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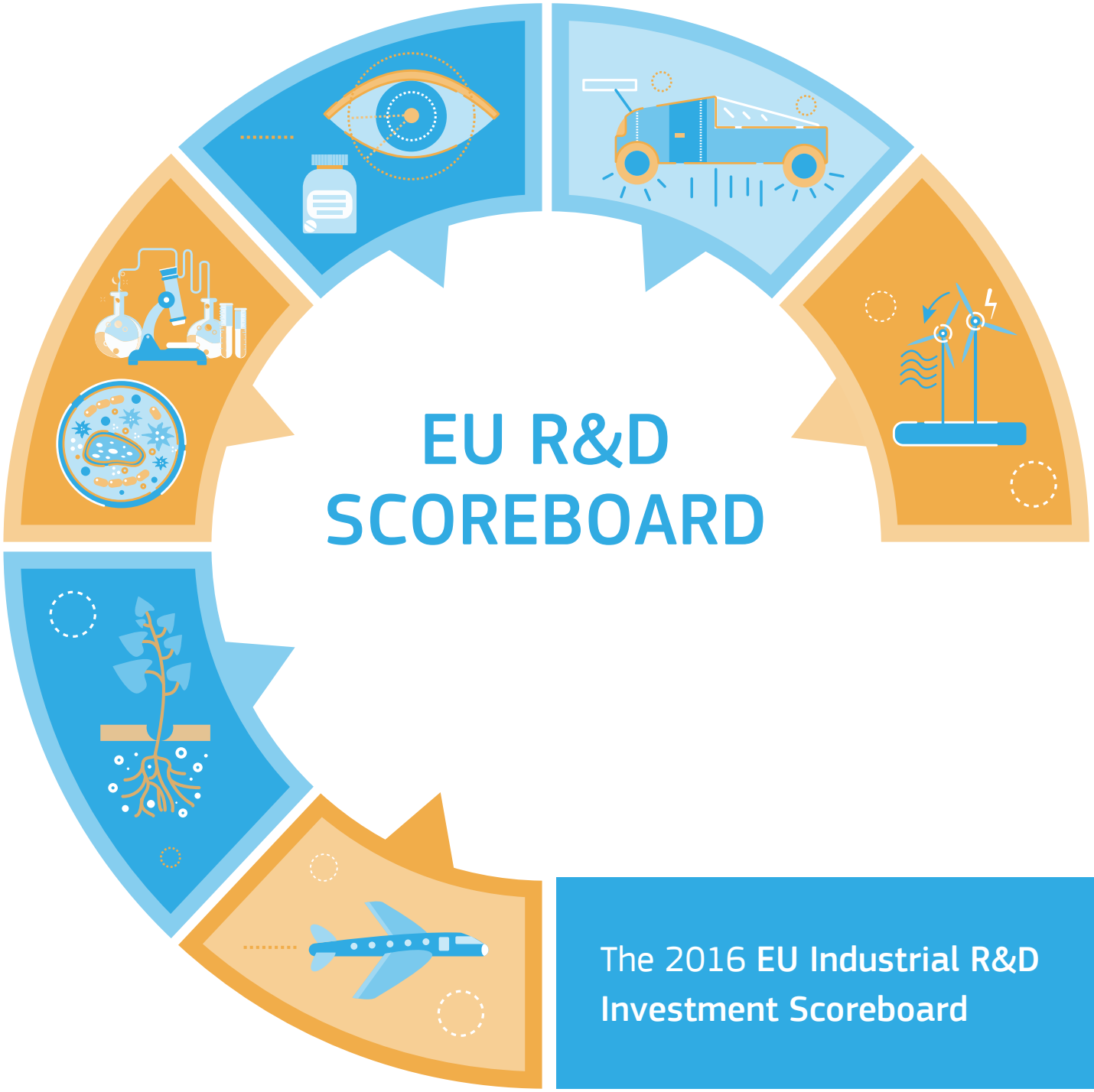

EU R&D SCOREBOARD

The 2016 **EU Industrial R&D Investment Scoreboard**

EUR 28185 EN

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IRIMA activities aim to improve the understanding of industrial R&D and Innovation in the EU and to identify medium and long-term policy implications.

