we apply an (iterated random coefficient regression) analysis based on a method developed by IRCRES. Following Woodridge (2002), the approach calculates unit responsiveness scores. This approach assumes that individual units react ('responsiveness') to the individual factors differently. The approach allows us to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, etc.), conditional on the other factors at play. (See Cerulli (2015))

Figure 1 illustrates the responsiveness scores for the automotive industry against a benchmark for manufacturing and for the service sectors. It illustrates that size-effects (GDP and the size of the sectors) are factors that are fairly consistent for all sectors in consideration. The figure makes clear that labour costs are much more important to manufacturing and the service sectors in general than to the automotive sector. Here the educational level and government budgetary appropriations for R&D (GBAORD) that play an instrumental role in relation to inward R&D in this sector. Details are presented in Annex A.5.

Figure 1: Motor Vehicles Inward R&D main drivers using Responsiveness Scores



5. Some overall tendencies

This box characterises key dimensions and aspects of the industry.

Box 1. R&D internationalization in motor vehicles, etc. (NACE 29)

The automotive industry plays a key role in the Europe 2020 strategy.

- Automotive R&D is mainly (and increasingly) driven by stricter standards on vehicle emissions and fuel consumption.
- Rapid technical change is driving the consolidation of automotive suppliers (including cross-border M&As), which now account for half of all R&D spending in the global supply chain.
- Greenfield investment has been strong (more than 50€ Billion per year since 2010) as firms attempt tap into local R&D resources, particularly in China, India and South Korea, but also in Europe. There have been some large cross-border M&As including BMW and Fiat, but little change is expected.
- Key challenges: electrification of powertrains and battery technology.
- Future technology: electronics and increasing use of ICT technologies that come from different subsystems of the supply chain, and fully autonomous (driverless) vehicles.

In this light, the case study highlights the following.

- The share of BERD performed abroad has remained relatively stable in the European Union since 2005. Internationalization of automotive R&D has focused on development, while research remains concentrated near the home bases of lead firms.
- The main European player in the automotive industry is Germany, but Italy, France, Sweden and the United Kingdom also engage in R&D activity that involves firms that are not headquartered in Germany. More than 85% of the value added in automobiles is produced in Germany; about 75% in both Italy and France; and less than 50% in Sweden and the UK.
- The level of economic development explains large national differences in the R&D intensity. However, there is no clear pattern of R&D activity in terms of the difference between the R&D intensity of national BERD and the R&D intensity of inward BERD.
- Labour productivity (both in terms of value added and production output) appears to be higher in the countries with inward FDI, except for France, Germany and Italy where it appears higher in the domestic economy.
- Countries close to the German border had a relatively higher growth of inward BERD. The Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia experienced high growth, although from a very low level. Production remains strong in these countries, but there is little indication that any significant R&D activities will be located in these countries in the near future.

Annex

Table A.1. *Total BERD in the automotive industry*

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	183	:	:	:	308	309	311	333	366	401	:	369	:	407	:	463
Belgium	109	126	114	105	77	78	99	97	104	123	88	84	89	113	126	148
Canada	111	150	308	302	306	313	363	391	421	:	:	158	:	:	:	124
Czech Rep.	114	109	132	174	175	169	183	244	259	290	327	134	136	162	183	250
Denmark	0	10	:	7	5	3	5	12	8	2	:	10	11	15	16	16
Finland	:	:	:	12	:	:	:	:	:	:	20	23	19	21	21	25
France	2100	2491	2671	3066	3189	3192	3363	3562	4206	:	2282	1658	1805	1918	1888	1908
Germany	7977	9420	10931	10660	11000	12079	12163	11502	12392	13519	15284	13821	14812	16312	17361	17187
Hungary	5	7	6	18	11	22	23	22	26	50	70	61	65	70	81	103
Italy	720	758	783	806	688	723	838	914	823	966	1159	993	1076	1298	1379	1453
Japan	9767	11045	13874	13710	14230	13667	13984	15564	15409	15008	18591	18840	22239	24606	27399	23435
Netherlands	84	127	98	116	105	118	113	130	105	139	146	124	142	284	278	292
Norway	15	16	35	54	48	35	30	28	38	40	33	30	15	27	29	30
Poland	37	46	30	18	10	13	24	43	36	27	41	80	23	44	54	130
Portugal	3	4	22	41	24	6	7	8	27	46	69	63	40	35	29	24
Romania	:	:	:	:	:	15	14	13	21	35	28	43	35	52	44	42
Slovakia	0	:	:	1	:	:	:	:	:	0	:	20	33	24	40	85
Slovenia	1	1	1	0	3	4	3	4	7	7	35	33	34	105	62	80
South Korea	938	887	1405	1222	1397	1471	1756	2191	2669	3009	2144	1992	2611	2944	3380	3629
Spain	:	:	:	254	294	190	225	268	257	254	295	348	382	357	341	328
Sweden	1053	1100	1257	1287	1394	1493	1442	1391	1575	1627	:	:	:	1053	:	:
UK	1350	1610	1417	1438	1456	1293	1163	1088	1106	1134	61	1083	1232	1493	1823	2053
USA	12769	17602	19905	18042	16176	14918	12603	12936	13247	11699	8956	8171	:	:	:	:

Inward BERD in the automotive industry

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria						59	157			345		337		369		411
Belgium			100	91	62	61	67	67	77	93		62		80		107
Canada	81	115	171	193	192	185	258	272	280	218	161	98	84	70	94	58
Czech Rep.	96	91	120	165	166	161	181	106	132	128	157	120	127	150	169	238
Denmark										0						2
Finland			3					2	3			10		5		
France	161			474	514	543		750	636	669		770				
Germany						1799		1852		2011		2184		2059		3074
Hungary							18	21	25	54				50		78
Italy														214		264
Japan	172	2250	2508	2203	2147	2466	2951	3093	3242	2837						
Netherlands													52	119	123	116
Norway										11				13		19
Poland	23	33	18	3	4	7	21	40	34	23		78		38		121
Portugal								6		30		0		0		0
Romania							1	1	2	0		34		41		40
Slovakia							0		1			26		47		44
Slovenia						0	0									13
Spain						254	360	480		203		170		292		271
Sweden	56	777	920	1201	1212	945		724		778						
UK	1020	935	1040	1073	1169			952	962	1229	1420			668		2200
USA	2279		3337	3249	3216	2993	2636	2944	2721	1781	1026	1144	1146	2178	3100	3671

BERD Flows Database

Table A.2. Inward BERD with summary statistics and missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Missing values	Total	Percent Missing
A1998	219	532	2211	0	19958	A1998	26	34	76.5
A1999	237	584	2419	0	22544	A1999	27	34	79.4
A2000	230	713	2972	0	28346	A2000	25	34	73.5
A2001	291	789	2846	0	29548	A2001	25	34	73.5
A2002	253	778	2857	0	29089	A2002	25	34	73.5
A2003	413	538	2187	0	26346	A2003	20	34	58.8
A2004	364	434	2001	0	24184	A2004	21	34	61.8
A2005	479	504	2003	0	24997	A2005	16	34	47.1
A2006	395	514	2273	0	27576	A2006	20	34	58.8
A2007	537	492	2058	0	29892	A2007	14	34	41.2
A2008	155	1164	4083	0	34262	A2008	30	34	88.2
A2009	422	470	2086	0	28983	A2009	19	34	55.9
A2010	153	1041	3619	0	31953	A2010	30	34	88.2
A2011	510	485	2169	0	32455	A2011	15	34	44.1
A2012	160	1152	4275	0	39118	A2012	30	34	88.2
A2013	530	626	2726	0	39895	A2013	13	34	38.2
A2014	32	96	205	0	974	A2014	33	34	97.1

The figure also shows that the US and Germany are among the smaller set of countries, which provide data for each year: for example, France is missing 2011 and the UK is missing in 2009. For reference to the missing values, see the annex.

Table A3: Labour productivity and BERD intensity in the Automotive Industry

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
EU	Total	44.9	68.9	69.0						
	Inward	41.2	56.6	57.6						
Austria	Total	81.0	98.0	90.8	15.1	13.7	16.8	10.0	9.8	10.1
	Inward	93.1	112.0	102.2	16.7	15.5	19.4	11.4	11.3	11.4
Belgium	Total	:	74.2	93.7	:	:	:	:	:	:
	Inward	:	81.6	108.5	:	:	:	:	:	:
Bulgaria	Total	5.5	9.4	11.1						
	Inward	5.7	10.1	12.0						
Croatia	Total	:	:	12.2	:	:	0.0	:	:	0.0
	Inward	:	:	12.6	:	:	0.0	:	:	0.0
Cyprus	Total	28.5	24.9	17.1	0.0	0.0	:	0.0	0.0	:
	Inward	:	:	:	:	:	:	:	:	:
Czech Rep.	Total	29.3	38.8	39.0	7.5	8.4	4.4	2.4	2.2	2.5
	Inward	32.0	42.6	43.1	7.8	8.7	4.6	2.5	2.3	2.6
Denmark	Total	57.2	61.6	63.0	:	:	2.9	:	:	2.3
	Inward	47.1	60.4	66.5	:	:	3.3	:	:	1.5
Estonia	Total	14.7	27.2	26.6	2.1	2.1	1.4	1.4	1.3	0.0
	Inward	16.0	29.4	28.1	1.7	2.2	1.0	1.1	1.0	0.0
Finland	Total	40.7	56.8	73.5	6.8	3.8	6.4	3.5	2.3	4.9
	Inward	54.9	88.0	86.6	14.4	4.4	13.7	8.4	3.8	10.3
France	Total	45.4	59.5	56.4	40.3	:	29.9	14.2	:	13.3
	Inward	41.5	57.3	50.6	30.3	:	27.8	12.3	:	12.4
Germany	Total	:	97.8	96.1	:	23.3	28.2	9.7	10.4	10.4
	Inward	58.7	71.0	:	29.8	21.8	:	11.9	9.8	11.7
Greece	Total	:	:	22.6	:	:	0.9	:	:	0.6
	Inward	:	:	:	:	:	:	:	:	:
Hungary	Total	33.2	46.8	43.9	2.4	1.7	2.5	1.6	1.9	2.2
	Inward	38.0	51.9	48.1	2.4	1.7	2.5	1.7	1.9	2.1
Ireland	Total	61.8	55.2	:						
	Inward	:	64.9	:						
Italy	Total	43.2	58.6	55.3	:	13.1	16.3	6.1	7.1	8.6
	Inward	34.6	62.9	65.1	:	9.1	11.3	4.6	4.8	6.1
Latvia	Total	12.1	24.7	26.9	0.0	:	:	0.0	:	:
	Inward	18.9	:	:	0.0	:	:	0.0	:	:
Lithuania	Total	7.9	21.2	19.8	:	:	:	:	:	:
	Inward	10.1	25.2	21.3	:	:	:	:	:	:
Luxembourg	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Malta	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Netherlands	Total	66.9	94.0	83.4	4.2	7.6	9.3	3.5	9.2	12.2
	Inward	88.2	127.7	101.4	:	:	10.4	:	9.0	10.8
Norway	Total	52.2	82.5	86.9	17.2	10.2	10.4	9.5	8.0	9.0
	Inward	:	82.7	91.5	:	15.5	14.2	:	11.9	10.2
Poland	Total	26.4	33.1	32.6	2.1	0.9	2.5	0.4	0.8	1.6
	Inward	30.4	36.8	36.3	2.5	0.9	2.7	0.4	0.7	1.7
Portugal	Total	29.6	36.7	34.0	0.1	0.2	0.0	1.5	2.0	1.7
	Inward	34.5	45.1	40.5	0.0	0.0	0.0	1.4	1.6	1.5
Romania	Total	11.5	10.6	16.3	2.7	3.1	1.8	1.1	0.7	0.6
	Inward	11.9	10.7	17.2	2.9	3.5	1.8	1.2	0.8	0.6
Slovakia	Total	23.0	31.1	35.5	2.3	2.6	2.0	0.3	1.0	1.2
	Inward	23.7	32.0	36.6	2.3	2.7	2.1	0.3	1.0	1.3
Slovenia	Total	30.3	38.2	38.8	5.9	6.6	8.5	2.5	3.6	3.9
	Inward	38.0	43.9	46.2	:	:	6.3	:	:	0.7
Spain	Total	48.4	60.5	63.5	4.9	4.2	3.9	3.5	4.0	4.0
	Inward	52.8	65.0	69.2	3.7	4.2	3.9	2.9	4.0	3.9
Sweden	Total	31.6	77.3	73.9						
	Inward	34.0	72.0	72.9						
UK	Total	46.2	98.4	108.3	:	5.7	13.3	6.3	4.8	8.0
	Inward	57.3	122.8	138.9	:	6.7	15.4	9.5	6.6	11.4

Source: Eurostat

R&D internationalization in computer programming, consultancy, information services and related activities (NACE 58.2 and 62-63)

Draft of 17 October by Mark Knell

1. Introduction

This case study presents a digest of R&D internationalization in computer programming, information services, software publishing and related activities (NACE 58.2 and 62-63), or what we call software and computer services. The industry is commonly classified as *Knowledge Intensive Business Services* (KIBS) because of its high R&D intensity. The main objective of this case study is to identify some of the key drivers of inward R&D in computer programming, information services and related activities. Based primarily on statistics on total BERD flows and inward-BERD flows (excludes domestic BERD), the study integrates productivity data from the Foreign Affiliates Statistics (FATS) together with several other indicators to investigate the underlying determinants that explain the observed patterns of R&D internationalization. Statistics for outward BERD are presented in a separate case study.

