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Estimating territorial business R&D expenditures using corporate R&D and patent data

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Abstract

This note describes a methodology to estimate territorial business R&D expenditure funded by the business sector, using R&D and patent data from top R&D investing companies. Since company data are available with a short delay, the aim is to provide timeliness estimations for business R&D in anticipation of its publication by official statistics. The estimation is made for worldwide industrial R&D expenditures, breaking down figures for main world regions and focusing on the EU and the member states where most of the top R&D investing companies have their headquarters (Germany, France and the UK). The industrial coverage comprises main innovative industries, focusing on manufacturing and knowledge intensive services.

1 Introduction

Territorial intramural R&D expenditures funded by the business sector (BERD) are collected and provided by statistical offices. They refer to R&D activities, as defined in the OECD Frascati manual, funded by industry and performed within the borders of territorial units. For each territory, these include basically the R&D activities of two types of companies: local companies headquartered in the territory and subsidiaries of foreign companies operating in the territory.

Other statistics on industrial R&D activities are provided by the EU Industrial R&D Investment Scoreboard (the Scoreboard) based on data stated by companies in their reports and audited accounts. The Scoreboard comprises the world top R&D investing companies, considering the part of R&D financed from their own funds and regardless of the location where the related activity is performed.

BERD statistics and the Scoreboard provide complementary information, however they cannot be compared directly because of a number of methodological differences. A main obstacle to compare the two data sources is the lack of information regarding the actual location of the R&D activities. Territorial statistics do not provide the details of the inward activity of foreign-affiliated companies nor the outward activity of local companies. On the other hand, the Scoreboard do not inform about the actual location of companies' activity which is generally not disclosed in their reports and accounts.

Cross-border activity of companies

A key issue to relate BERD and *Scoreboard* data is the missing information about the cross-border R&D activity of companies. This problem can be addressed by analysing the ownership structure of parent companies and the location of R&D activity of their subsidiaries at home and abroad. The latest edition of the *Scoreboard* comprised 2500 parent companies that have more than 600k subsidiaries. The *Scoreboard* full dataset includes also information about the activity of subsidiaries and their worldwide distribution, and has been recently completed with patent information retrieved from PATSTAT[1]. Henceforth, the location of the innovation activity can be estimated by analysing the patent portfolio of the companies including the international location of companies' affiliated inventors. In particular, the actual location of innovation activities can be tracked using the country of residence of the inventor(s) at the origin of the patented technology[2]. Therefore, the breakdown of the patent activity of the

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[1] PATSTAT is the European Patent Office's Worldwide Patent Statistical Database which contains data about 70 million applications of more than 80 countries. See more details at http://www.epo.org.

[2] The choice of the inventor's country of residence is the most relevant for measuring the technological innovativeness of R&D labs located in a given country.

subsidiaries at home and abroad gives an indication of the international innovation of the parent companies. Conversely, from a territorial viewpoint, this gives an indication of the inward activity of foreign affiliated companies and the outward activity of local companies. Therefore, the exploitation of patent data and the geographic distribution of parent companies, their subsidiaries and related inventors can help to link BERD and *Scoreboard* data. This link can be fully implemented by establishing a relationship between companies' R&D investment and their patent activity.

Concentration of industrial R&D

Another major difference between the two data sources is the partial coverage of the *Scoreboard* (top R&D investors) compared with the full approach of territorial statistics. However, as shown by experience, industrial R&D is highly concentrated at company, country and sector levels[3]. The 2500 companies included in the 2105 *Scoreboard* invested €607.2bn, an amount equivalent to approximately 90% of the R&D expenditure financed by the business sector worldwide. Along this line, a small subset of *Scoreboard* companies account for a large share of the total *Scoreboard*. For example, the top 100 companies account for 53%, the companies based in the three largest R&D countries (US, Japan and Germany) account for 63% and the four largest industries (health-, auto- and ICT-related) account for 60% of the total R&D investment. This concentration feature is often observed simultaneously by country and industry. For example, in 2014, three Automobiles companies accounted for 32% of the R&D of companies based in Germany. There are also more extreme cases such as Finland's where a single ICT company accounted for almost ¾ of the total R&D of *Scoreboard* companies based in that country.

The implications of the concentration of the industrial R&D are twofold. First, it means that a relatively small number of representative companies may help to provide a fair estimation of the industrial R&D for the different aggregation levels (global, by country or by industrial sector). Second and contrariwise, it means that small deviations of the R&D figures of a reduced number of companies may lead to wrong estimation of the aggregated R&D figures. Consequently, the sample of companies to make the estimation of BERD should be selected carefully and the R&D figures of the most representative companies should be thoroughly verified.

The above considerations suggest that company data can be applied to establish empirical correlations between the *Scoreboard* and BERD data and that a stronger correlation would be found for larger data aggregates, e.g. global, large R&D countries or large R&D industries.

[3] See for example, the Introduction chapter of the 2015 *Scoreboard* report.

2 Correlation between BERD and Scoreboard data

This section explores the correlations between BERD and the Scoreboard for the different levels of aggregation that can be built from the Scoreboard data.

First, an overall comparison BERD-Scoreboard is presented using Scoreboard data for the period 2006-2014 and corresponding available BERD figures.

Second, a subsample of the Scoreboard is selected including representative companies which data are more promptly available [4]. This subsample is compared with the full Scoreboard sample, including different data aggregations for main countries and industrial sectors.

Finally, the subsample of the Scoreboard is correlated with BERD data, including the cross-border activity of companies supported by patent data of the subsidiaries of the Scoreboard companies.

2.1 Overall correlation BERD-Scoreboard

This section presents a preliminary comparison of R&D figures provided by BERD and the Scoreboard. Data used come from the 2015 Scoreboard, including figures for the 2006-2014 period, and equivalent BERD figures when available. As explained above, it is difficult to compare directly the two datasets due to differences such as the sampling period and exchange rates. BERD figures refer to business R&D expenditure funded by the business sector and performed by all sectors. Scoreboard data refer to the cash R&D investment financed by companies themselves.

The following figures show the evolution of the BERD and Scoreboard worldwide and for the main regions.

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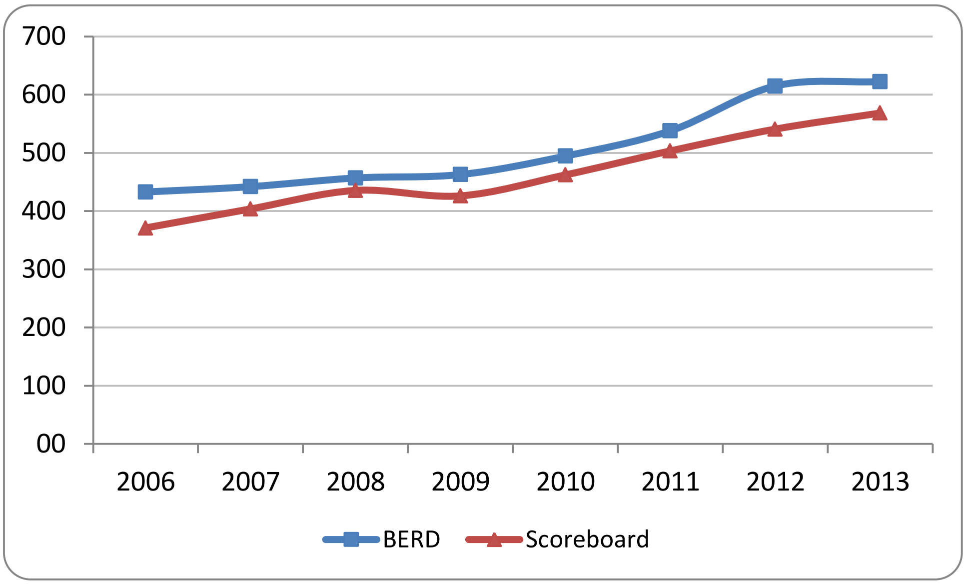
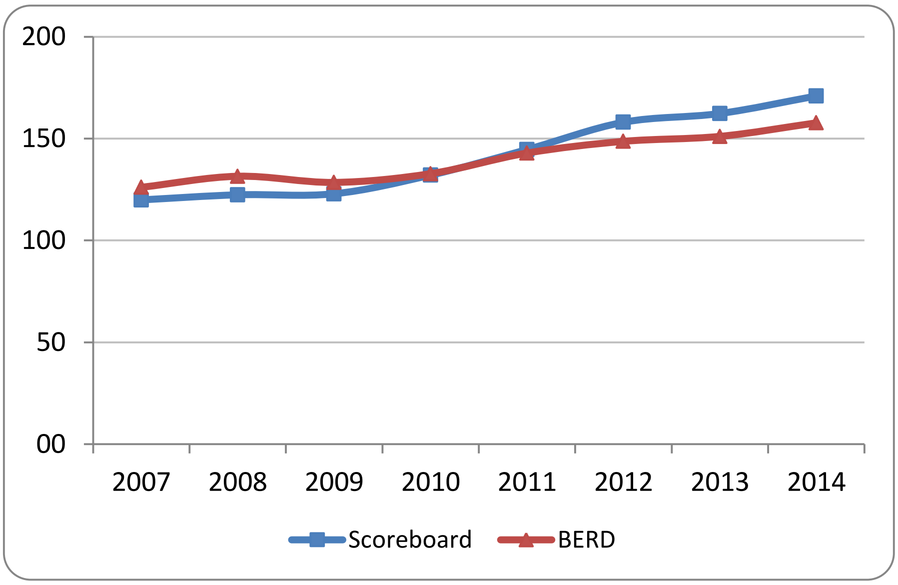
[4] Due to differences in accounting practices, company data are available at a range of dates for a given fiscal year. For example most EU companies close their accounts on the 31st December of the fiscal year whereas most Japanese companies close them on the 31 March of the following year. Also US companies have different reporting periods, results of some large US R&D companies are only available around the middle of the following year.