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EU R&D SCOREBOARD

The 2016 EU Industrial R&D Investment Scoreboard

The 2016 EU Industrial R&D Investment Scoreboard

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0 SUMMARY / INTRODUCTION

Summary

The "EU Industrial R&D Investment Scoreboard" (the *Scoreboard*), published annually since 2004, monitors top EU based R&D investing companies benchmarking them with top R&D investors located in other parts of the world. The *Scoreboard* is part of the European Commission's monitoring activities to improve the understanding of trends in R&D investment by the business sector. In the context of the EU agenda for Jobs, Growth and Investment, the contribution of the business sector to reach the 3% objective for R&D intensity in the European economy is crucial. Evidence from the *Scoreboard* shows that most of the EU R&D gap with respect to main world competitors comes from an insufficient number of leading innovative companies in key high-tech sectors. The *Scoreboard* shows the details of how this gap is made up from the differing contributions of individual R&D companies.

The *Scoreboard* relies on economic and financial information on the World's top 2500 companies that invested €696 billion in R&D –representing about 90% of the total expenditure on R&D financed by the business sector worldwide. The data is collected from the latest available companies' accounts (i.e. for this year's edition usually the fiscal year 2015/16[1]). It complements official territorial statistics (such as BERD) in the study of important questions related to companies' innovation behaviour in a global context. It is a reliable, up-to-date benchmarking tool for comparisons between companies, industries, and geographical areas, as well as to monitor and analyse the scale and dynamics of industrial R&D.

This *Scoreboard* edition shows important variations of companies' R&D investments and economic results across countries and industries. This reflects the persistent market and economic uncertainties and opportunities in which global R&D companies continued to operate in 2015/16.

[1] The latest available annual account is taken into account for each individual company. Due to differences in accounting practices, however, these refer to a range of dates from late 2014 to the first half year of 2016 (see methodological notes in Annex 2).

Highlights

1 In 2015/16, the world top 2500 R&D *Scoreboard* companies invested a total of €696bn in R&D, an increase of 6.6% over the previous year, driven by the R&D growth in high tech industries. In contrast, companies' net sales declined (-3.7%), mostly due to low-tech sectors and particularly to oil-related companies.

2 The group of EU companies within the top 2500 increased their R&D by 7.5%, above the rate of the US companies at 5.9% and the Japanese companies at 3.3%.

3 In contrast to the increases in R&D, the combined sales of the EU group fell by 3.6%, the US group fell by 4.0% but sales rose by 0.3% for the Japanese group. The sales decreases were driven by low world oil and commodity prices which reduced the sales of oil and mining companies which have modest R&D investments but large sales. Japan has no large companies operating in these sectors. For the same reason, overall operating profits fell for both the EU and US groups.

4 As in the past few years, companies based in China continued to show the best performance in terms of R&D growth (up by 24.7%) but presented also a significant decrease in net sales (-6.2%). Companies based in South Korea and Taiwan showed a more modest R&D growth and also a slight decrease in net sales.

5 Global R&D is concentrated with the top 100 global R&D investors accounting for 53.1% of the R&D of the whole top 2500 and the top 50 companies accounting for 40%. There are 15 EU companies in the top 50 with 23 from the US, 4 from Japan, 3 each from China and Switzerland and one each from South Korea and Taiwan.

6 The top 50 large companies listed by R&D intensity (R&D to sales ratio) are dominated by the high tech sectors of biotechnology & pharmaceuticals, software and technology hardware. The US is very strong in these three sectors and accounts for eight of the top 10 companies in the top 50. These three sectors are the global top three by R&D growth, in the top four for sales growth and at the top for profitability.

7 The largest groups of companies in the world top 2500 companies are drawn from the ICT (information, communications and telecoms industries), health care and automotive industries. However, the sector mix or specialisation of the various world regions is very different. The US has 69% of its R&D in its top three sectors of biopharmaceuticals, software and technology hardware whereas both the EU and Japan have automotive as their top sector by amount of R&D. Software is only the eighth largest sector in the EU and the ninth in Japan.

8 These substantial sector mix differences explain why the overall R&D intensity of the US group is 5.8% compared to only 3.2% for the EU companies. It is also why overall EU profitability at 6.8% is much lower than for the US with 12.9%. The gap in the proportions of highly intensive R&D has widened over the last ten years because of the outperformance of the US's ICT and biotech sectors. For example, the US software sector has doubled its proportion of US R&D over the last 10 years.

9 The *Scoreboard* also contains details of the top 1000 EU R&D investors which comprise the 590 in the global set together with an additional 410 with R&D down to €6m. The EU 1000 contains 274 firms from the UK, 217 from Germany, 117 from France and 392 from 19 other EU countries. The 906 firms based in the top 10 member states showed an R&D increase of 7.4% over the previous year.

10 The 2016 *Scoreboard* also contains chapters analysing the dynamics of company growth over the last 12 years, industrial R&D flows across borders and the effect of mergers and acquisitions on transfer of R&D between countries.