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

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

Knowledge-based services are heterogeneous and more complex then the services described by Smith. Hill (1999) suggests that software should not be considered a service, but an intangible good that is an outcome of R&D activity and subjected to intellectual property rights. This fuzzy distinction may explain Baumol (1985; 2002) reasoning that software production could be classified as an *asymptotically stagnant impersonal service* because it is both progressive (increasing returns) and the stagnant (constant returns) at the same time. Horn (2000) also makes the suggestion that productivity growth in software creation has been rising rapidly, though not as quickly as computer hardware.

There are not only scale economies created by spreading fixed and sunk costs over time, but increasing returns may appear in the development and production of new software, often reliant on existing knowledge and existent coding. Software production can lead to radical improvements in productivity (software engineering), but new technological opportunities have been met by growing (often intermediate) demand, mainly in the creation of custom software (Peneder et al. 2003). The fuzzy distinction may also explain some of the challenges presented in measuring BERD intensity and BERD growth in the software industry.

2. Computer programming, consultancy, information services and related activities

Computer programming, information services, software publishing and related activities (NACE 58.2 and 62-63) are classified as Knowledge Intensive Business Services (KIBS) based on its R&D intensity and R&D growth. There is considerable variation across the different enterprises in the industry, but R&D intensity tends to be very high in this industry, sometimes surpassing 50% as in the case of Facebook. Software and computer services have observed fairly high growth over the past two decades, and it appears that Inward BERD is also growing rapidly, but there is a problem in getting sufficient statistics (see annex). Besides being a key driver in economic growth, another striking feature of KIBS is their role in the internationalisation of R&D. The industry contains several large enterprises with subsidiaries located a many different countries. It also has many complementary subsidiaries in computer, electronic and optical products industry (NACE 26) involved in software production.

Industrial R&D is highly concentrated in software and computer services, and is much higher in the US and East Asia than in Europe. US-based firms account for almost two-thirds of total BERD in this industry (the Eurostat R&D Survey estimates that US companies account for 77% of Global R&D), as it has led the way in the development of software/internet companies such as Google, Facebook, Twitter, Linkedin, eBay and Amazon. Six out of the top enterprises had American headquarters, including Microsoft, Google, Oracle, IBM, Facebook, and Yahoo! Three of the top 10 enterprises had their headquarters in Asia, including Fujitsu in Japan and Baidu and Tencent in China. Only SAP had their headquarters in Europe. Several of these have subsidiaries or joint ventures located in Europe. Germany has an extended network covering more than 130 countries. Large transnational firms tend to be *strategic asset seekers* in the industry, often setting up R&D facilities within a cluster of enterprises with the aim of enhancing the technological assets of the parent company.

Eight of the top ten enterprises experiencing the fastest in growth in R&D activity between 2013 and 2015 were located in the United States. King Digital Entertainment (Ireland) had the highest BERD growth averaging more than 110% per year over the three-year period. Facebook observed the highest growth of BERD among the top 10, averaging more than 50% per year over the three-year period. Companies based in the US increased their R&D investment by about 13%, performing better than enterprises in Europe and Japan. There is a significant gap for the EU vis-à-vis the US in terms of number of companies and R&D investment in software. Nevertheless, the *Scoreboard* also shows a number of world-beating EU companies of substantial size in these sectors, as well as a significant number of high-performance companies showing the potential to further climb-up in the ranking of world top R&D investors. Many software companies located in China showed double digit R&D growth, such as Baidu (69.9%) and Tencent (52.2%) in 2015.

Table 1a. Top 10 Global enterprises in software and computer services.

World Rank	Name	Ownership	BERD (mil.)	BERD intensity	BERD growth	Sales (mil)

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

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

Source: EU R&D scoreboard 2015.

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

Table 1b. Top 10 European enterprises in software and computer services.

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

Notes: See previous note.

Source: EU R&D scoreboard 2015.

3. Inward R&D in computer programming, information services and related activities

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

Table 2. Inward BERD as a percentage of total BERD in computer programming and related activities

	2007		2009		2011		2013	
	Total	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*	*Total*	*Inward Share*
Austria	255	35.7%	166	24.7%	274	47.4%	352	53.7%
Belgium	264	31.8%	236	36.9%	324	39.2%	422	46.4%
Canada	:	:	787	13.1%	1,167	21.1%	1,002	28.4%
Czech Rep.	103	43.7%	121	47.9%	171	45.0%	194	47.4%
Israel	:	:	:	:	1,915	71.1%		:
Italy	390	55.9%	277	:	290	:	859	:
Netherlands	275	:	624	9.8%	1,381	7.7%	1,376	10.4%
Slovenia	6	:	19	:	52	:	36	11.1%
UK	1,464	66.5%	1,328	:	1,773	:	2,093	65.7%
USA	24,838	1.1%	10,966	3.8%	12,603	5.3%	:	:
USA*			*29,889*	*1.0%*	*32,693*	*1.5%*	*38,436*	*1.6%*

Source: BERD flows database and OECD ANBERD database.

Notes: Inward BERD based on NACE 62-63 and does not include NACE 58.2. NACE 58.2 represents less than 5% of average of Total BERD in software and computer services, except for the United States. USA* total represents Total BERD for NACE 58.2 and 62-63.

Table 2 also corroborates the relative importance of inward flowing R&D to the overall R&D carried out in the sector in the individual countries. Enterprises in small countries appear much more international in that the share of inward BERD is much higher, mainly because they are part of the global production process. The table also indicates the general increase in total R&D from 2009. Many countries in Europe show a general growth trend from 2011 to 2013 in total BERD and total BERD in both the United States and Europe. The shares appear relatively consistent across observations, except for the UK where the share of inward BERD is relatively high for its size.

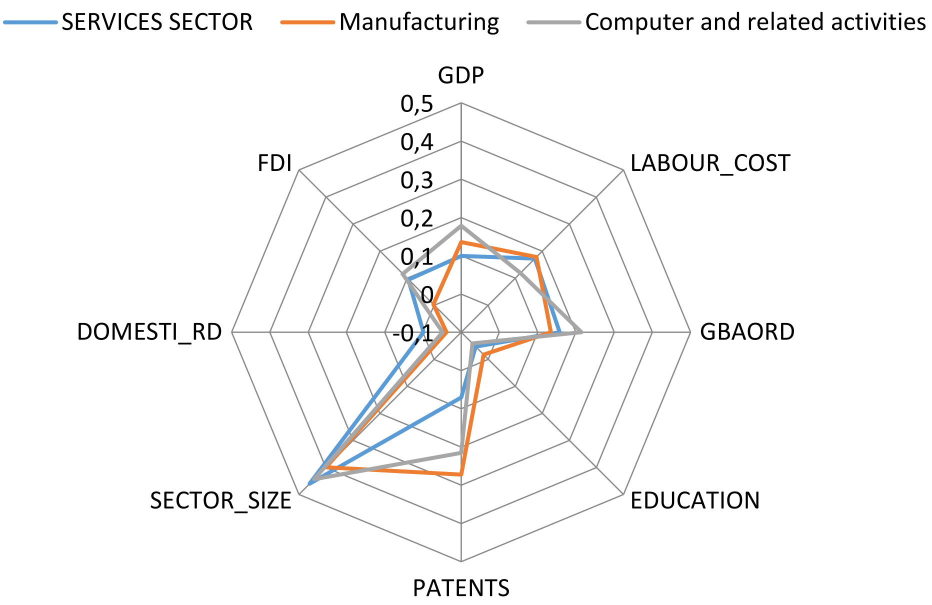
Table A3 shows apparent labour productivity, BERD intensity (share of BERD in value added) and the share of R&D employment for 2009, 2011 and 2013. Apparent labour productivity appears higher in virtually all of the foreign affiliates when compared with their domestic counterparts. (explain). There is very little information on share of BERD in value added or share of BERD of employment, but what is there show mixed results.

4. *Inward R&D in software and related services* using responsiveness scores

This section explores the impact of drivers of inward R&D in the software and related services. Here we apply an (iterated random coefficient regression) analysis based on a method developed by IRCRES. Following Woodridge (2002), the approach calculates unit responsiveness scores. This approach assumes that individual units react ('responsiveness') to the individual factors differently. The approach allows us to measure and to rank the change of the outcome (external R&D in a given country) when a given factor changes (GDP, level of patenting, size of sector, etc.), conditional on the other factors at play. (See Cerulli (2015))

Figure 1 illustrates the responsiveness scores for the software and related services against a benchmark for manufacturing and for the service sectors. It illustrates that size-effects (GDP and the size of the sectors) are factors that are fairly consistent for all sectors in consideration. The figure shows a strikingly similar across the different sectors. Here the educational level and government budgetary appropriations for R&D (GBAORD) that plays an instrumental role in relation to inward R&D in this sector. Details are presented in Annex A.5.

Figure 1: Computer and related activities Inward R&D main drivers using Responsiveness Scores



5. Overview of the Knowledge based intensive services

There are a number of characteristics of the industry(ies) that are noteworthy and that can help to shape the direction and depth of R&D internationalisation. The box includes some of these.

Box 1. R&D internationalization in computer programming etc (NACE 58.2 and 62-63)

Over half of R&D investment in key enabling technologies (KETs) is in software and computer services.

- A few large companies mainly located in the United States and China drive R&D growth rate in Software & Computer Services.
- Rapid growth and technical change is driving the software industry in the US, but there are several firms in Europe who are potential leading innovators.
- Both greenfield investment and cross-border M&As appear to be accelerating.
- Key challenges: better software and further development of artificial intelligence
- Future technology: high performance computing, building data value, social computing, internet-based applications, embedded systems, human centered computing, enterprise applications and the generation of software-intensive systems.

Despite considerable improvement in statistical collection in recent years, coverage of the internationalization of R&D activity in services is a problem in many countries making it difficult to create comparable statistics both across countries and industries and across time. For example, we do not know much about the business cycle and trend effect of service related R&D activity. The inter-sectoral variance in services is even larger than in manufacturing. What this implies is that a large part of R&D is concentrated in a small number of sectors, primarily business services including ICT.