Figure 1: Global BERD and *Scoreboard* data (€bn)



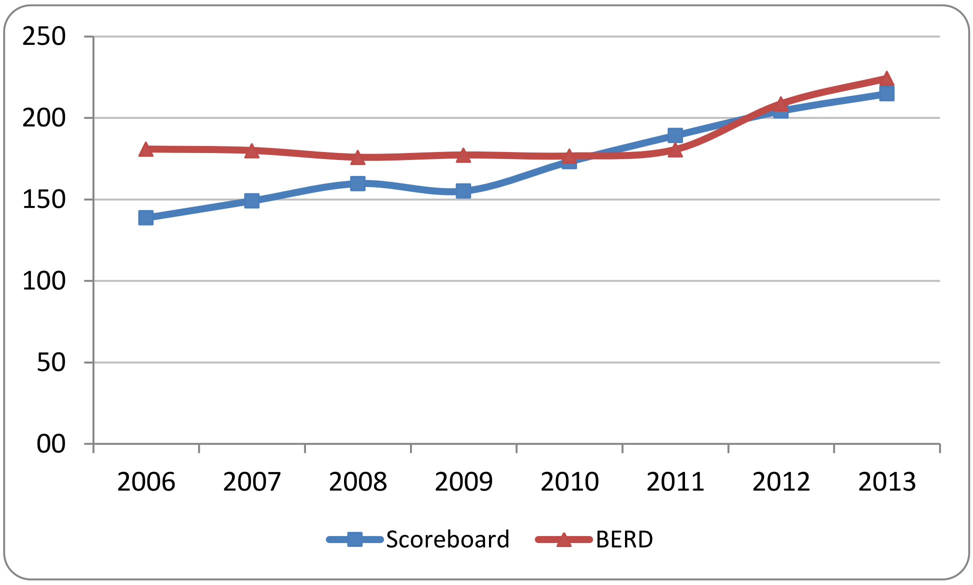
Note: *Correlation coefficient = 0.98*
Sources: *BERD data provided by Eurostat including most countries reporting R&D and EU R&D Scoreboard data.*

Figure 2: EU BERD and *Scoreboard* data (€bn)



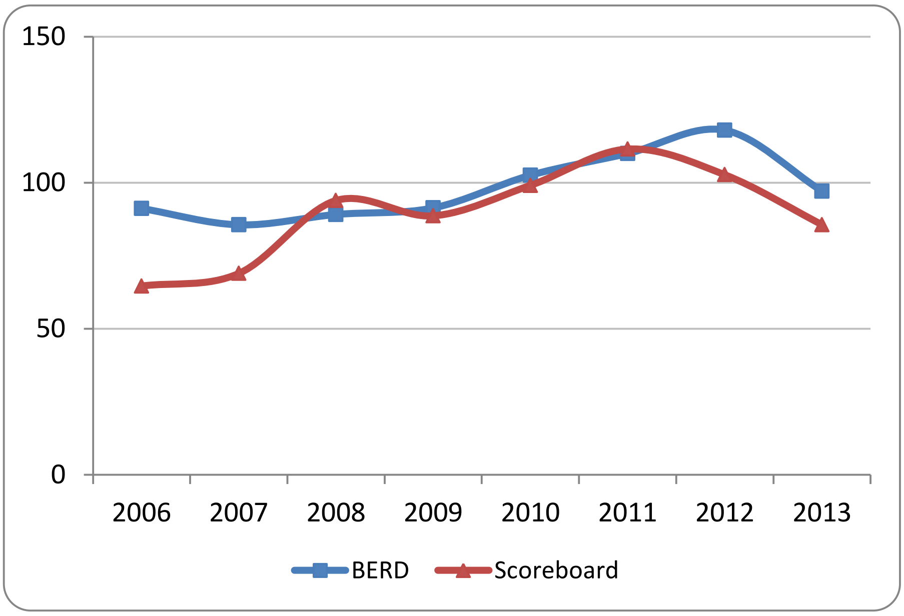
Note: *Correlation coefficient = 0.99*
Sources: *BERD data provided by Eurostat for the 28 EU countries and EU R&D Scoreboard data for companies headquartered in the EU.*

Figure 3: US BERD and *Scoreboard* data (€bn)



Note: Correlation coefficient = 0.81
Sources: BERD data provided by Eurostat for the US and *Scoreboard* data for companies headquartered in the US.

Figure 4: Japan BERD and *Scoreboard* data (€bn)



Note: Correlation coefficient = 0.76
Sources: BERD data provided by Eurostat for Japan and EU R&D *Scoreboard* data for companies headquartered in Japan.

The evolution of BERD and *Scoreboard* for the world and EU samples (Figures 1 and 2) show a very good correlation, 0.98 and 0.99 respectively. For the world sample, the good correlation could be expected, since at world level, the sample of companies shows the highest representativeness and the effects of companies' cross-border activities discussed in section 2 is offset. The good correlation showed by the EU may be due to the focus of the Scoreboard in the EU, i.e. to achieve a more harmonised, representative and balanced sample of companies.

The comparison of BERD and the Scoreboard for the US and Japan appear less correlated, 0.81 and 0.76 respectively. As discussed above, this could be due to the methodological differences between the two data sources that may be more pronounced in the case of these countries.

2.2 Representative Subsample of the Scoreboard

A subsample of the Scoreboard is defined taking into account the following criteria: i) representativeness of the dataset in terms of country and industrial composition; ii) prompt availability of R&D data; iii) focus on the EU, particularly on the largest R&D countries.

The characteristics of the selected subsample consisting of 350 global companies are shown in Table 1. The most representative sample in terms of R&D investments is the EU one, followed by the US and the Rest of the World (RoW). Because most of the Japanese companies close their accounts on the 31 March of the following year, only few Japanese companies are included in this subsample.

Table 1: Subsample of the *Scoreboard* dataset

	EU	US	Japan	RoW	Total
Number of companies	135	129	8	78	350
R&D in 2014(€bn)	137.3	160.6	5.9	79.1	382.9
World R&D share	22.6	26.4	1.0	13.0	63.0
Region R&D share	80.3	69.2	6.8	67.4	

In order to improve further the EU sample, a number of companies have been added for the 3 largest EU member states. The characteristics of the German, French and UK sub-samples are summarised in Table 2.

Table 2: Breakdown of the *Scoreboard* sub-sample for top EU countries

	Germany	France	UK
Number of companies	89	59	53
R&D in 2014(€bn)	58.3	26.2	19.3
Country R&D share	91.6	91.7	71.4

The industrial classification used in this work is an aggregate (and reduced) version of the ICB classification normally applied in the Scoreboard, the focus in fact is on the most innovative manufacturing and services industries (see Table 3).

Table 3: Industrial classification of the subsample of *Scoreboard* companies

Industrial Sector	Sector classification ICB 3&4 digits	R&D in 2014 (€bn)	R&D share within industry (%)	R&D share in the EU (%)
ICT producers	Computer Hardware; Electronic Office Equipment; Semiconductors; Telecommunications Equipment; Electronic & Electrical Equipment	97.93	69.7	14.0
Health industries	Pharmaceuticals; Health-biotechnology; Health care equipment & services	94.53	76.7	20.6
ICT services	Computer Services; Internet; Software & Computer Services; Fixed Line Telecommunications; Mobile Telecommunications	34.36	47.4	6.4
Automobiles	Automobiles; Auto Parts	63.21	66.7	26.2
Industrials	General Industrials; Industrial Engineering, Industrial Metals & Mining, Industrial Transportation	23.8	51.0	8.2
Aerospace & Defence	Aerospace; Defence	17.83	87.7	5.8
Chemicals	Chemicals	10.21	48.5	2.9
Other	Leisure Goods; Oil & Gas Producers; Banks and Financial Services; Construction & Materials; Food producers; etc.	40.86	46.9	15.9

The following figures show the comparison of the whole Scoreboard with the selected subsamples.