Key findings

Significant worldwide rise of corporate R&D, driven by high-tech industries, while revenues declined mostly due to the challenging environment in which many low-tech sectors operated

The top 2500 *Scoreboard* companies invested in R&D €696.0bn in 2015/16, an increase of 6.6% with respect to 2014/15, a similar growth rate to the year before (6.8%). In contrast, companies' net sales declined (-3.6%), compared with an increase of 2.2% in 2014/15 (see Figure S1 and Table S1).

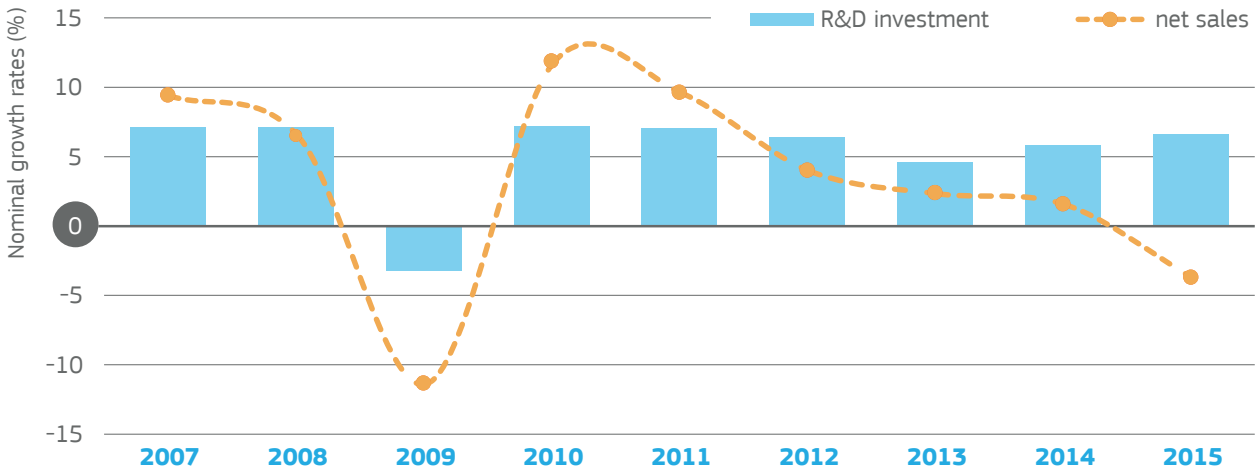

FIGURE S.1 – WORLDWIDE GROWTH RATE OF R&D AND NET SALES OVER THE PERIOD 2011-2015.
Note: Figures for 1622 out of the 2500 companies for which R&D and net sales are available for the 10 years period.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

EU companies increased R&D above both the world's and US's growth rates

The companies based in the EU increased R&D investment at a higher rate than the world's average, at 7.5% while decreasing net sales (-3.6%). The same trend of robust R&D investment growth rates coupled with net sales decline is observed for companies located in other world regions. Companies based in China continued to show outstanding growth rates for R&D (24.7%), but the decline in net sales is also the highest among main regions (-6.2%). US companies reported a significant increase in R&D (5.9%) but below the one observed for EU ones. The Japanese companies showed a modest R&D increase (3.3%) while net sales remained practically unchanged (see Table S.1).

Factor	Global	EU	USA	Japan	China	RoW
No. of companies	**2 500**	590	837	356	327	390
R&D IN 2015/16, €bn	**696.0**	188.3	268.6	99.9	49.8	89.4
World R&D share, %	**100.0**	27.1	38.6	14.4	7.2	12.8
One year change, %	**6.6**	7.5	5.9	3.3	24.7	2.4
Net Sales, €bn	**17 686.8**	5 678.4	4 518.8	2 859.6	1 978.9	2 651.2
World net sales share, %	**100.0**	32.1	25.5	16.2	11.2	15.0
One year change, %	**-3.6**	-3.6	-4.0	0.3	-6.2	-4.8
R&D intensity, %	**3.8**	3.2	5.8	3.3	2.5	3.3

TABLE S.1 - OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2016 SCOREBOARD.
Note : The RoW group comprises companies based in Taiwan, South Korea, Switzerland, Canada and a further 19 countries.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

In all world regions, the growth in R&D was driven by companies operating in the largest R&D-investing industries (ICT, health and auto), that also increased significantly net sales, while the overall fall in net sales was mostly due low-tech sectors and in particular due to oil- and other commodity-related companies where world prices were depressed (see Figure S.2).