Annex

Table A.1. *Total BERD in* in computer programming, consultancy, information services and related activities

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria	33				104	120	140	167	198	255		166		274		352
Belgium	175	204	142	158	241	244	195	201	256	264	228	236	299	324	408	422
Bulgaria	0	0			0	0	2	3	5	7	6	7	9	5	11	17
Canada	390	435	719	963	736	707	735	823	784			787	1039	1167	1072	1002
Croatia											1	8	8	6	6	5
Cyprus	0	1	1	1	1	3	4	5	5	6	7	7	5	4	2	1
Czech Republic	5	7	12	12	20	52	60	83	92	103	135	121	132	171	189	194
Denmark	239	225		352	448	473	468	720	736	712		563	635	609	468	419
Estonia	0	1	1	2	3	2	7	10	18	23	31	26	27	29	40	36
Finland				189	229	235	271	276	288	356	359	319	318	354	384	442
France	376	464	496	702	825	907	1019	1082	1091		906	1204	1497	1627	1704	1806
Germany		866		1047		1338	1335	1669	1634	1629	1706	1956	2011	2376	2511	2770
Greece	23	28	37	47	56	61	61	57						38		55
Hungary	3	3	5	6	9	6	7	7	15	18	36	62	44	52	100	138
Iceland	10	13	17	16	16	19	25	35	40	36	25			30		20
Ireland	59	90	165	252	320	379	378	391	392	393		298	293	344		418
Israel													1648	1915	2357	
Italy	173	162	154	260	268	235	360	367	303	390	222	277	275	290	302	859
Japan	2245	2264	2116	1691	1668	1923	2183	1854	1787	1384	1663	1954	2361	2372	2379	1409
Latvia			1	0	0	1	1	1	2	1	4	4	4	2	1	4
Lithuania	0					1	1	2	4	1	2	3	8	7	7	9
Luxembourg												19		9		2
Malta					1			2	3	5	3	3	4	7	9	14
Netherlands	96	107	242	273	297	224	216	213	319	275	545	624	1015	1320	1295	1338
Norway	178	190	216	243	244	266	223	292	326	391	270	238	304	365	454	502
Poland	0	0	1				9	25	29	36		31	81	101	159	172
Portugal	10	17	21	26	27	29	27	26	67	108	125	132	124	102	120	119
Romania	1	0	0	0	2	7	0	1	15	25	0	15	9	21	39	16
Serbia												0	1	0		
Slovakia						0	1	0	1	2			5	5	30	30
Slovenia	0	0	0	0	0	0	0	1	5	6	13	19	20	45	30	31
South Korea	117	187	379	685	544	440	429	504	624	578	93	109	155	258	217	205
Spain				203	260	279	317	388	447	650	667	658	645	650	645	655
Sweden	231	292	378	327	244	206	312	445	506	436						0
UK	1017	1082	1003	1085	1378	1744	1562	1565	1995	1464	1479	1328	1390	1773	2036	2093
USA	14996	14170	19281	24860	26343	21329	22633	24530	26915	24838		10966	10250	12603	12581	
USA*											31911	29889	30006	32693	34954	38436

Inward BERD in in computer programming, consultancy, information services and related activities

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Austria										91		41		130		189
Belgium			21	25	85	92	41	39	90	84		87		127		196
Canada			104	174	131	121	149	240	169	208	208	103	226	246	256	285
Czech Rep.	2	3	5	6	10	23	24	41	40	45	64	58	61	77	93	92
Eastonia							1	3	9							
Ireland		70		128				233								
Isreal										1046	1245	1202	1247	1361		
Italy				105	135	122	135	138	145	218						
Japan						25	21	36	31							
Netherlands											47	61	110	97	100	137
Poland								15	22							
Sweden						114										
UK	435	551	305	590	716			702	823	973						1375
USA				429	181	246	176	123	201	285	211	418	746	662	858	799

BERD Flows Database

Table A.2. Inward BERD with summary statistics and missing values

Variable	Obs	Mean	Std. Dev.	Min	Max	Variable	Missing values	Total	Percent Missing
A1999	3	208	299	3	551	A1999	30	33	90.9
A2000	4	109	138	5	305	A2000	29	33	87.9
A2001	7	208	219	6	590	A2001	26	33	78.8
A2002	6	210	255	10	716	A2002	27	33	81.8
A2003	9	83	80	0	246	A2003	24	33	72.7
A2004	11	50	68	0	176	A2004	22	33	66.7
A2005	12	131	200	0	702	A2005	21	33	63.6
A2006	12	128	230	0	823	A2006	21	33	63.6
A2007	11	268	379	0	1046	A2007	22	33	66.7
A2008	4	432	546	64	1245	A2008	29	33	87.9
A2009	6	318	455	41	1202	A2009	27	33	81.8
A2010	4	570	538	61	1247	A2010	29	33	87.9
A2011	6	434	502	77	1361	A2011	27	33	81.8
A2012	3	402	403	93	858	A2012	30	33	90.9
A2013	6	489	501	92	1375	A2013	27	33	81.8

Table A3: Labour productivity and BERD intensity in the Computer programming, consultancy and related activities

		Apparent labour productivity			Share of BERD in value added			Share of R&D employment		
		2009	2011	2013	2009	2011	2013	2009	2011	2013
Austria	Total	64.4	69.1	70.7	5.0	6.7	7.7	7.2	9.9	:
	Inward	92.5	97.2	96.3	4.0	8.9	11.6	5.4	14.2	:
Belgium	Total	:	79.5	76.8	:	:	:	:	:	:
	Inward	:	173.4	:	:	:	:	:	:	:
Bulgaria	Total	15.2	18.8	20.6	:	:	:	:	:	:
	Inward	21.8	24.6	25.7	:	:	:	:	:	:
Croatia	Total	:	27.9	27.2	:	:	:	:	:	:
	Inward	:	43.6	48.5	:	:	:	:	:	:
Cyprus	Total	55.2	68.2	64.1	:	:	:	:	:	:
	Inward	70.8	:	97.8	:	:	:	:	:	:
Czech Rep.	Total	38.1	41.6	37.2	4.3	:	:	4.3	:	:
	Inward	50.7	54.0	47.9	:	:	:	4.4	:	:
Denmark	Total	95.8	76.9	79.7	:	:	:	:	:	:
	Inward	109.9	83.6	91.1	:	:	:	:	:	:
Estonia	Total	:	36.8	41.0	:	:	:	:	:	:
	Inward	36.0	38.8	41.5	:	:	:	:	:	:
Finland	Total	68.5	72.2	:	:	:	:	:	:	:
	Inward	81.0	86.3	:	:	:	:	:	:	:
France	Total	64.9	66.8	63.8	5.8	6.5	6.9	:	:	:
	Inward	88.8	103.7	92.8	5.6	5.5	6.6	:	:	:
Germany	Total	82.3	81.9	85.5	:	:	:	:	:	:
	Inward	86.1	105.3	187.1	:	:	:	:	:	:
Greece	Total	:	:	24.9	:	:	:	:	:	:
	Inward	:	:	65.4	:	:	:	:	:	:
Hungary	Total	20.5	24.0	26.2	:	:	:	:	:	:
	Inward	38.9	43.1	39.7	:	:	:	:	:	:
Ireland	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Italy	Total	54.0	63.2	63.0	:	:	:	:	:	:
	Inward	79.9	86.2	84.8	:	:	:	:	:	:
Latvia	Total	19.6	20.6	24.1	:	:	:	:	:	:
	Inward	28.9	31.1	40.2	:	:	:	:	:	:
Lithuania	Total	15.9	21.0	22.3	:	:	:	:	:	:
	Inward	23.5	29.9	32.1	:	:	:	:	:	:
Luxembourg	Total	:	76.7	78.6	:	:	:	:	:	:
	Inward	80.9	84.5	84.9	:	:	:	:	:	:
Malta	Total	49.9	78.6	68.5	:	:	:	:	:	:
	Inward	:	:	:	:	:	:	:	:	:
Netherlands	Total	69.6	71.9	75.3	:	:	:	:	:	:
	Inward	88.9	96.7	101.8	:	:	:	:	:	:
Norway	Total	96.5	114.6	122.1	:	:	:	:	:	:
	Inward	:	131.1	142.9	:	:	:	:	:	:
Poland	Total	35.5	37.7	37.8	1.7	:	:	3.5	:	:
	Inward	47.1	44.5	43.1	1.4	:	:	2.4	:	:
Portugal	Total	37.0	35.5	34.4	:	:	:	:	:	:
	Inward	60.5	56.7	55.2	:	:	:	:	:	:
Romania	Total	16.6	19.7	20.4	:	:	:	:	:	:
	Inward	24.3	26.5	26.5	:	:	:	:	:	:
Slovakia	Total	47.0	39.1	37.5	:	:	:	:	:	:
	Inward	44.8	38.5	39.8	:	:	:	:	:	:
Slovenia	Total	33.8	36.4	35.1	:	:	:	:	:	:
	Inward	64.5	69.5	63.6	:	:	:	:	:	:
Spain	Total	52.3	52.8	52.4	:	:	:	:	:	:
	Inward	70.3	63.9	61.3	:	:	:	:	:	:
Sweden	Total	63.5	77.9	78.8	:	:	:	:	:	:
	Inward	69.1	86.9	97.0	:	:	:	:	:	:
UK	Total	78.8	82.3	90.4	3.6	4.1	4.0	:	:	:
	Inward	109.8	120.9	129.2	4.2	4.7	4.8	:	:	:
USA	Total	:	:	:	:	:	:	:	:	:
	Inward	:	:	:	6.7	5.0	5.8	:	:	:

Source: Eurostat and OECD

FISCAL INCENTIVES AND THEIR IMPACT ON INAWRD BERD. A CASE STUDY.

INDRODUCTION

Since The Lisbon Strategy, European Commission has considered investments in Research and Development (R&D) as one of the main priorities for Europe to become more competitive in a globalized world. Today, "Europe 2020 strategy for Growth" sets a target for Member States to reach 3% of their GDP dedicated to R&D.

Research and development, resulting in new goods, new processes and new knowledge, is a major source of technical change and economic growth. Indeed, there is a widespread belief among policymakers that foreign direct investment (FDI) in R&D may generates positive productivity effects for the host countries. The adoption of foreign technology and know-how, the introduction of new processes and products by foreign firms, and the creation of linkages between foreign and domestic firms, are all elements that can play an important role in modernizing a national economy and promoting economic development.

More and more foreign-controlled multinational enterprises are perceived by governments as a pivotal actor in the national economic systems and as a motor for change and innovation. As result, in recent years there have been an increasing competition among countries to attract R&D activities of multinational enterprises.

The economic literature suggests that there are several drivers for BERD location decision of MNE's. Some of them are assets that can be hardly modified by a policy intervention, whereas others are subject to changes induced by a sets of policy instruments in the hand of national Governments.

Availability of skilled employees; quality of public research; an efficient intellectual property rights regime; quality of institutions, are all assets on which Governments can intervene to attract foreign investments in R&D;

Among all these elements, the most straight-forward policy instrument is to provide public incentives to business R&D, which may be both fiscal and financial. In recent years a growing number of new and different subsidy schemes for business R&D have been implemented.

In this section we will try to understand and measure the importance of the tax incentive as a driver of R&D investments decision of MNE's.

Due to the lack of data, we will concentrate our analysis only on six countries, namely Germany France, UK, Japan, Canada and United States .

In the first section we will briefly describe the different type of tax incentives; in the second section we will provide an overview of the recent literature in the impact of tax incentives on BERD investments. In the last section we will try to understand the impact of R&D tax schemes on inward BERD.

1. TAX incentives in R&D.

In recent years, R&D tax incentives have become an important policy instrument to encourage firms to invest in R&D. According to OECD Scoreboard, in 2015 28 of the 34 OECD countries and a number of non-OECD economies give preferential tax treatment to R&D expenditures, doing it with several instruments.