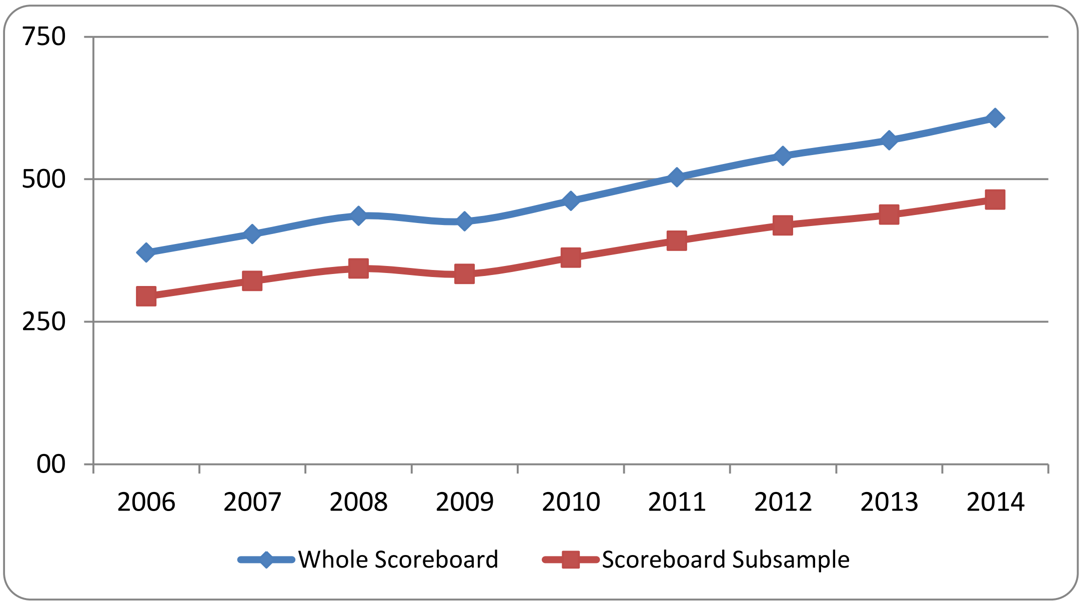
Figures 5, 6 and 7 show the Scoreboard-subsample comparison for the global, EU and US datasets respectively.

Figures 8, 9 and 10 show the Scoreboard-subsample comparison for the top 3 R&D countries of the EU.

Figures 11, 12 and 13 show the Scoreboard-subsample comparison for the EU regarding main R&D-related industries (automobiles, health and CT services).

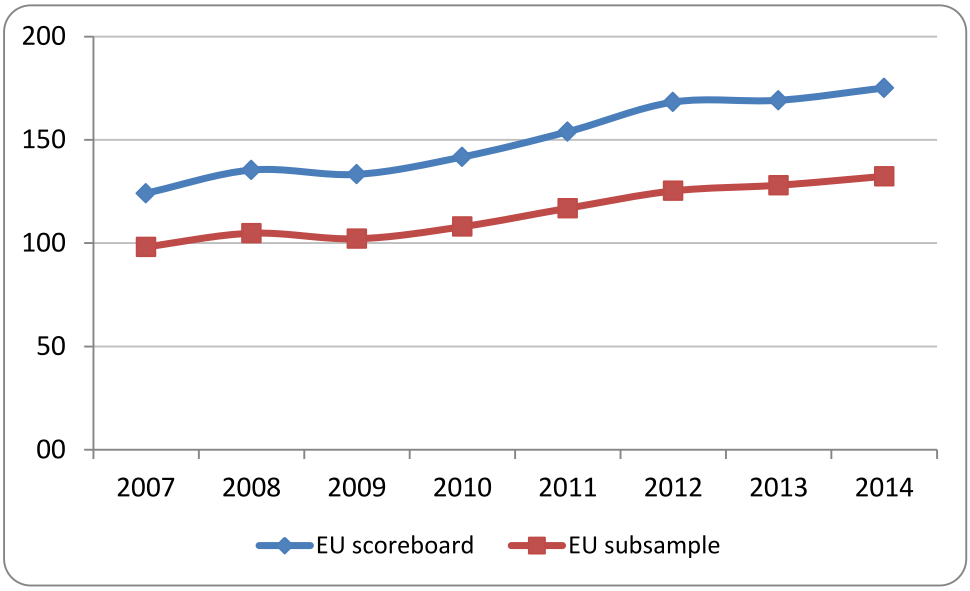
Comparison of Scoreboard and subsample for the global, EU and US datasets

Figure 5: Worldwide comparison of the *Scoreboard* with the subsample of companies (€bn)



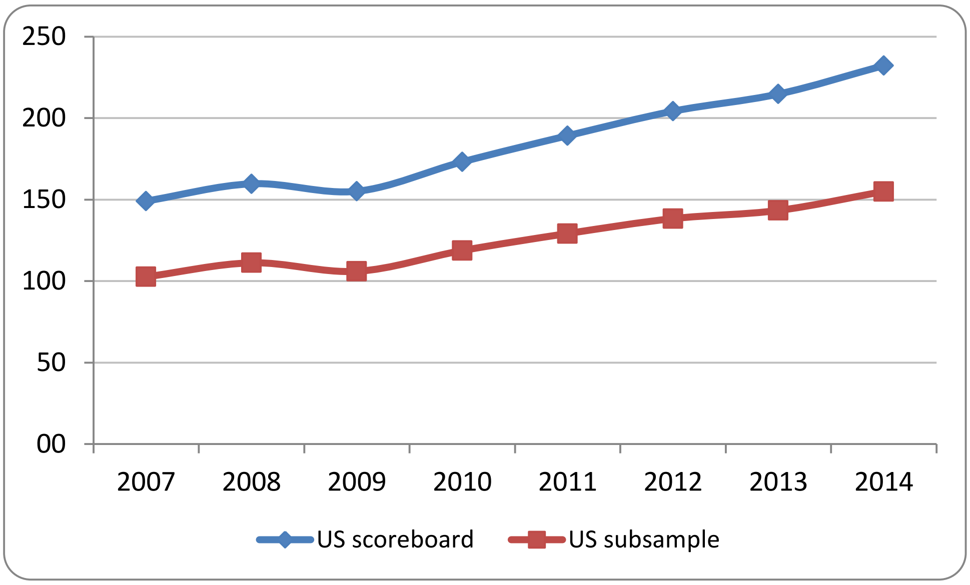
Note: Correlation coefficient = 0.99

Figure 6: Comparison of the *Scoreboard* with the subsample of EU companies (€bn)



Note: Correlation coefficient = 0.99

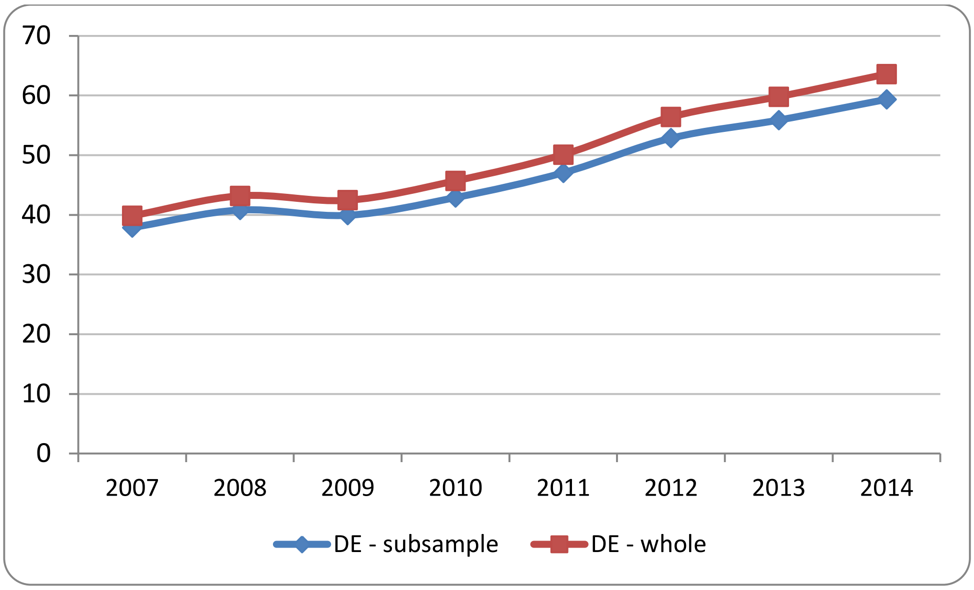
Figure 7: Comparison of the *Scoreboard* and subsample of US companies (€bn)