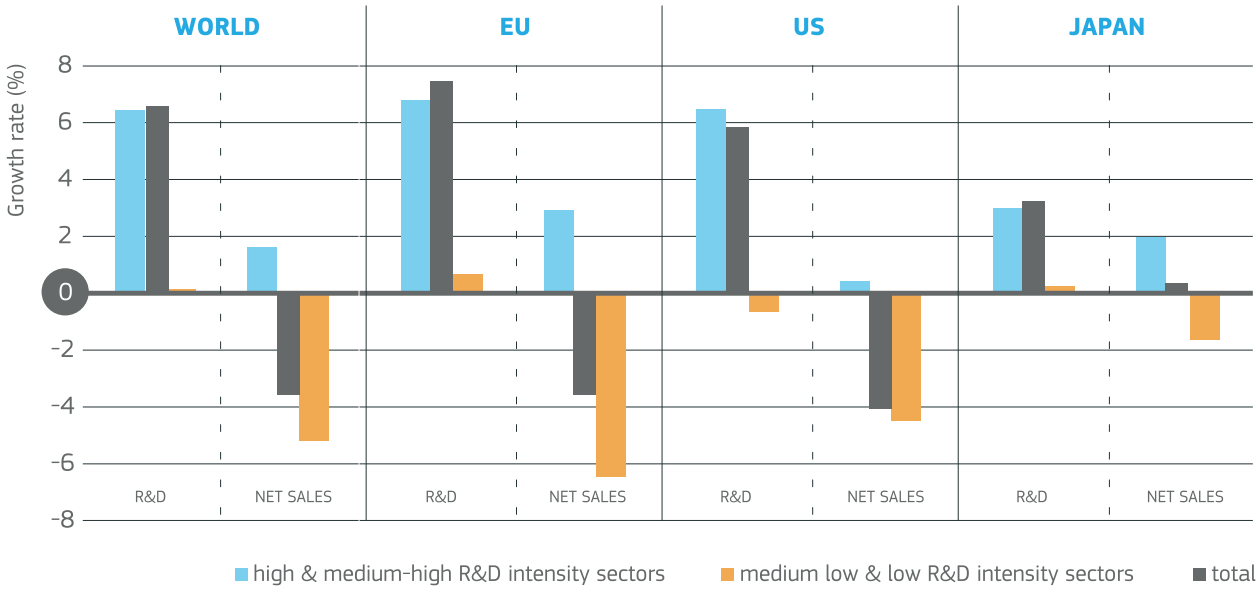

FIGURE S.2 – WORLDWIDE GROWTH RATE OF R&D AND NET SALES IN 2015/16 BY MAIN WORLD REGION AND TWO GROUPS OF CHARACTERISTIC R&D INTENSITY.
Note: R&D figures for the top 2500 R&D investors and net sales for 2240 companies reporting sales in 2014 and 2015.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

R&D investment performance of companies located in other world regions was mixed

Companies from South Korea and Taiwan continue to show positive R&D growth, while those in Switzerland and Canada show a decline. These trends in R&D are accompanied in all cases by a decline in net sales, except for companies based in Canada (see Table S.2).

Factor	Switzerland	South Korea	Taiwan	Canada
No. of companies	58	75	111	32
R&D in 2015/16, €bn	28.0	25.4	14.0	4.7
Worl R&D share, %	4.0	3.7	2.0	0.7
One year change, %	-1.5	3.7	7.1	-2.3
Net Sales, €bn	377.6	822.5	511.9	115.1
One year change, %	-3.3	-1.7	-0.3	1.7
R&D intensity, %	7.4	3.1	2.7	4.1

TABLE S.2 - PERFORMANCE OF COMPANIES BASED IN THE LARGEST COUNTRIES OF THE RoW GROUP.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

An important number of players among the top industrial R&D investors are based in the EU

Among the top 50 R&D investors (by amount of R&D) there are 15 EU companies, the same number as in last year's ranking and 30 companies among the top 100, one more than last year.

For the third consecutive year, the two top R&D investors remain the same (Figure S.3): Volkswagen (€13.6bn) from Germany in 1st place and Samsung Electronics (€12.5bn) from South Korea in 2nd position. The other companies in the top-ten are Intel, Alphabet and Microsoft (€11.0bn) from the US; Novartis (€9.0bn) and Roche (€8.6bn) from Switzerland; Huawei (€8.4bn) from China; Johnson & Johnson (€8.3bn) from the US and Toyota Motor (€8.0bn) from Japan.