In particular, incentives for business R&D expenditures include allowances and credits, as well as other forms of tax treatment, such as allowing for the accelerated depreciation of R&D capital expenditures or innovation or patent boxes, under which income attributable to intellectual property (IP), developed through R&D, is taxed at favourable rate.

The specific design, type and number of R&D tax incentives differ substantially across countries. Tax incentives may vary for the scope of the policy, the target, for the stability and the time horizon of the policy over time.

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

In addition, the tax exemption can refer to different sorts of R&D expenditures. Usually, an R&D tax incentive applies to specific inputs that are used in R&D processes (incentive base) and requires some degree of novelty for the intended outcome (requirement of novelty).

Also the target of a tax scheme can vary across countries and years. Governments may decide to incentivize R&D activities in a certain zone, or increase the level of R&D spending of a specific group of enterprises, diversified according to their size, their age of their field of activities.

The effectiveness of R&D incentives, both direct and indirect, also depends on the stability and the time horizon of the policy. For instance, when R&D tax policy changes often the impact of R&D tax incentives may be reduced.

In the table below we present a taxonomy of the instruments, their definition and the Country where the policy is implemented.

Table 1. Instruments, definition and Countries, where the policy is implemented

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

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

1.2. An overview of the recent literature on R&D fiscal policy impact.

A large body of literature has investigated how R&D tax incentives and corporate taxation can be an important element at the base of the location decision of a MNE's.

De Mooij and Ederveen (2003), conducing a meta-analysis of several studies on the impact of corporate taxes, find that a decrease by one percentage point in the host country tax rate leads to an increase of foreign direct investment by around 3.3 percent. Wilson (2009), working on the several States of U.S., finds that R&D tax incentives attract R&D from other federal States, while the overall amount of R&D from U.S. is not affected. He concludes that incentives are "a zero-sum game among States".

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

On the same line, other studies find out that R&D activities are especially sensitive to corporate taxes changes (Desai et al., 2006; Stöwhase, 2002; Grubert and Slemrod, 1998).

The location of patent applications by European corporations is also responsive to corporate income tax rates (OECD, 2013b). Karkinsky and Riedel (2012) estimated that an increase of one percentage point in the corporate tax rate results in a fall in the number of patent applications of 3.5 to 3.8 percent.

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

2. Econometric test

Data description

Independent variable (INWARD BERD)

We employ inward BERD data from 1998 to 2013.

B) Dependent variables

Data on direct and indirect taxation comes from OECD.[1] In our econometric tests we run two models, the first with indirect taxation, the second with the variable "direct taxation".

As we have already explained we have panel data on R&D taxation for only eight OECD countries, Australia, France, United Kingdom, Japan, Korea, Netherlands, Canada and United States. [2] However we will conduct our econometric analysis only on 6 of them, since we do not have inward data for Australia and Korea.

In order to measure the influence that Government support for research and development activities may have on Inward investments R&D, we use the GBAORD index, accounting for Government budget appropriations or outlays for research and development. GBAORD include all appropriations (government spending) given to R&D in central (or federal) government budgets. The source of data is OECD, Science Technology and Innovation (STI) indicators.

Patents Application are used as a proxy of the innovation capabilities of Countries. Data are taken from World Bank, World Development Indicators. As to capture the capability innovation of the Country we have add to the number of patent applications of resident the patent applications of non-resident.

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

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[1] http://www.oecd.org/sti/rd-tax-stats.htm

[2] See the annex for more information on the estimation methodology.

Data on corporate income taxation are taken from OECD tax database.

In table 2, we present the trends in government tax incentive and direct support for business R&D, 2000-2013. Tax support is expressed as a percentage of total (direct plus tax) government support for business R&D.

Table 2. Tax support as a percentage of total (direct plus tax) government support for business R&D., 2000-2013

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

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

2012	N/D	83	70	75	54	85	50	26
2013	N/D	85	70	82	58	87	48	N/D

2.1 Model Specification

In order to test the effect of R&D tax incentive we employ a fixed effects model.

Usually, fixed effects model is useful when we are only interested in analyzing the impact of variables that vary over time. Fixed effects model explore the relationship between independent variables and dependent variable within an entity.

Each Country has its own characteristics that, may or may not, influence the predicted variable. When we use a fixed effects model we assume that something within the Country may impact both the dependent and independent variables. This is because there is the assumption of correlation between error term and independent variables.

"Fixed effects model" drop the effect of those time-invariant attributes so we can assess the net effect of the independent variables on the dependent one.

Another important assumption is that time invariant attributes are unique to the country and should not be correlated with other countries characteristics. Each country is different, therefore the error term and the constant (which captures the regional characteristics) should not be correlated with the others.

2.2 Estimation results

Firstly we run our econometric test as to identify the effect of indirect taxation on R&D. In the second specification of the model we use, among the dependent variables, the logarithm of direct Government founding to R&D. This second specification will allow us as to capture the different impact on inward BERD of direct funding and tax incentives for R&D.

In both tests we also try to measure the impact of corporate income tax.

The results shows (see the table 2 below) a significant and positive correlation between taxation and Inward BERD. Only the variable accounting for "resident total patents" (ln_PATENT) has an effect on Inward higher than "R&D tax exemption".

Even if the sign of the coefficient is negative, thus indicating that an increase of the corporate taxation will imply a decrease in Inward, the variable "log of corporate income tax" is not significant.

ln_total_inwad	Coef,	Robust Std, Err	t	P>|t|	[95% Conf, Interval]	
ln_tot tax incentives	0,0755327	0,0352526	2,14	0,099*	-0,022344	0,1734096
ln_GBAORD	0,0533611	0,2354612	0,23	0,832	-0,6003841	0,7071063
ln_PATENT	0,6080022	0,2701073	2,25	0,088*	-0,141936	1,35794
FDI	0,0029954	0,0040638	0,74	0,502	-0,0082876	0,0142784
ln_corp_inc_tax	-0,9771489	0,6688605	-1,46	0,218	-2,834203	0,8799057
_cons	4,483535	3,773259	1,19	0,3	-5,992712	14,95978
sigma_u	0,9364492					
sigma_e	0,130551					
rho	0,9809350	(fraction of variance due to u_i)				

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

In the second specification of the model we do not find any positive and significant correlation between direct funding Government support (variable Log tot_dir_ level) and inward BERD. This seems in line with the logic of the direct support that it is often designed and implemented to meet the need of young or small firms, that are often in disadvantage position vis-à-vis large firms or multinational enterprises.

Also in this case corporate income tax is negative but not significant and the variable accounting for "resident total patent" has the highest positive and significant coefficient.

Standard errors in parentheses

ln_total_inward	Coef,	Robust Std. Error	t	P>|t|	[95% Conf, Interval]	
ln_tot_tax incentives	0,01551	0,0594885	0,26	0,807	-0,1496567	0,1806766
ln_GBAORD	0,1889022	0,1871569	1,01	0,371	-0,3307287	0,7085331
ln_PATENT	0,6658718	0,2479136	2,69	0,055*	-0,0224468	1,35419
FDI	0,0008446	0,0055422	0,15	0,886	-0,014543	0,0162321
ln_corp_inc_tax	-2,22697	1,357173	-1,64	0,176	-5,995085	1,541145
_cons	7,202758	3,850437	1,87	0,135	-3,48777	17,89329
sigma_u	0,92559338					
sigma_e	0,13313524					
rho	0,97973008	(fraction of variance due to u_i)				

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

Annex 1. R&D tax incentives, estimation methodology

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

Australia: Estimates, on an accrual basis, refer to the R&D tax concession and R&D Tax Incentive, as published in the Taxation Expenditures Statement. The R&D Tax Incentive provides a refundable tax offset for eligible entities with an aggregated turnover of less than AUD 20 million, unless controlled by tax exempt entities, and a non-refundable tax offset for all other eligible entities. The Research and Development (R&D) Tax Concession was replaced by the R&D Tax Incentive for income years beginning on or after 1 July 2011. The key elements of the R&D Tax Concession were: (1) a 125% Tax Concession (for investment in R&D which is 'Australian-owned') introduced in 1986; (2) an R&D Tax Offset for small companies, enabling them to cash out any tax losses (in relation to Australian-owned R&D only) introduced in 1986; (3) an R&D incremental (175% Premium) Tax Concession for additional investment in Australian-owned R&D (available as of 1 July 2001); and (4) a 175% International Premium incremental tax concession for additional investment in 'foreign-owned' R&D (available as of 1 July 2007). Break in BERD data series in 2001 and 2006.
Canada: Estimates, on a cash basis, refer to the scientific research and experimental development tax credit for current and capital R&D expenditures, as published in the Tax Expenditures and Evaluations reports. They do not reflect the cost of provincial governments' R&D tax incentives provided by many Canadian provinces in order to ensure the comparability of R&D tax incentive estimates across

countries. Estimates for the cost of accelerated depreciation provisions are not available.
France: Estimates, on an accrual basis, refer to the crédit d'impôt recherche (CIR) and special provisions for social security contributions by young and innovative firms (JEIs) and young university enterprises (JEUs), but exclude the cost of accelerated depreciation incentives for capital R&D. The JEI and JEU status were established in 2004 and 2008 respectively. Since 1 January 2008, the CIR - previously hybrid - has been calculated solely on the volume of R&D expenditures, with no ceiling. An enhanced tax credit rate of 35% was initially applicable up to an R&D expenditure ceiling of EUR 16 million, which was increased to EUR 100 million in 2008. As a temporary measure, an immediate refund of all unused credit was offered to all firms (instead of 3 years waiting period) in 2009. Break in BERD data series in 2004. The estimate of direct funding for 2013 is based on imputing the share of direct government-funded BERD in the previous year to the current ratio of BERD to GDP.
Japan: Estimates, on a cash and final revenue loss basis, cover the system of volume-based and incremental R&D tax credits in Japan. The volume-based R&D tax credit is currently available in addition to either an incremental-based R&D tax credit or high R&D intensity-based tax credit. Prior to fiscal year 2003, only an incremental-based R&D tax credit had been available which was complemented by a volume-based R&D tax credit in 2003, only one of which could then be selected by firms. In 2006, the R&D tax incentive system in Japan was altered and an incremental tax credit became available as an additional measure aside the volume-based R&D tax credit. In 2008, the incremental component of R&D tax relief system was further modified to introduce on a temporary basis (until March 2017) a high R&D intensity-based tax credit as alternative option to the incremental R&D tax credit.
Korea: The R&D tax credit has a volume and incremental component only the larger one of which applies; a volume-based R&D tax credit is further available for high-growth firms with original technology. The Growth Industry and Basic Technology tax credit is set to expire in 2015. Korea additionally offers an R&D investment credit for developing new R&D facilities. No further details available on cost estimates.
Netherlands: Estimates, on a cash basis, refer to the WBSO payroll tax credit for R&D labour. The estimates for 2012 and 2013 further reflect the value of the R&D tax allowance (RDA) for non-labour related R&D expenditures which was introduced in January 2012. In 2005, the scope of the R&D definition applicable under WBSO was broadened. In 2009, the WBSO tax credit rate for SMEs and large firms was increased from 42% for the first EUR 110,000 (14% above this threshold) to 50% (64% for start-ups) for the first EUR 150,000 of the R&D wage bill (18% above this threshold). The R&D wage expenditure threshold was further increased to EUR 220,000 in 2010. Break in BERD data series in 2011.
United Kingdom: Estimates, on an accrual basis, refer to the Research & Development Relief for Corporation Tax. The estimate for fiscal year 2013 further refers to the Research and Development Expenditure Credit (RDEC) Scheme for large companies, introduced for expenditure incurred on or after 1 April 2013. Estimates for the cost of accelerated depreciation provisions are not available. R&D tax credits were first introduced for SMEs in 2000 and extended to large companies from 2002. In July 2008, the deduction rates applicable under the Research & Development Relief for Corporation Tax were increased from 150% to 175% for SMEs and from 125% to 130% for large companies. The SME rates were subsequently increased to 200% in 2011 and to 225% in 2012. As of 2008, an enlarged definition of SMEs (from 250 employees and GBR 50M of turnover to 500 employees and GBR 100M of turnover) has also been applicable for tax purposes. For accounting periods ending on or after 1 April 2012, the R&D expenditure threshold of GBP 10,000 per year ceased to apply and the total amount of tax support per R&D project has been capped at EUR 7.5 million.