Note: Correlation coefficient = 0.99

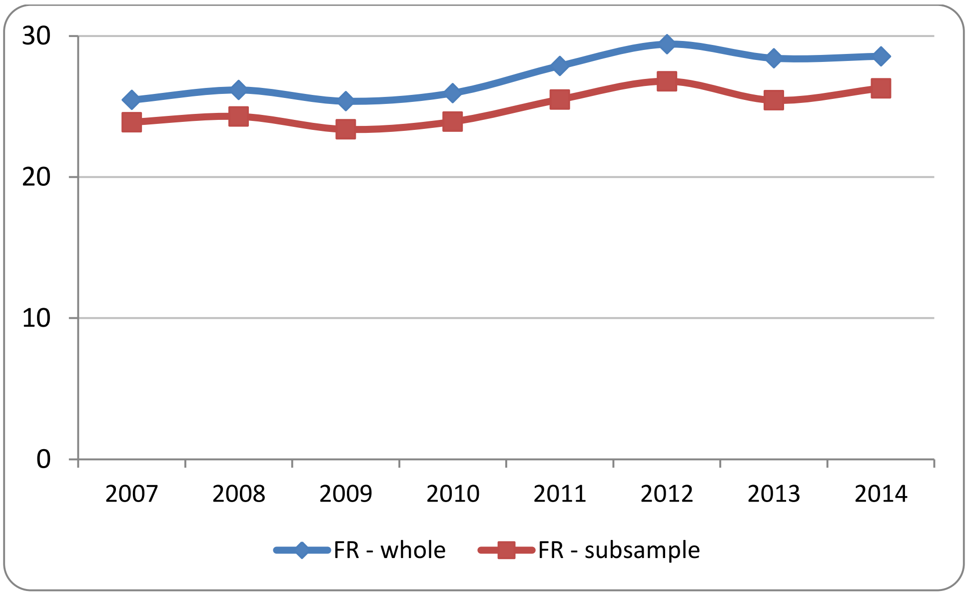
Comparison of Scoreboard and subsample for the 3 top R&D countries in the EU

Figure 8: Comparison of the *Scoreboard* and subsample of German companies (€bn)



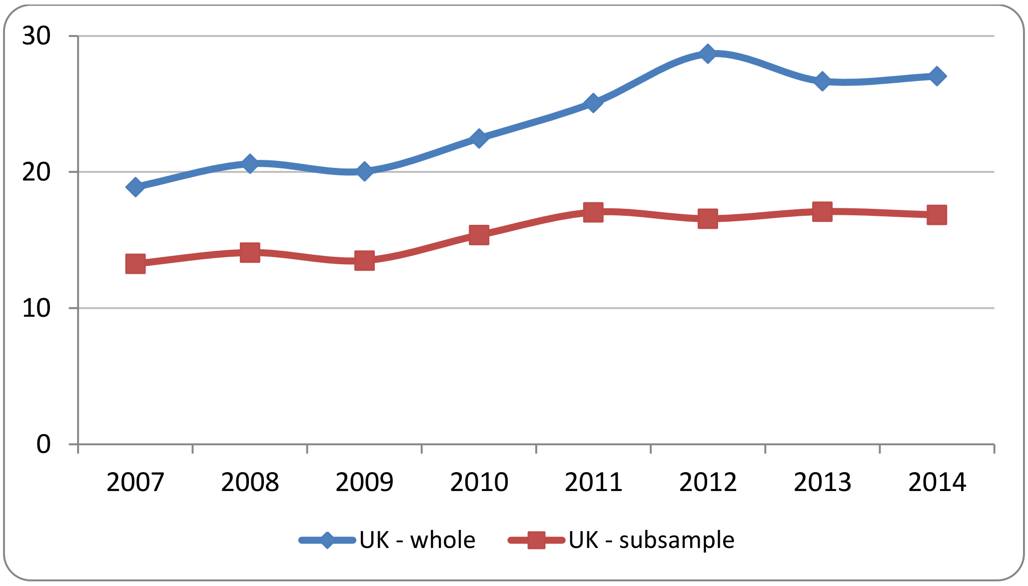
Note: Correlation coefficient = 0.99

Figure 9: Comparison of the *Scoreboard* and subsample of French companies (€bn)



Note: Correlation coefficient = 0.98

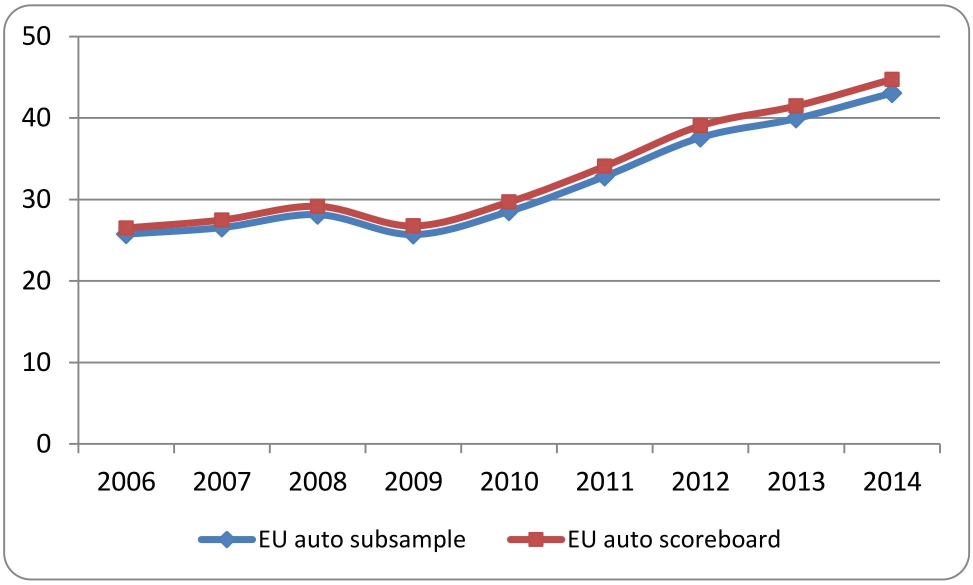
Figure 10: Comparison of the *Scoreboard* and subsample of UK companies (€bn)



Note: Correlation coefficient = 0.93

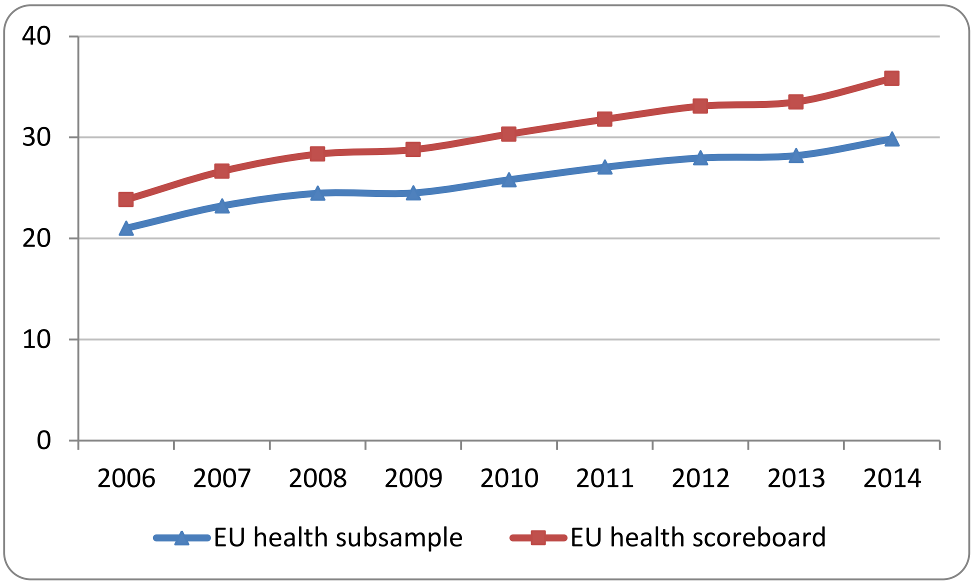
Comparison of Scoreboard and subsample for the EU and main industrial sectors

Figure 11: Comparison of the *Scoreboard* and subsample of EU companies for the automobile sector (€bn)



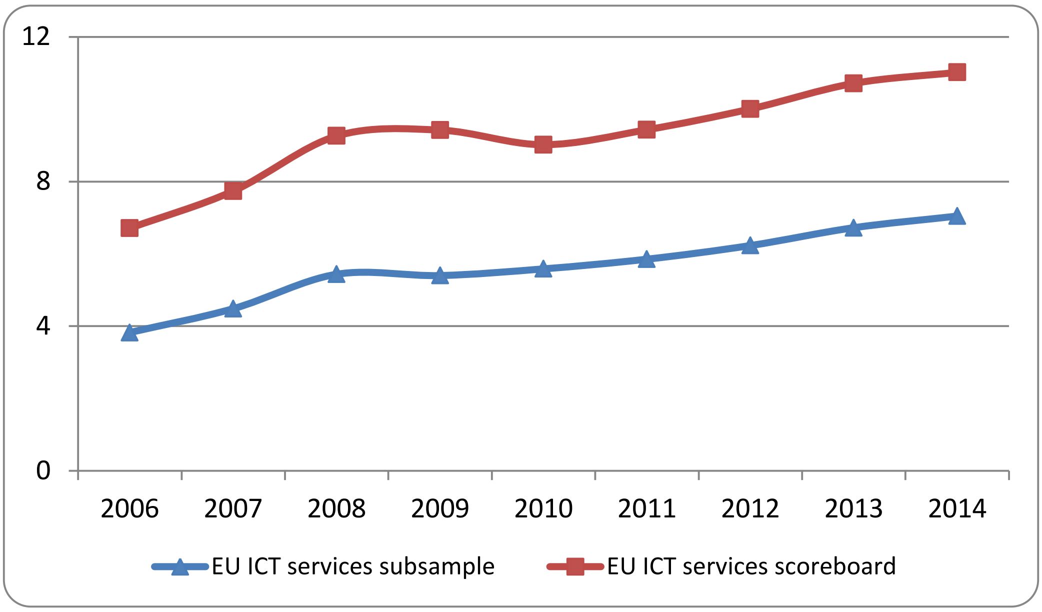
Note: Correlation coefficient = 0.99

Figure 12: Comparison of the *Scoreboard* and subsample of EU companies for the health industries (€bn)



Note: Correlation coefficient = 0.99

Figure 13: Comparison of the *Scoreboard* and subsample of EU companies for the ICT services industries (€bn)



Note: Correlation coefficient = 0.98

The selected subsample and the Scoreboard show also a good correlation for other large data aggregates, e.g. the largest R&D industries, namely the ICT services and ICT producers and health-related sectors.