United States: Estimates refer to the federal research and experimentation tax credit (only corporations), based on SOI corporate tax return data. For international comparability, the cost of allowing for the expensing of research and experimentation expenditures is not included. The federal research credit is a temporary provision. It expired at the end of 2013 and was retrospectively extended from January 1 through December 31 2014 (Tax Increase Prevention Act of 2014).The research credit has four components: the regular research credit (RRC), an alternative simplified research credit (ASC), a credit for certain energy research and a credit for basic research. From 1997 through 2008, companies had the option of claiming an alternative incremental research credit (AIRC) instead of the regular research credit. Under current law, companies have the option of claiming the ASC rather than the regular credit the former of which was first made available for taxable years beginning after December 31, 2006.

Special analysis topic 2: The economic crisis and BERD flows

The global financial crisis has severely affected the international economy and the flows of trade and investments. Inward and outward R&D activities of multinational enterprise have also declined in most of the advanced economies. In the last years the share of overseas R&D activities of the emerging economies has increased (especially China and India) whereas the relative importance of European and North American Countries has partially declined.

As the graphs below clearly shows, Europe has recorded the most pronounced decline in Inward BERD investments. Even if, during the period 2003-2007, investments in R&D have registered an ascending trend, supported by the economic development at world level, by the liberalization of regulations on foreign investments and by the implementation on a large scale of internalization strategies, this trend has been certainly hit by the crisis.

In addition, among the effects of the crisis there have been a redistribution of R&D activities of MNE's, not only between Countries, but also between industries. In particular, the service sector has increasingly gained more importance with respect to manufacture industries. The progressive shift from traditional to most innovative industries, especially knowledge-intensive, may be partially explained by the relative weight that some of the determinants of the internationalization of business R&D have acquired during the last years.

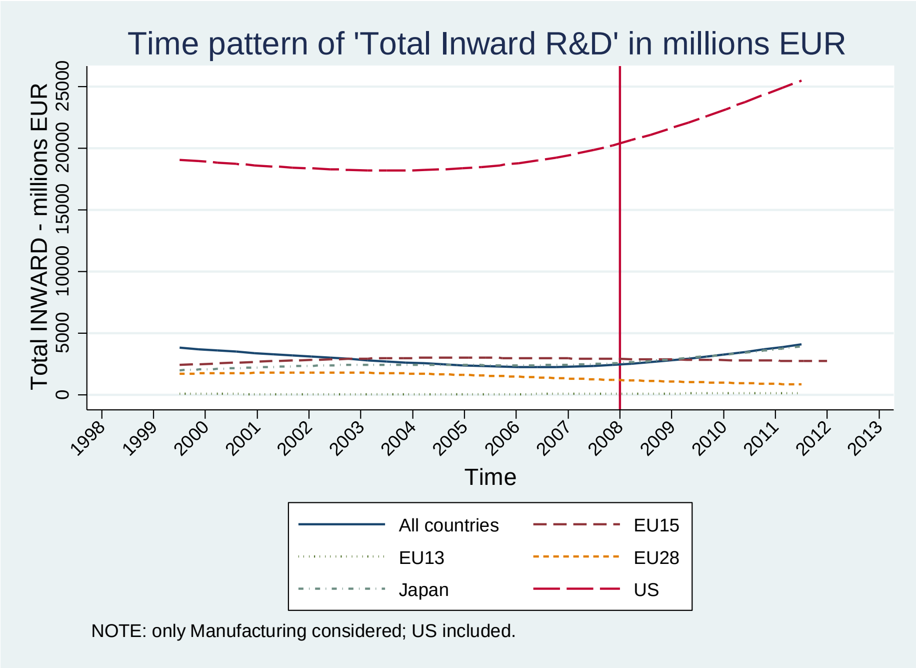
The aim of this analysis is trying to understand if the traditional factors that have been at the base of the flows of BERD investments in the last years are still deploying their effects or, as consequence of the crisis, they have reduced their strength. Through univariate regressions we are able to catch the presence and the magnitude of a structural break of each of the main drivers between the two periods (pre and after the crisis).

We will analyse the role of a series of factors that have been recognized as crucial determinants of Inward BERD: GDP of host economies; the level of Foreign direct investments; GBAORD; the share of labour force with a tertiary education; Labour cost; the number of patents as proxy of innovation capabilities of a particular Country.

Time Pattern of Inward BERD

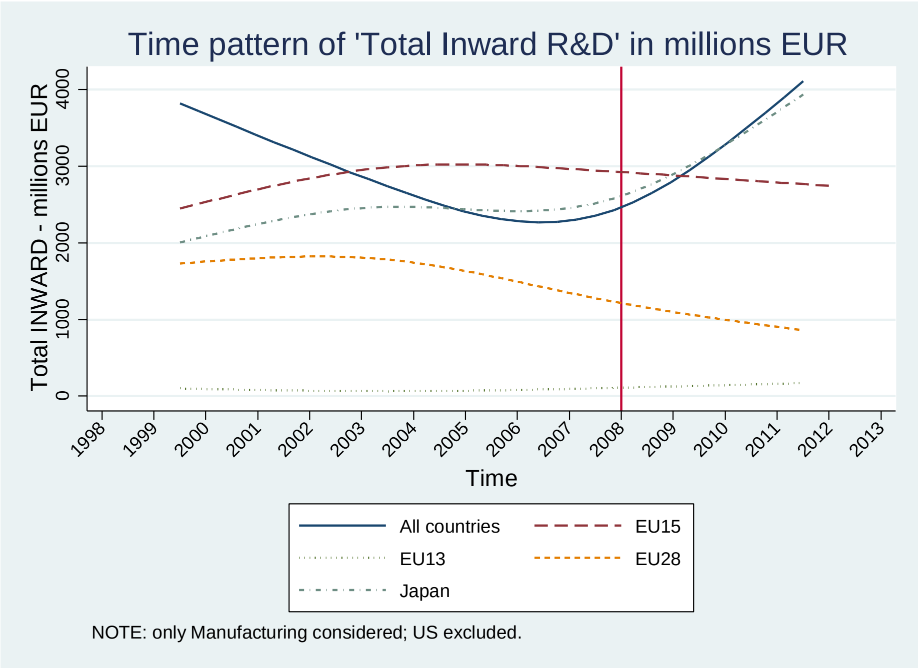
In this section we present how inward BERD developed in recent years for five countries or groups of countries, namely United States, European Union, EU 15, EU13 and Japan. We start from the observation that the trend of the average inward investments in manufacturing sector in the US has increased after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

Fig 1. Time pattern of "Total average Inward R&D investments in the manufacturing sectors. Per groups of Countries"



In the second graph, we are able to understand better the average trend in the manufacturing sector in European countries. Here, the average Inward BERD has slightly decreased after the crisis. This is true both for EU28 and for EU15. The average for "All Countries" records an increasing trend, maybe driven by US and Japan.

Figure 2. Time pattern of Total average Inward R&D investments in the manufacturing sectors. Per groups of Countries without US.



As we have already stressed, among the effect of the crisis there also has been a redistribution of investments from traditional sectors to most innovative ones. Indeed, it is evident that in all the Countries considered (or groups of Countries) there has been an increasing trend of Inward BERD in the service sector (see the tables below). The increase is much more pronounced in US than in other Countries observed. In the European Union the positive trend is much more evident for EU 15 than for the rest of Europe. Japan records a negative trend in the Service sector, while the trend is positive in the manufacturing industry.

Figure 3 Time pattern of Total Average Inward BERD in the service sectors per groups of Countries.

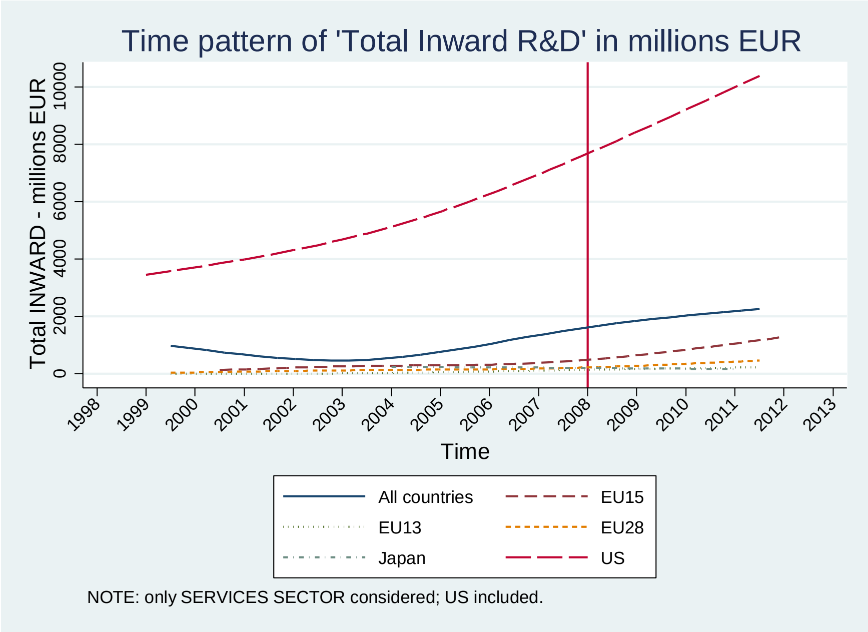
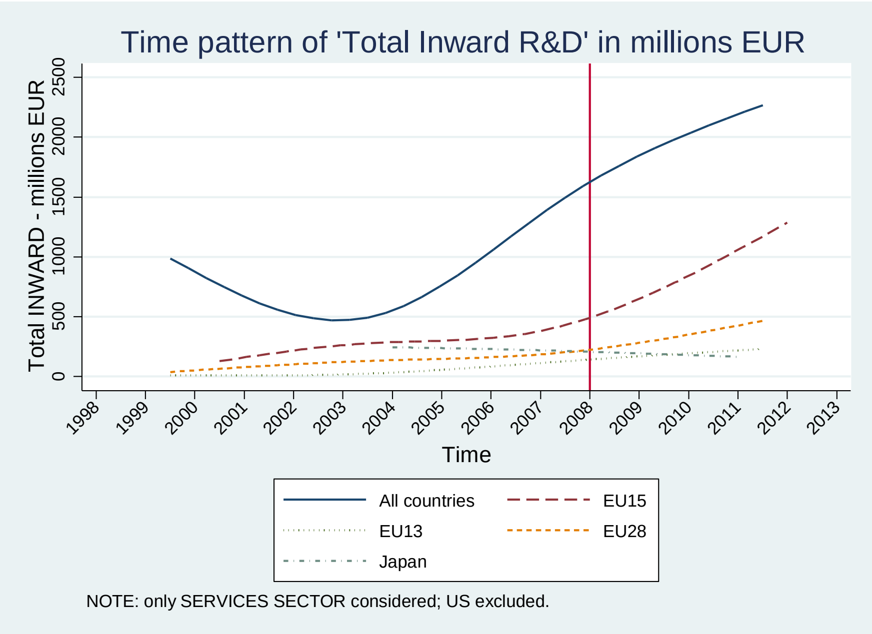


Figure 4 Time pattern of Total Average Inward BERD in the service sectors per groups of Countries, without US.



The Model

The model aims to test whether the response of the inward R&D to each driver had a significant change between the pre and post crisis period. To this aim, we use a univariate regression model with a switch at the crisis period. Before going on with the presentation of the model and results, however, it is important to notice that this analysis only look at the "association", not at direct "causation", between Inward BERD and each considered single factor. Indeed, the statistical setting of this analysis is different from that developed by our previous econometric model (see chapter 2). Here, we identify the "total" effect of a factor on Inward BERD, which sums up the "direct" and "indirect" effects; in the multivariate regression approach provided in chapter 2, on the contrary, we aimed at identifying only the "direct" effect of each driver. It should not come as a surprise therefore that the sign of the effects for some factors may be different.

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

The model is:

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

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

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

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

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

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

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

where:

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

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

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

For each identified driver, we will comment on sign, size and significance of such difference. For instance, if for driver x we find that the interaction coefficient is negative and significant, it means that the response of the inward BERD to this driver decreases its strength after the crisis (and vice versa for a positive value).

Results

The results of the econometric test are reported in the table below (see Table 1). As we can see, three factors have increased their strength in the aftermath of the crisis, namely GDP, Labour cost and FDI. While the first two are positive and significant, Foreign direct investments have increase their strength but, as in the pre-crisis period, are still not significantly correlated with Inward BERD.

Conversely, GBAORD and the "total labour force tertiary educated", the factors that accounts for the stock of human capital in a particular Country, have partially decrease their importance as driver. The number of patent application in percentage of GDP, used as an indicator of the innovation capabilities of the host economy, seems to be not significantly correlated with total inward, both before and after the crisis. In fact, the value of the interaction coefficients $\beta_1 - \beta_0$ indicate a feeble loss of importance of the driver in aftermath of the economic crisis.

Table 1. Results of the model

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

Table 2. Summary of results

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

Comments and conclusions

Not surprisingly, results are a bit different from those of the previous econometric model, and provide some additional information. For instance, differently from what found before, GDP and GBAORD are both positive and significant (even if the latter decreases its positive value after the crisis). This can show that, while a "direct" effect of these factors may be negative on Inward BERD, the indirect effect of each of them on other *moderating* factors can be higher, thus ultimately compensate the direct negative sign.

At this stage, unfortunately, we are not able to estimate a fully specified structural model representing all the mediating channels between specific factors and Inward BERD. However, some possible channels can be envisaged. More specifically, we can maintain that when a EU15 country experienced a decrease in GDP, peculiar feedback effects can take place. This country can become both economically and politically weaker, thus increasing the "negotiation power" of multinationals vis-à-vis local authorities. This may attract further BERD investment, driven by the aim of exploiting such phase of weakness. Moreover, countries affected by negative downturns generally try to adopt counter-cyclical policies, such as R&D fiscal incentives, which represents effective instruments for fostering BERD Inflows (see also the R&D fiscal incentive case study). Therefore, the "total" effect of GDP may finally have a positive sign on Inward BERD, although a negative direct impact.

R&D Internationalization, Global Innovation Collaboration and Foreign Ownership

Mark Knell

Version 12 October 2016

1. Introduction

The *Oslo Manual* provides guidelines for creating new input and output indicators that capture the innovation process and for composing survey questionnaires. It draws from Schumpeter's distinction between five several different kinds of innovation: new products, new production methods, new markets, new sources of supply and new forms of organization. The manual was revised three times since the original edition was issued in 1992, the most recent of which was to provide more detailed questions on organizational and marketing innovations and extend coverage of the survey to services. A fourth revision is currently being carried out. The survey provides information on knowledge inputs going into the innovation process including R&D expenditures within the firm, collaboration with other firms and organizations, and R&D acquired outside the firm, all of which are all relevant for an analysis of R&D internationalization.

Innovation is a complex phenomenon involving both technical and non-technical aspects. R&D activities often lead to new products and processes, but innovation can take place without the presence of any R&D activity. Foreign-owned firms are often seen as an important conduit for the transfer of knowledge to its affiliates and also important facilitators of knowledge spillovers to the local economy. Research and innovation cooperation between firms and other organizations, whether domestic or international, represents the formalized links or networks in which individual firms operate. These agreements can be made with transnational corporations, up-stream suppliers, downstream customers, competitors, the government and universities and other research institutes. The form of ownership and the type of collaboration can have important consequences, but it is not necessary for individual firms within the networks to contain any R&D activity.

This case study focuses on a few relevant questions that were asked in the 2012 survey, which was carried out in 2013 and covered the time period between 2010 and 2012. It is similar to previous surveys carried out over the past 20 years, but it has refined the questionnaire over time. The case study takes an aggregated perspective, using data that are publically available through Eurostat. Its main advantage is that it provides much greater coverage of the different countries using the harmonized survey. Its main disadvantage is that it does not allow for the flexibility of analysing the data at the level of the individual enterprise. Individual countries may allow access to the data, some allow access to the anonymised data or access to the safe room, but others provide very limited or no access.

The following section provides a brief analysis of the relative importance of innovative firms that are part of a global enterprise group, and in particular the importance of innovative foreign owned enterprises in the European context. This section also looks at the relative importance of innovativeness in geographic markets, with emphasis placed on the prominence of global markets.

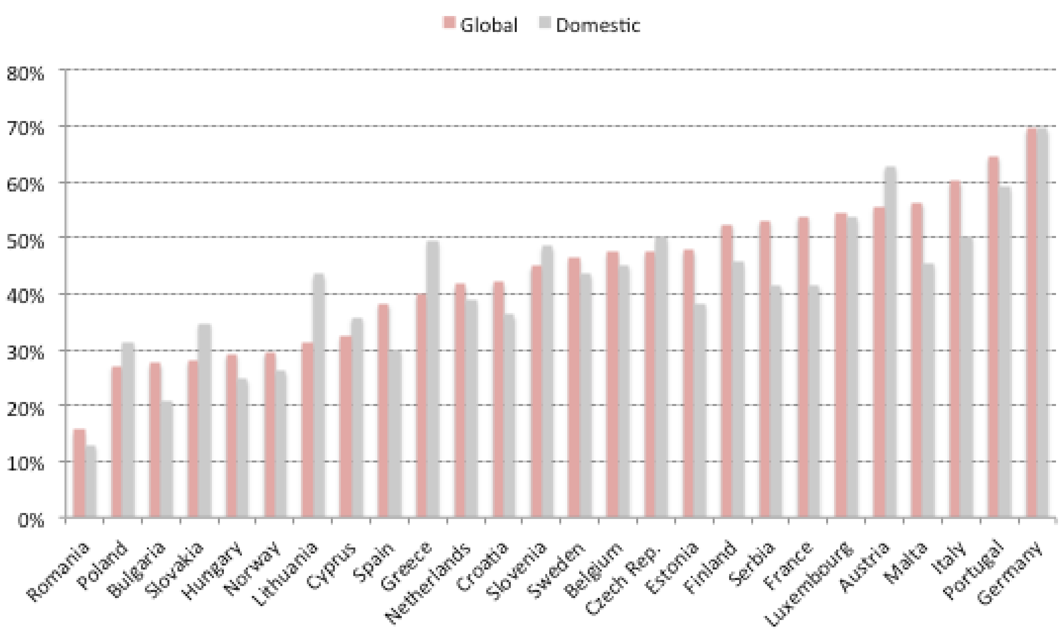
Section three focuses on the distinction between in-house R&D activity and external R&D. This distinction does not coinside directly with the one between total R&D activity and inward activity only a fraction of the market will be internationalized. The fourth section focuses on differences between domestic and international collaboration, without foreign-ownership included.

2. Innovation in Foreign-owned enterprises

It is possible to study innovation in foreign owned enterprises by considering the first question of CIS-2012 by first asking whether the firm is a member of an enterprise group. This means that each enterprise in the group can serve different markets, as with national or regional subsidiaries, or serve different product markets. An enterprise group is an association of enterprises under common ownership and controlled by the group head or parent. The CIS-2012 distinguishes between enterprises with their head office located outside the home country, but does not distinguish between multinational firms with their the head office located inside the home country, but with multinational subsidiaries. It then identifies all enterprises that are part of an enterprise group and enterprises groups that have a foreign head office. In this section of the study we only look at have head offices located abroad.

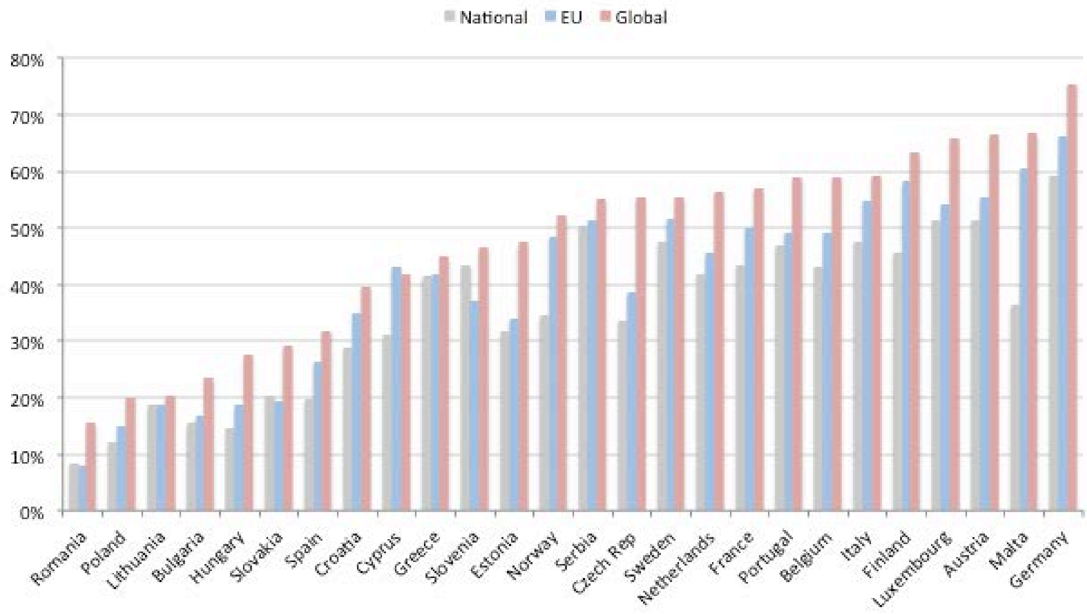
Figure 1 illustrates the share of enterprises with some kind of innovation activity, including the introduction of new product, process, organizational or marketing activities, as well as firms that have abandoned or suspended or on-going innovation activities. The figure also illustrates the difference between multinationals located abroad (pink) and domestic multinationals (grey). The order of the countries from left to right goes from the least innovative countries to the most innovative ones. In most instances, enterprises with head office abroad tend to be more innovative than those located within the home country. As expected Germany is the most innovative country and Romania is the least innovative, but there . . .

Figure 1: Share of innovative firms that are part of a global enterprise group



The second general issue that can be raised about the innovative enterprise is the geographic market in which it is located. One might expect there to be some kind of correlation between the internationalization of R&D and the location of global markets. Enterprises that want to compete in global markets have an incentive to introduce new product, process, and organizational or marketing activities. Figure 2 shows those enterprises that tend to be more innovative in global and European markets (though to a lesser degree) than in national markets. The figure also illustrates . . . As in the previous figure, Germany appears to be the most innovative country and Romania is the least innovative. . . .