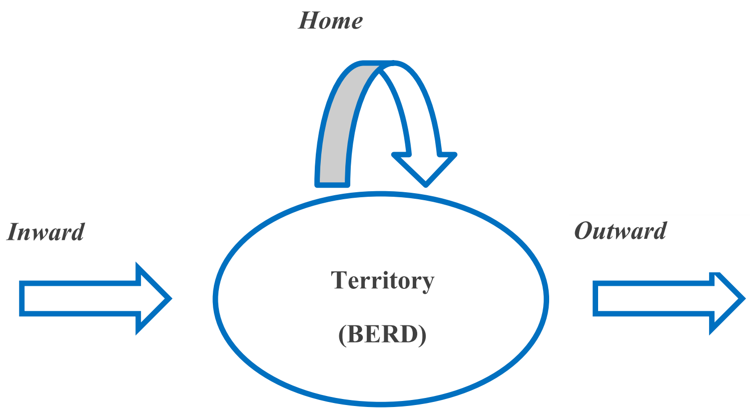
2.3 Cross-border activity of companies

As explained in section 2, the transnational R&D activity of companies represents a main limitation to compare BERD and Scoreboard R&D figures. The cross-border activity of companies can be characterised by breaking down the R&D activity of parent companies into their subsidiaries' activities at home and abroad.

From a territorial viewpoint, the BERD comprises the R&D activity funded and performed at home by the local companies and the inward R&D activity of foreign affiliated companies. On the other hand, the Scoreboard comprises the R&D activity funded and performed at home by the local companies and the R&D activity of their subsidiaries that is performed abroad (outward activity).

The BERD-Scoreboard relationship is schematised in the following figure and equations.

Figure 14: Territorial perspective showing companies' inward, home and outward R&D activity



Let's refer to country/region i and to company j and to apply the following definitions:

NPCi = Number of parent companies headquartered in country/region i

NFAi = Number of foreign affiliated companies operating (performing R&D) in country/region i

NSAi = Number of subsidiaries of companies headquartered in country/region i operating abroad (financing R&D that is performed abroad)

RDPH i,j = R&D activity funded by parent company j and performed in the headquarter country/region i (**home activity**)

RDOA i,j = R&D activity funded by parent company j, headquartered in country/region i and performed abroad (**outward activity**)

RDIA i,j = R&D activity funded by foreign affiliated company j and performed in country/region i (**inward activity**)

For country/region i the BERD and *Scoreboard* R&D activities at time t are defined as:

$$IndRD_{it} = \sum_{j=1}^{NPCi} RDPH_{ijt} + \sum_{j=1}^{NFAi} RDIA_{ijt} \qquad (1)$$

The territorial intramural R&D activity funded by industry and performed in country/region i (**best estimator of BERD**)[5] is given by the sum of the **home** and **inward** activities.

$$SB_{it} = \sum_{j=1}^{NPCi} RDPH_{ijt} + \sum_{j=1}^{NSAi} RDOA_{ijt} \qquad (2)$$

The R&D activity funded by companies headquartered in country/region i is given by the sum of the **home** and **outward** activities.

Therefore, by rearranging equation (2) and substituting $\sum_{j=1}^{NPCi} RDPH_{ijt}$ in equation (1), the relationship between best BERD estimate and *Scoreboard* can written as:

$$IndRD_{it} = SB_{it} + \sum_{j=1}^{NFAi} RDIA_{ijt} - \sum_{j=1}^{NSAi} RDOA_{ijt} \qquad (3)$$

And therefore, the BERD can be estimated as:

$$BERD_{it} = \alpha_i + SB_{it} + \sum_{j=1}^{NFAi} RDIA_{ijt} - \sum_{j=1}^{NSAi} RDOA_{ijt} + \varepsilon_{it} \qquad (4)$$

Where α_i is a country-specific constant and ε_{it} is an error term, which is assumed normally distributed with zero mean and standard deviation equal to σ_ε. The error term and α_i are necessary in order to take into account the fact that the *Scoreboard* companies do not cover 100% of R&D investments operated by private companies and by the differences between the two data collection methodologies discussed above.

The *Scoreboard* dataset includes information about companies' subsidiaries and their location worldwide, however, the R&D performed by subsidiaries is generally not disclosed in the consolidated reports and accounts. Nevertheless,

[5] Assuming that the other differences between the two data sources are less significant.

this can be estimated analysing the patent activity of the parent companies and their subsidiaries, which can be retrieved from PATSTAT using string matching algorithms. Indeed, previous work has investigated the innovation output of the *Scoreboard* companies using patents as a proxy indicator[6]. That work set-up the patent profile of the parent companies and their subsidiaries including the international location of companies' affiliated inventors. This information allows estimating the R&D of the subsidiaries. At first we assume that the relationship between a company's R&D investment and its patent activity is proportionally distributed across different locations. Of course, we are aware that companies may develop specific technologies in different locations and this could bias our results to the extent at which the patent-R&D relation within a company varies across the technologies developed.[7] For this purpose, we are currently developing a methodology to estimate the average R&D cost of each patented technology and further improve the allocation of private R&D expenditures across countries and our BERD nowcasting.

From company to territorial R&D perspective

As a first approach we use the geographic distribution of patents to estimate the actual location of R&D for the *Scoreboard* companies. We get a dataset comprising, for each parent company, the breakdown of its patent activity, indicating the applicant country (headquarter), inventor country and share of patents. Therefrom we estimate the geographic distribution of R&D and we aggregate the information at country level to obtain the terms of equations 2 and 3 (inward, outward and home R&D activity) as follows.

From the dataset we have for a period of time t:

XP_{ijk} = Share of patents of company k based in country i (application country) with inventors located in country j

So that for each parent company k based in country i:

$$\sum_{j=1}^{NSk+1} XP_{ijk} = 1.0 \qquad (5)$$

where NS_k = Number of subsidiaries of company k located abroad and

RD_{ij} = R&D investment by company j based in country i

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[6] Report of the IRITEC project "World Corporate Top R&D Investors: Innovation and IP bundles" (http://iri.jrc.ec.europa.eu/other-reports.html).

[7] It should noted that this issue is not addressed by simply considering the variation of patent propensities (the patent/R&D ratio) across industries.

Then, for a given country i and period t, the home R&D activity is:

$$\sum_{j=1}^{NPCi} RDPH_{ijt} \ = \ \sum_{\substack{k=1 \\ i=j}}^{NPCi} XP_{ijk} \ * RD_{ik} \qquad (6)$$

the inward R&D activity is

$$\sum_{j=1}^{NFAi} RDIA_{ijt} = \sum_{\substack{j=1 \\ j \neq i}}^{NCFi} \ \sum_{k=1}^{NFAij} XP_{jik} \ * \ RD_{jk} \qquad (7)$$

and the outward R&D activity is

$$\sum_{j=1}^{NSAi} RDOA_{ijt} = \sum_{\substack{j=1 \\ j \neq i}}^{NCSi} \ \sum_{k=1}^{NFAij} XP_{ijk} \ * \ RD_{ik} \qquad (8)$$

where:

NFA_{ij} = Number of companies from country i having affiliates in country j

NCF_i = Number of countries with parent companies having affiliates in country i

NCS_i = Number of countries where parent companies from country i have subsidiaries

Henceforth, we can estimate the latest BERD figures by using the latest R&D information from the *Scoreboard*, normally available with a short delay, applying ordinary least squares to equation (4).

In the following (figures 15, 17, 19 and 21) we display the different components of R&D activity (inward, home, outward) discussed above and calculated using the *Scoreboard* sub-sample and the relative patent data for the EU and the top 3 member states (Germany, France, UK). Similar results are obtained for other representative data aggregates of the *Scoreboard*, e.g. large countries such as the US and the large industrial sectors presented in Table 3.