Figure 2: Share of innovative firms and geographic markets

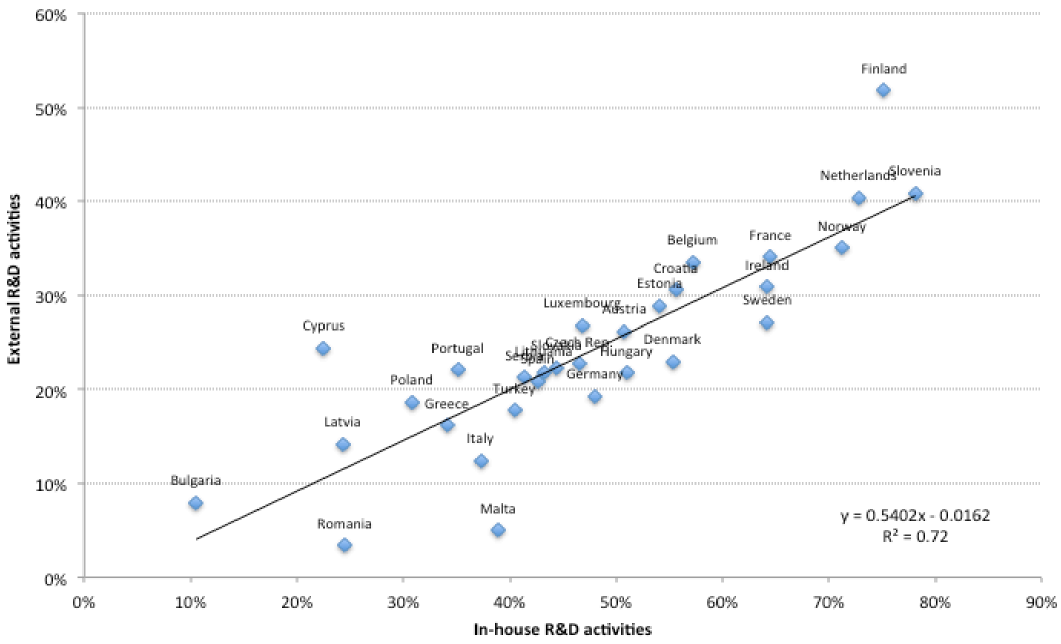


3. In-house R&D activity and external R&D

The Frascati Manual (2015) identifies R&D funds sourced abroad (part of intramural R&D expenditures) and R&D activity performed abroad (part of extramural R&D expenditures) as essential for identifying R&D internationalization. In the manual intramural expenditures are classified as R&D performed within a statistical unit and extramural expenditures are classified as payments for R&D performed outside the statistical unit. Most OECD countries report detailed information about R&D financed abroad, including information at the industrial level, by size of firm and sometimes by sector, but few countries report R&D activity performed abroad, especially at the industrial level, by size of firm and by sector. Extramural R&D expenditures can take place between domestic enterprises, national organizations and international organizations and firms, which means only a part of extramural expenditures are relevant for R&D internationalizations. By contrast, the OECD Handbook on Economic Globalisation Indicators (2005) focused on the measurement of R&D internationalization by prioritising the flows of R&D funding of affiliates of multinational enterprises.

Figure 3 illustrates intramural and extramural R&D expenditures as it is collected according to the harmonized innovation survey. The figure confirms the suggestion of Veugelers (1997) that external technology sourcing is positively related to internal R&D, which is in turn associated with multitechnology firms and products. Strategic technology alliances and networks are another form technology sourcing. The figure shows that R&D activity is highly correlated with the share of innovativeness and the complementarity between internal R&D and technology sourcing. As in the previous figures, there is a strong positive relationship between the level of development, R&D activity and the degree of innovativeness.

Figure 3: Share of innovative enterprises carrying out External R&D and in-house R&D activities



4. Foreign-owned enterprises and global collaborative agreements

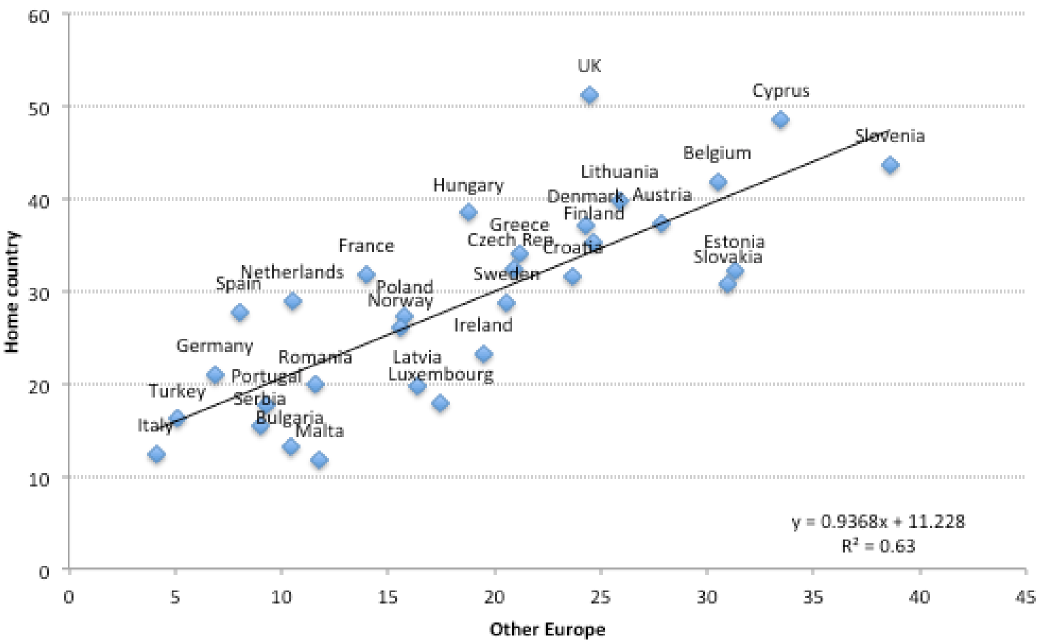
The next step in the story is to ask whether firms rely on in-house R&D activity or collaborate with other enterprises. Collaborative agreements can include joint research and development projects (investment), acquiring and sharing specific kinds of knowledge, or some informal or "arm's length" relationship based on a minimal exchange of information. Penrose (1959) and Richardson (1972) give emphasis to the need to transfer, exchange and pool resources complementary to the firms own capabilities. Transnational corporations enterprises are often at the heart of the relationship and seen as important catalysts for creating, controlling and transferring technology through its own network of affiliates (Dunning, 1993). Their importance lies not only in providing new machinery and equipment, access to better materials, and methods of production, but also new business practices, management systems and organization of work (Damijan and Knell, 2005). Cooperation between different enterprises provides the potential to improve the ability of enterprises to deal with complexity and other nonlinearities, improve the scale and scope of innovative activities and to reduce the risk and uncertainty associated with the introduction of new products and designs (Dodgson, 2000).

The Community Innovation Survey has included several questions on whether an enterprise had actively collaborated with other enterprises or institutions on innovation activities. There were eight types of innovation cooperation partners by 5 different locations. External partners include suppliers, customers, lead users, universities, research centers and industry competitors. A partner's location is relevant for the R&D internationalization in so far that international cooperation of innovation activities were involved.

Own R&D activity is essential for the firm to enter into a collaborative agreement, both as a prerequisite to join as well as to gain benefit from the agreement. Cohen and Levinthal (1989, 1990) stressed that own in-house R&D activities are needed to efficiently use the external sources of knowledge. Freemen (1991) and Veuglers (1997) established that own R&D activity is positively correlated with the intensity of networking and it positively affects a firm's ability to exploit the opportunities arising from innovation cooperation. However, there was little evidence in the 2012 survey that in-house R&D activity or external R&D activity was correlated with innovation cooperation with other enterprises in different locations.

Figures 4 through 6 illustrate some collaborative relationships in the global economy. The strong positive relationship between collaboration in the home country relative to the rest of Europe shown in figure 4 suggests that international collaboration is complementary to home country collaboration. There appears to be no particular pattern other than there is a slight tendency for larger countries to be somewhat less collaborative, especially relative to other Europe. In other words, the smaller the country, the more likely it will seek collaborative partners. The UK appears as an outlier, both in terms of actively seeking collaboration with domestic partners, but also with European partners.

Figure 4: Home country innovation collaboration relative to European collaboration



There is also a positive relationship in figure 5, though not as strong, concerning innovation collaboration between the United States and Europe. Here the size of the country did not matter as much in this case, but it becomes fairly obvious that the English speaking countries, including the Nordic countries and the Netherlands where it is a second language, are above the regression line, whereas the others were below the line. There appears to be little collaboration between the United States and Italy and Germany, perhaps because the data were not corrected for firm size. There was no data from the UK.

Figure 5: Innovation collaboration with the United States relative to Europe

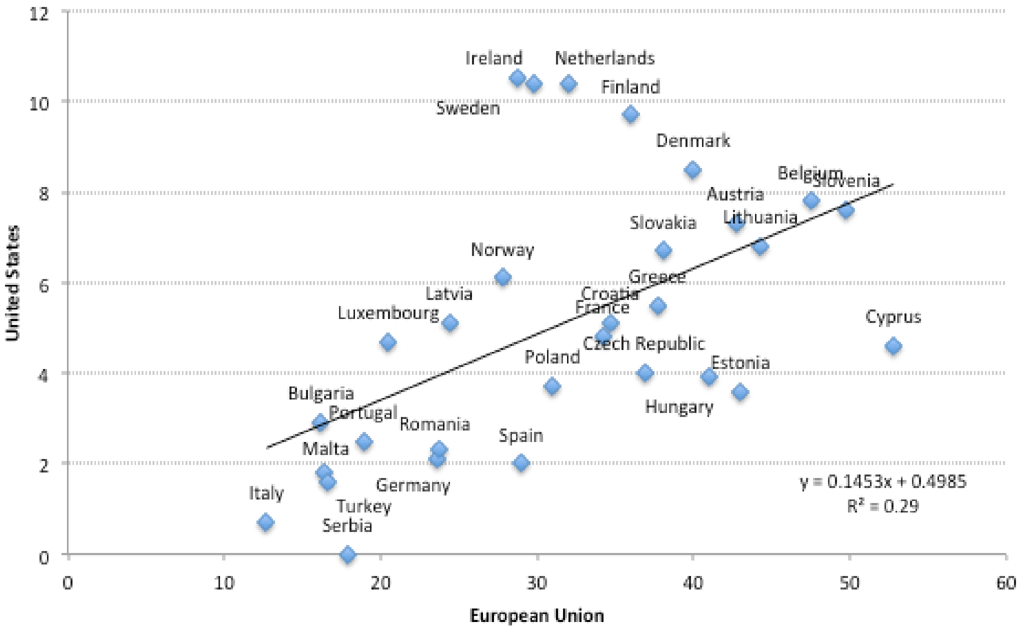
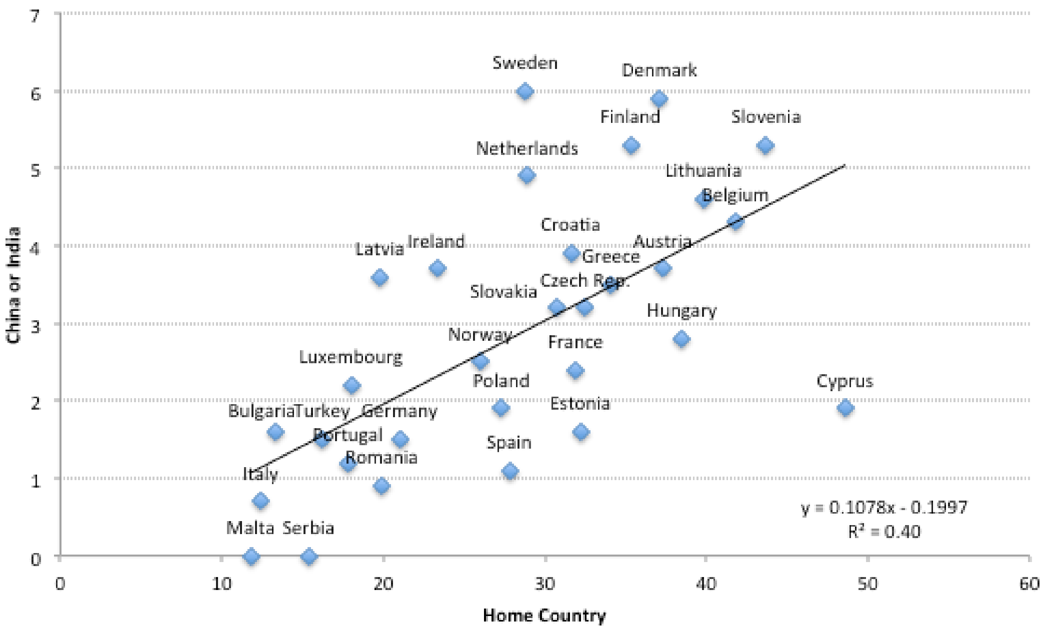


Figure 6 shows positive relationship innovation collaboration with China or India relative to the home country. There is no clear pattern in this case except that three of the four Nordic countries are far about the regression line. Collaboration was almost twice as likely in the United States relative to China or India.