Cross-border R&D activity for the EU, Germany, France and the UK

The combination of company R&D and patent data help in understanding the scale and dynamics of industrial R&D flows across territorial borders. This information can be also broken down by industrial sector. For example, the results for the EU, Germany, France and the UK (figures 15, 17, 19 and 21) by sector show:

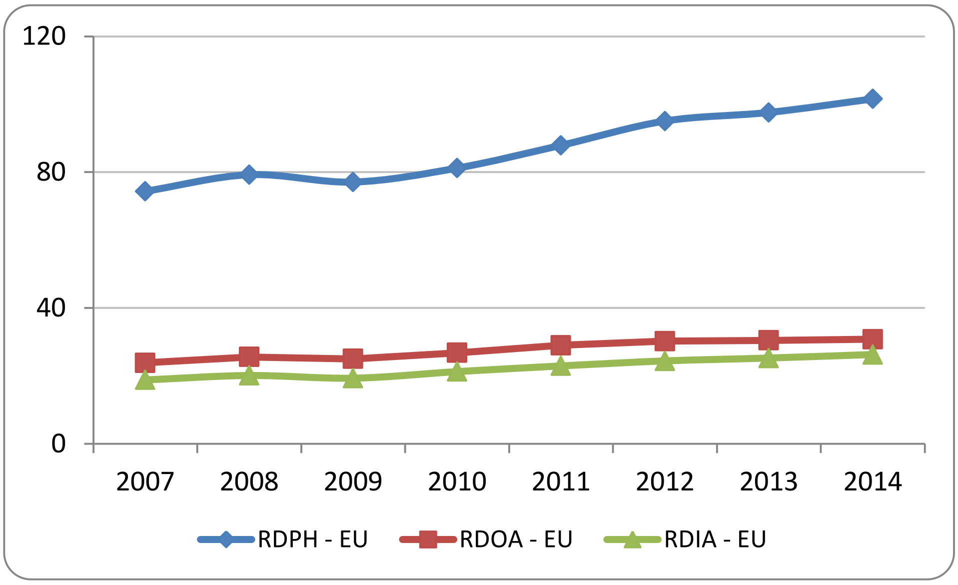
- Companies headquartered in the EU perform at home more than 75% of their R&D. The EU's territorial R&D has a steady negative inward-outward balance (less than 4% of BERD), mostly due to deficits in industries such as ICT producers, Automobiles and Chemicals. On the other hand, the EU shows a modest positive R&D balance in Industrials, Aerospace & defence and Pharmaceuticals.

- Companies headquartered in Germany perform at home about 70% of their R&D. Germany shows a positive inward-outward R&D balance (ca. 5%), mostly due to a large surplus in Industrials and a small one in Pharmaceuticals & biotechnology. In contrast, Germany shows a small negative balance in ICT producers and ICT services and Chemicals.
- Companies headquartered in France perform at home about 60% of their R&D. France shows a negative inward-outward R&D balance (ca. 15%), mostly due to deficits in sectors such as ICT producers, Pharmaceuticals and Industrials. Conversely, France shows a relatively large surplus in Aerospace & defence and Chemicals.
- The UK presents very high cross-border R&D flows. Companies headquartered in the UK perform at home only about 30% of their R&D. The UK's BERD shows a large negative inward-outward balance (more than 25%), mostly due to deficits in sectors such as Pharmaceuticals, Automobiles and Oil. On the contrary, the UK shows a modest positive R&D balance in Aerospace & Defence and Software & computer services.

Comparison of BERD and best BERD estimator (IndRD) for the EU, Germany, France and the UK

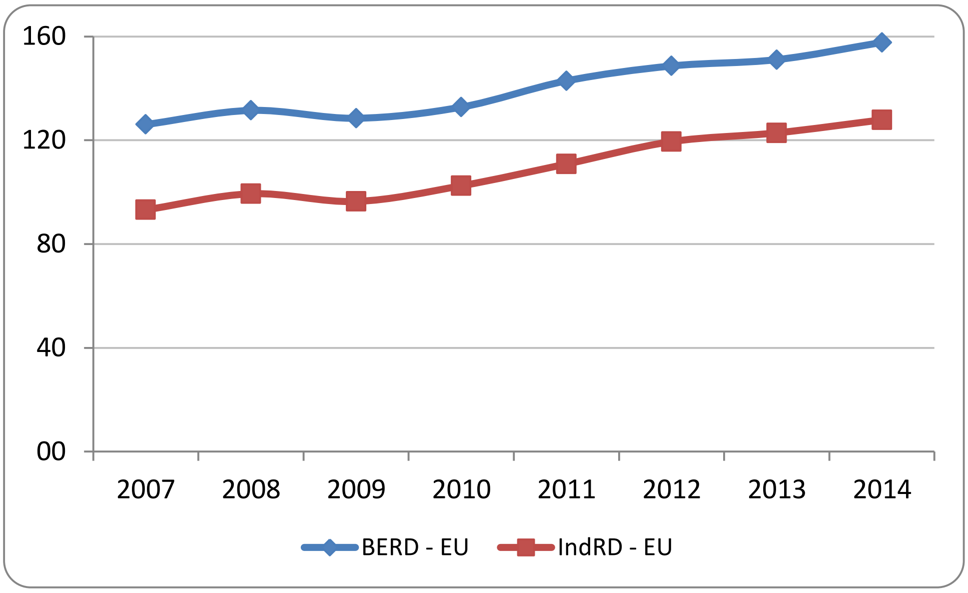
Figures 16, 18, 20 and 22 show the BERD historical data together with the best estimator of BERD (IndRD) presented in equation (3). The figures show that the correlation among the two statistics is in general very good, ranging between the 0.99 in the case of the EU aggregate and the 0.89 for France and UK. These positive results suggest that by applying equation (4) it is possible to elaborate robust BERD estimates from a subsample of representative companies for which recent R&D data are available.

Figure 15: *Scoreboard* data for the EU including companies' home, inward and outward R&D activities (€bn)



Note: Non-euro currencies converted at the exchange rate on 31.12.2014

Figure 16: Correlation of BERD and best estimate for BERD (IndRD) for the EU (€bn)



Note: Correlation coefficient = 0.99

Figure 17: *Scoreboard* data for Germany including companies' home, inward and outward R&D activities (€bn)

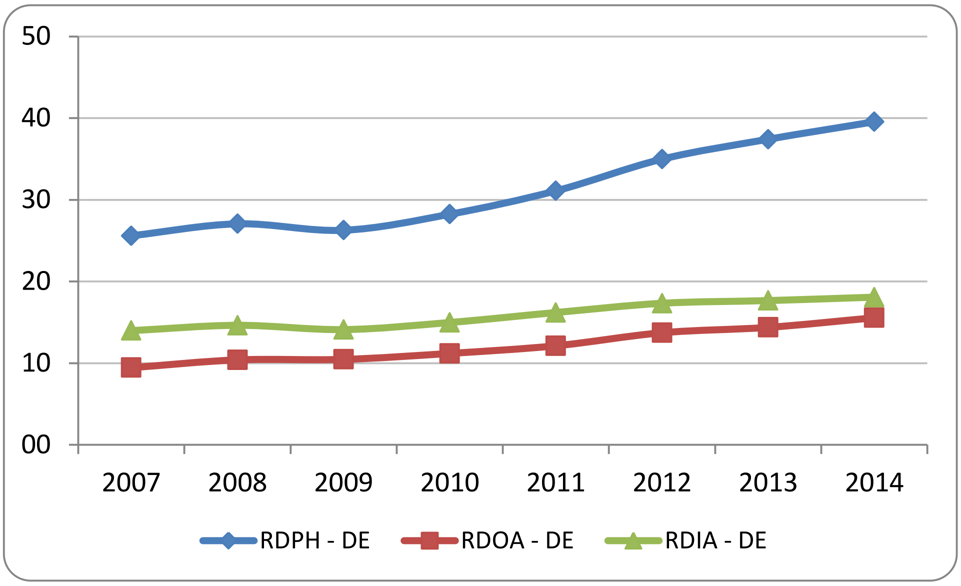
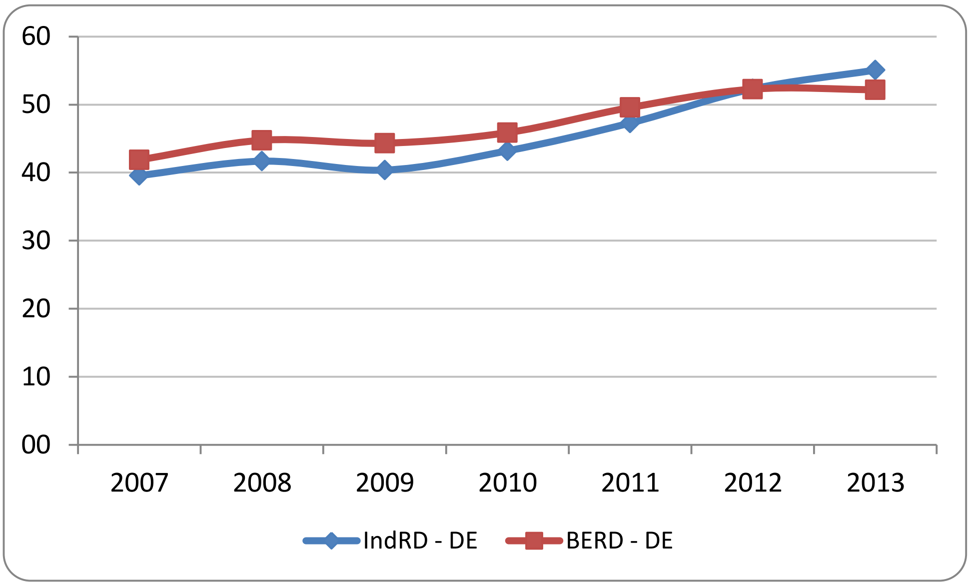