Figure 6: Innovation collaboration with China or India relative to the home country



5. Some concluding comments about the use of the survey

The main advantage of the Innovation survey is that it provides complete coverage of the different countries using a harmonized survey. It would be a great advantage if these data were to be aggregated in such a way to identify whether the firm is foreign owned. Although it is possible to use the anonymised database, it includes less than half of the countries included in total survey. A related issue is whether the R&D survey could be made available in different aggregations, or as an anonymised database. This would create a lot of interesting possibilities.

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Special data topic 2: Using R&D-FDI projects, by source and destination, 2010-2015

This case study examines the link between the source and destination of cross-border R&D and related design activities. The analysis makes use of the fDi Markets database (Financial Times Ltd), which provides information on the number of announced greenfield FDI projects[1]. Announced projects include information about R&D activities, including design, development and testing" that originate in (are funded by) one country but are carried out in another. The fDi Markets database provides an alternative, but complementary picture of the internationalization of R&D activity from 2010 to 2015. It differs from the BERD data in its source; its unit is reported projects that are R&D and/or design in focus[2].

In this case study, the numbers are purely counts of R&D-FDI projects. The purpose is to explore alternative data sources to better understand the internationalisation of R&D activities. During this period there were 3,480 FDI projects with R&D activity recorded for projects that fall into the following sectors.

- Automotive Components
- Automotive OEM
- Business Machines & Equipment
- Consumer Electronics
- Pharmaceuticals
- Chemicals
- Business Services
- Software & IT services
- Electronic Components
- Industrial Machinery, Equipment & Tools
- Engines & Turbines

These classes, as defined and applied by FT markets, are seen to involve but extend somewhat beyond the cases studied in chapter 4. While this case study does not include the monetary amount of R&D investment during the time period, it does show the relationship between the source of the investment and the expected destination of investment over a given time period. The matrix in table1 summarizes the number of announced greenfield R&D FDI projects, by source and destination, from the beginning of 2010 to the end of 2015.[3] It presents the source (originating) country (or region) by row and the destination (receiving) country (region) by column. UNCTAD (2016) present similar statistics in Annex table 7, but presents them in terms of the world as destination and the world as source (investor). Table 1 presents the data as a square matrix in a highly aggregated form, but the matrix can be rectangular.

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1 The analysis is based on the basic tables generated by the Industrial Research and Innovation Monitoring and Analysis (IRIMA II) project, jointly carried out by the European Commission's Joint Research Centre (JRC) and the Directorate General Research and Innovation.

2 Details on the collection and compilation of the data by FT Markets (https://www.fdimarkets.com/). See also documentation from the IRIMA II project.

3 The matrix resembles a transport-planning problem.

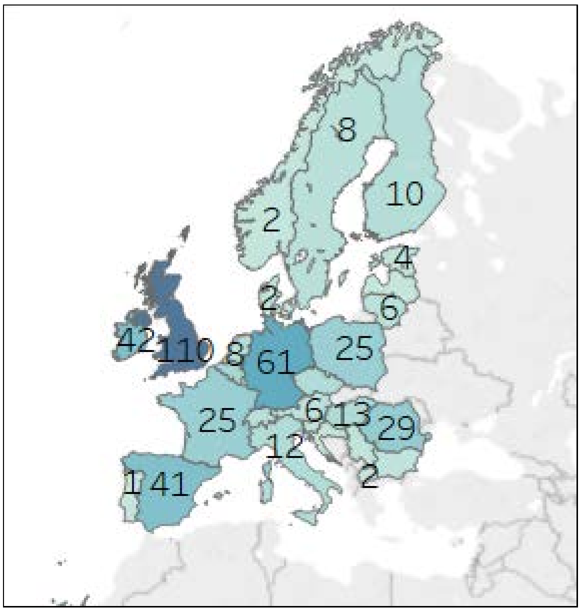
Table 1. Number of announced greenfield R&D FDI projects, by source and destination, 2010-2015.

	W Europe	E Europe	USA+	E Asia	Other	*Total*
W Europe	344	140	235	209	418	*1346*
E Europe	6	6	2	2	3	*19*
USA+	412	109	72	255	545	*1393*
E Asia	114	18	105	100	127	*464*
Other	80	20	54	24	80	*258*
Total	*956*	*293*	*468*	*590*	*1173*	*3480*

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

When individual countries are included in the matrix, the diagonal will be zero because FDI flows are bilateral. The table in the appendix contains the data in Table 1, but disaggregates Europe and the United States as individual countries and then aggregates all of the other remaining countries. When countries are aggregated, then investment project can go between two countries within the same region. For example, in the disaggregated data there appears to have been 5 R&D projects that went from France to Germany and 8 R&D projects that went from Germany to France. All of these projects appear in Table 1 as a flow within western Europe itself. A further example is that there appears to have been 19 R&D from eastern Europe to the world, whereas there were 140 projects from western Europe to the eastern Europe and 190 projects from North America to eastern Europe. The following map illustrates the number of inward fdi projects for the industrial sectors introduced above (2010-2012).

Map 1: Inward fdi projects by destination country for selected sectors: 2010-2012



Source: FT fdi projects database, via IRIMA II. Viewer in Tableau.

It is possible to disaggregate the number of announced greenfield R&D-FDI projects, by sector or industry. Table 2 illustrates the automotive industry by source and destination. This table contains almost 370 cross-border R&D projects, representing the most significant countries involved in automotive production. For example, there were 95 R&D-FDI projects supported by Germany, but carried out in another country, including East Europe, China, India and the United States. The major players in the auto industry are Germany, the US and Japan, which confirms the inward BERD statistics.

There were many greenfield R&D-FDI projects between the major players over the 6-year period. The data also highlights the important role that China, India, Brazil as well as the Visegrád countries (Czech Republic, Hungary, Poland and Slovakia) play as destinations for R&D-FDI projects.

Table 2. Number of announced greenfield R&D FDI projects, by source and destination, in the Automotive industry, 2010-2015.

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

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

Table 3 illustrates the ICT sector by source and destination. This table contains more than 2000 cross-border R&D projects, or more than half of the half of the projects included in this case study. This example includes both hardware and software, which is one of the strengths of US technology. US enterprises initiated almost 900 international projects around the world, without any clear preference for location. However, it is noticeable that the US initiated 60 projects in Ireland and 83 in East Europe, whereas Ireland initiated only three projects in the US and the whole of East Europe initiated two projects in the US. A similar trend though not as pronounced occurs between the US and East Asia and India and even to a much lower degree between Europe and Asia. These data indicate that there is a transfer of ideas and knowledge between countries in West Europe and the United States, but a more direct flow from the US to countries below the technology frontier.

Table 3. Number of announced greenfield R&D FDI projects, by source and destination, in the ICT sector, 2010-2015.

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

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

The machinery and equipment industries are shown in Table 4. This table contains more than 350 cross-border R&D projects. This example also shows the US to be an important player having supported 100 projects and being the destination to 45 projects. The data complements the inward

BERD statistics by illustrating that Europe is a good location as both source and destination R&D-FDI projects.

Table 4. Number of announced greenfield R&D FDI projects, by source and destination, in the machinery and equipment industries, 2010-2015.

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

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

Table 3 illustrates the chemical and pharmaceutical industries by source and destination. This table contains more than 600 cross-border R&D projects, representing almost a third off all projects in the industry. This example shows that Europe supports more than half of all R&D-FDI projects, if Switzerland is included. The US supports about half of all projects in Asia. In this example east Asia (mainly China) and the developing countries are the main destination countries.

Table 5. Number of announced greenfield R&D FDI projects, by source and destination, in the chemical and pharmaceutical industries, 2010-2015.

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

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

Table A1. Number of announced greenfield R&D FDI projects, by source and destination, 2010-2015.
Own calculation based on based on information from the Financial Times Ltd, fDi Markets (www.fDimarkets.com)

Destination/ Source	Austria	Belgium	Bulgaria	Croatia	Cyprus	Czech Rep.	Denmark	Estonia	Finland	France	Germany	Greece	Hungary	Ireland	Italy	Latvia	Lithuania	Luxembourg	Netherlands	Poland	Portugal	Romania	Slovakia	Slovenia	Spain	Sweden	UK	Iceland	Liechtenstein	Norway	Switzerland	USA	non-EU	total
Austria	0	0	0	0	0	1	0	0	0	3	2	0	0	0	0	0	0	0	1	1	0	0	0	0	2	0	2	0	0	0	0	1	2	8
Belgium	0	0	0	0	0	0	0	0	0	2	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	4	20	35
Bulgaria	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2
Croatia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cyprus	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	3
Czech Rep.	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	5
Denmark	0	0	0	0	0	0	0	1	0	1	3	0	0	0	1	0	2	0	0	1	0	1	0	0	0	0	1	0	0	0	0	11	19	41
Estonia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
Finland	0	0	0	0	0	0	0	2	0	1	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	1	0	5	20	34
France	0	2	0	0	0	0	1	0	2	0	5	0	3	3	1	0	0	0	0	6	0	7	1	0	9	0	11	0	0	0	2	23	112	188
Germany	5	2	1	1	0	6	2	0	2	8	0	0	10	7	4	0	0	0	2	3	1	13	1	1	23	2	17	0	0	2	4	56	210	383
Greece	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Hungary	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Ireland	0	0	1	0	0	1	0	0	2	1	0	0	0	0	0	0	0	0	0	2	0	1	0	0	1	0	4	0	0	0	0	5	13	31
Italy	0	2	0	0	0	0	0	0	0	2	3	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	3	0	0	0	0	2	9	23
Latvia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lithuania	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Luxembourg	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	6	7	21
Netherlands	0	3	0	0	0	1	1	0	0	2	5	0	0	3	0	0	0	0	0	3	1	0	0	0	5	2	9	0	0	0	0	16	25	76
Poland	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	4
Portugal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Romania	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2
Slovakia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slovenia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	5	18	30
Sweden	0	0	0	0	0	0	2	0	1	1	2	0	1	0	1	0	1	0	0	2	0	1	1	0	0	0	4	0	0	0	0	2	22	41
UK	0	3	3	0	0	2	0	1	2	3	13	0	1	6	2	0	1	1	1	11	2	10	0	1	12	2	0	0	0	1	0	42	113	233
Iceland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	3
Liechtenstein	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	2
Norway	0	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	5	0	1	3	0	0	0	0	0	1	3	0	0	0	1	4	8	29
Switzerland	3	2	0	0	0	1	1	1	1	10	17	0	1	1	1	0	2	0	1	1	0	0	0	0	4	0	8	0	0	0	0	20	79	154
USA	2	16	7	3	0	14	3	4	14	38	53	1	4	65	9	1	15	2	11	29	1	21	4	1	21	4	141	0	0	4	5	0	824	1317
non-EU	4	5	0	1	0	6	2	1	5	12	64	0	6	14	6	0	5	1	7	7	1	8	1	1	15	5	71	0	0	1	1	166	377	793
Total	14	36	14	5	0	32	12	10	30	92	179	3	26	100	25	1	34	4	24	71	6	63	8	4	93	18	286	0	1	9	14	372	1894	3480