Figure 18: Correlation of BERD and best estimate for BERD (IndRD) for Germany (€bn)



Note: Correlation coefficient = 0.97

Figure 19: *Scoreboard* data for France including companies' home, inward and outward R&D activities (€bn)

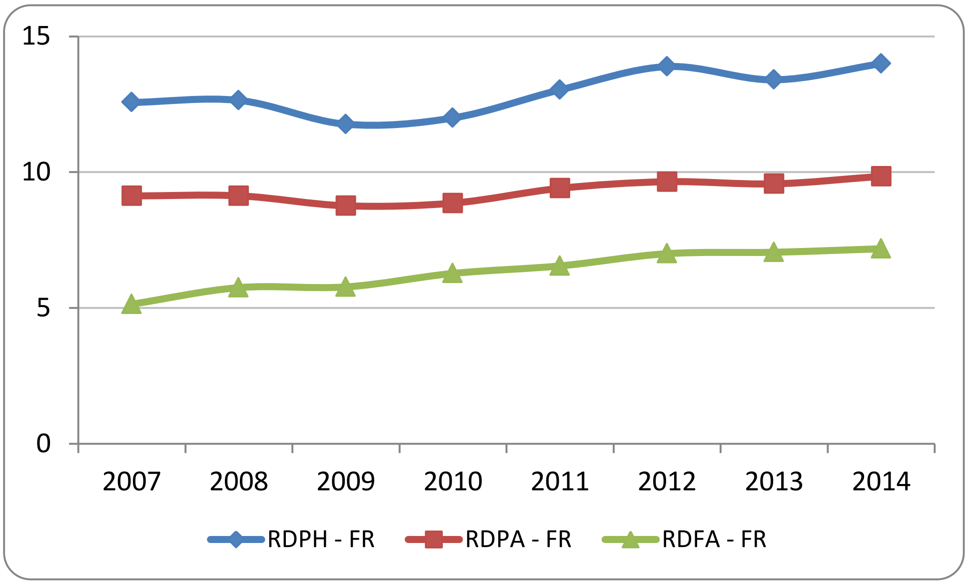
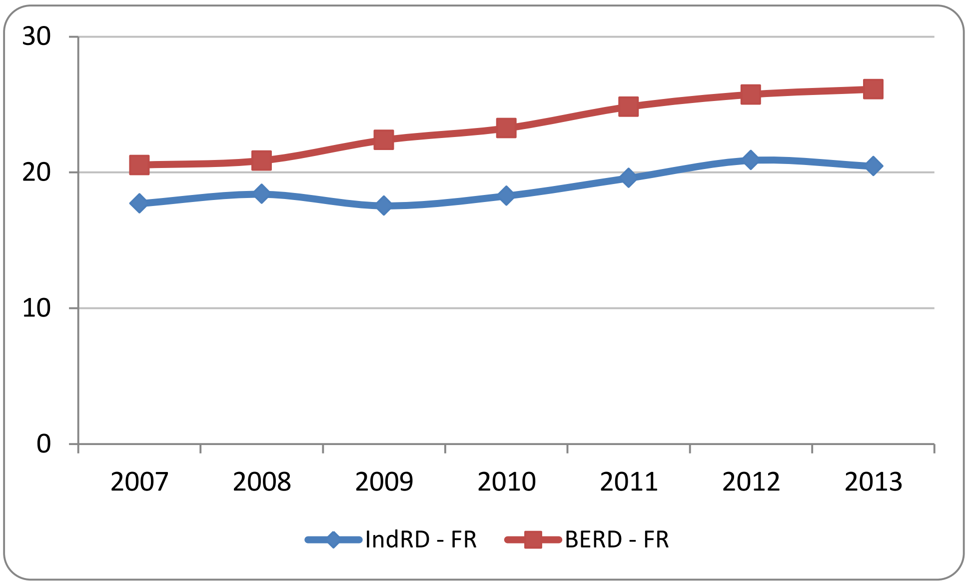
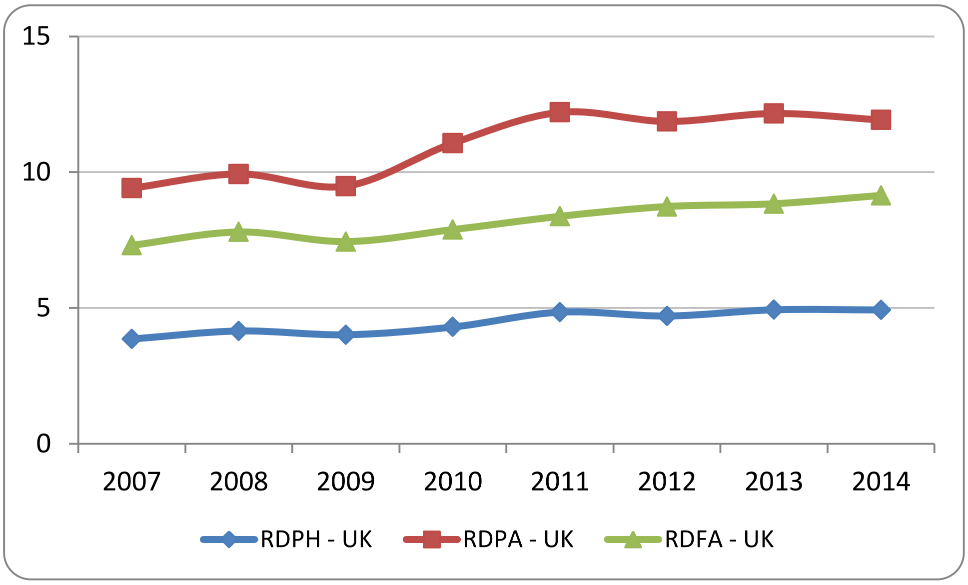


Figure 20: Correlation of BERD and best estimate for BERD (IndRD) for France (€bn)



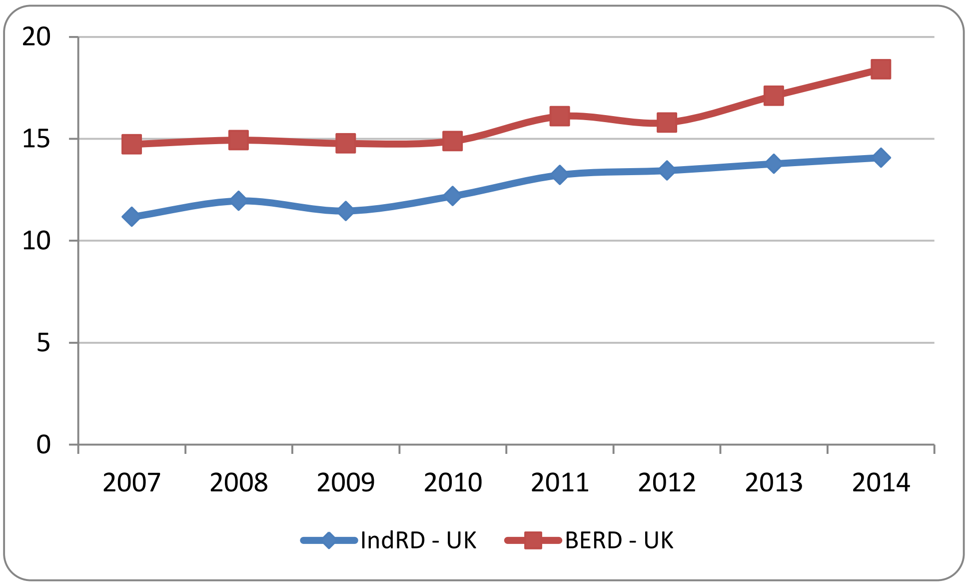
Note: Correlation coefficient = 0.89

Figure 21: *Scoreboard* data for the UK including companies' home, inward and outward R&D activities (€bn)



Note: Pounds converted to euros at the exchange rate on 31.12.2014

Figure 22: Correlation of BERD and best estimate for BERD (IndRD) for the UK (€bn)



Note1: Pounds converted to euros at the exchange rate on 31.12.2014
Note2: Correlation coefficient = 0.89

3 Case study: estimating territorial business R&D performance in 2015

As an illustrative example, in this chapter an application of the methodology discussed before is presented. The case study is performed using preliminary R&D company data for the EU R&D Scoreboard 2016 edition. In particular, a sample of 350 among the most representative companies in the sample has been selected. In order to geographically allocate R&D expenditure, we have used the COR&DIP dataset, a dataset developed by JRC in collaboration with the OECD containing patent data for the *Scoreboard* companies.

The main findings of this pilot exercise can be summarized as follows:

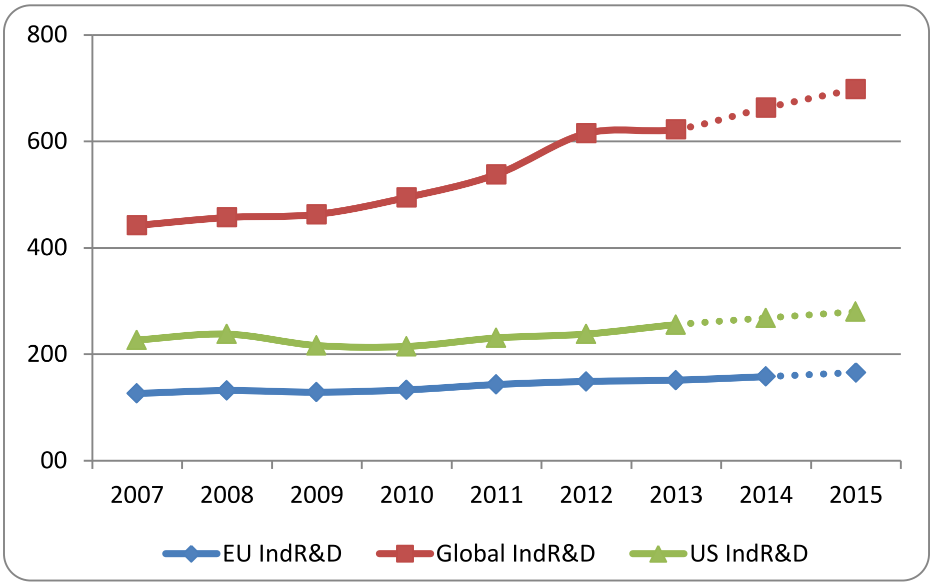
1) *Industrial R&D continued to growth substantially in 2015 …*

The global R&D funded by industry increased by 5.5% in 2015 to €699.1bn, compared with an increase of 6.5% in 2014. **In the EU, the industrial R&D also grew at a similar rate, 5.6% to €165.0bn**, more than the 3.4% increase of 2014. The US industry spent €279.7bn in R&D, 4.4% more than the previous period (see Figure 23).

2) *… mostly driven by R&D increases in ICT services*

Worldwide, the growth of industrial R&D in 2015 was driven by a robust increase of R&D in knowledge-intensive services provided by the ICT - namely from companies operating in Computer Services, Software and Internet - and Health industries. Poor R&D performance was shown by the Chemical sector followed by Aerospace & Defence, (see Table 4).

Figure 23: Evolution of industrial R&D worldwide, in the EU and the US (€ bn)



Note1: Global and US figures for 2014 & 2015 are estimated. EU figure 2015 is estimated.
Note2: Non-euro currencies converted at the exchange rate on 31 December 2015.

3) EU and US showed different sectoral performance

In the EU, the industrial R&D significantly increased in ICT services (16.5%), and showed also a double digit growth in Health (14.5%), Automobiles (9.1%) and Industrials (11.5%). However, ICT services is relatively small in terms of R&D in the EU, having a limited impact on the overall R&D growth. Considering the R&D weight of EU industries, the highest contribution to the EU R&D growth was made by Automobiles, followed closely by Health sectors. The poor performance of Aerospace & Defence and Others sectors constrained the overall EU's R&D growth.

In the US, the top R&D investors in Computer services and Internet boosted the R&D of the ICT services sector that increased strongly by 18.5%. Many other US industries showed only a modest increase in R&D while the Chemicals sector showed a poor performance (-7.8%) due to a significant R&D reduction of a few large Chemical producers based in the US.

Table 4: Industrial R&D annual growth in 2015 for the EU, the US and worldwide

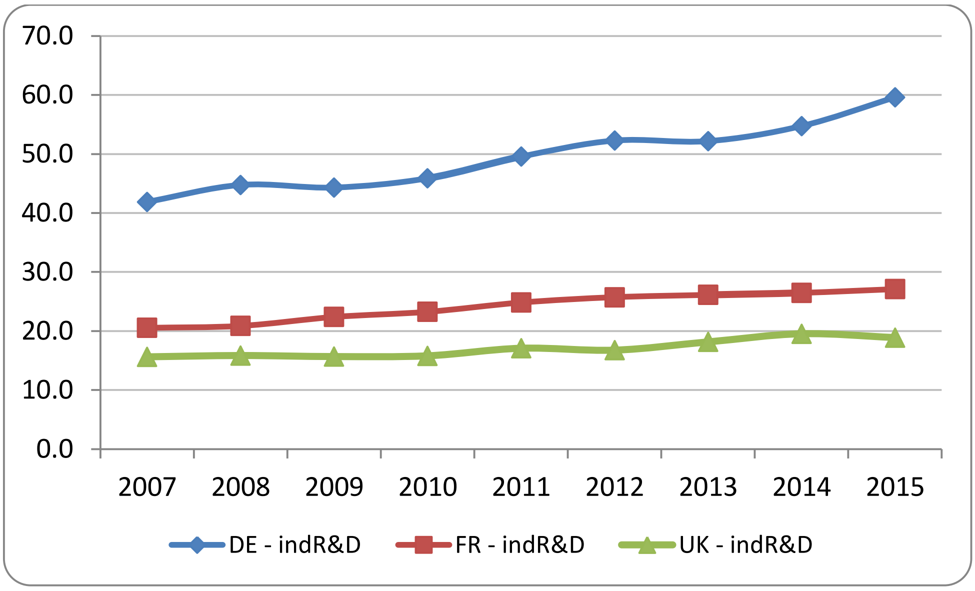
Industrial Sector	EU (%)	US (%)	Global (%)
ICT services	16.5	18.5	13.8
Automobiles	9.1	-1.1	7.9
Health industries	14.5	5.5	11.4
ICT producers	0.4	4.5	4.5
Industrials	11.5	-0.8	-0.4
Aerospace & Defence	-3.3	1.8	-1.1
Chemicals	4.0	-7.8	-2.2
Others	-1.4	-12.1	3.4

4) Within the EU, the top 3 Member States show mixed R&D performance

In Germany, industry grew R&D strongly (8.9%) to €59.6bn, improving the R&D growth showed in 2014 (6.7%) and the stagnation in 2013 (-0.2). German R&D was mostly fuelled by the Automobiles & parts sector (about 60% of the R&D growth) and to a lesser extent by Pharmaceuticals (about 15% of the R&D growth). (see Figure 24).

French industry increased R&D by 2.4% to €27.1bn, breaking the decreasing trend observed in the past three years. The R&D performance of the French industry was driven by double digit R&D growth from leading companies in sectors such as Automobiles, Pharmaceuticals, Software and Telecom equipment.

Figure 24: Evolution of industrial R&D in the top 3 R&D countries of the EU (€bn)



Note1: Pounds converted to euros at the exchange rate on 31.12.2015
Note2: Figures for 2015 are estimated

The UK industry reduced R&D in 2015 by 3.3% to €18.9bn, contrasting the significant R&D increase showed in 2014 and 2013 (7.6% and 8.3% respectively). Although large companies based in the UK increased significantly R&D, e.g. in sectors such as Pharmaceuticals and Financial services, this has been offset by a poor performance of companies from other industries such as the large UK's Oil sector. The UK's R&D is also reduced because the high R&D outward flows of UK companies in sectors such as Pharmaceuticals, Automobiles and Oil.

4 Conclusion

BERD and *Scoreboard* figures are not directly comparable because a number of conceptual and methodological differences. The main problem is the cross-border R&D activity of companies that normally is not disclosed in companies' reports and official statistics. However, descriptive statistics of the two datasets show similarities and a good correlation for high levels of aggregation of the data, i.e. for large countries/regions and large industrial sectors in terms of R&D.

A subsample of representative *Scoreboard* companies can be selected to overcome problems regarding on-time data availability. Representative, and relatively small, samples can be defined thanks to the characteristic feature of industrial R&D, i.e. highly concentrated by country/region and type of industry. The choice of the sample should take into account the representativeness of the data in terms of territorial and industrial scope for each specific case. For example Germany and the UK require different sample in terms of size and composition because of their very different industrial R&D composition and geographic distribution.

Including companies' cross-border activities into the analysis allows better characterisation of the data and better correlation BERD-*Scoreboard*. From this correlation, it is possible to produce early estimates of BERD figures from *Scoreboard* data that are more rapidly available. The use of patent data of companies' subsidiaries as a proxy indicator of the innovation output helps to characterise the location of companies' innovation activities worldwide.

Our pilot exercise showed that the combination of corporate R&D and patent data can help in understanding the scale and dynamics of industrial R&D flows across territorial borders. Overall, companies headquartered in the EU contribute to about 80% of the EU's territorial business R&D, the rest coming from foreign affiliates operating in the EU. These figures hide a high degree of heterogeneity across industrial sectors. For example, the EU shows an inward-outward R&D balance of -6.3% in the ICT producers sector and +5.5% in Health industries. More detailed analysis is required in order to better understand the reasons behind these differences and their policy implications.

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