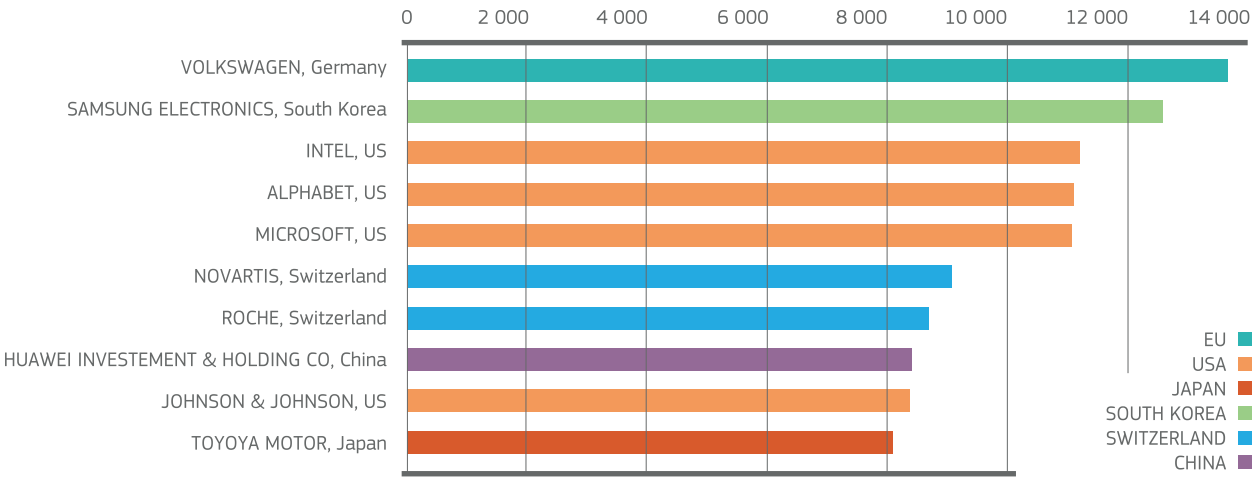

FIGURE S.3 – TOP 10 COMPANIES OF THE 2016 SCOREBOARD.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

The Software industry showed the highest R&D growth worldwide, led by global software firms

The Software sector showed the highest one-year R&D growth rate (12.3%) followed by Pharma (9.8%), IT hardware (7.6%) and Auto (6.7%) (see Table S.3). The performance of the Software sector is mostly due to the R&D growth of US companies such as Alphabet (22.4%) and Facebook (80.6%) and Chinese companies such Baidu (46.2%). The German company SAP (16.6%) is the fourth contributor to the R&D growth of this sector.

SECTOR	GLOBAL R&D GROWTH (%)	EU	USA	JAPAN	CHINA
Software & Computer Services	**12.3**	12.2 (9)	11.5 (77)	-8.3 (3)	38.3 (7)
Pharma & Biotechnology	**9.8**	13.2 (28)	13.0 (46)	2.3 (8)	27.5 (1)
Technology Hardware & Equip.	**7.6**	0.0 (14)	5.1 (57)	4.7 (6)	35.0 (13)
Automobile & Parts	**6.7**	9.2 (46)	-0.6 (15)	5.5 (27)	14.2 (4)
Electronic & Electrical Equipment	**5.5**	9.6 (19)	3.1 (13)	3.7 (25)	23.7 (6)
Health Care Equip. & Services	**5.0**	20.7 (32)	-3.1 (55)	10.9 (9)	14.1 (2)
General Industrials	**3.7**	10.6 (19)	0.5 (39)	0.6 (30)	14.7 (7)
Industrial Engineering	**3.3**	-1.7 (32)	-1,4 (26)	9.6 (14)	24.8 (16)
Leisure Goods	**2.9**	7.5 (1)	13.0 (10)	0.2 (61)	15.8 (3)
Chemicals	**2.3**	6.7 (23)	-3.8 (31)	5.0 (30)	28.0 (2)
Aerospace & Defence	**1.2**	-0.8 (46)	2.8 (39)	2.0 (0)	44.7 (1)
TOP 11 INDUSTRIES	**7.3**	**8.2 (25)**	**7.0 (41)**	**3.7 (15)**	**28.6 (6)**
Other Industries	**1.8**	4.6 (39)	-6.8 (22)	-0.1 (11)	15.4 (15)
ALL INDUSTRIES	**6.6**	**7.5 (27)**	**5.9 (39)**	**3.3 (14)**	**24.7 (7)**

TABLE S.3 – RANKING OF TOP 11 INDUSTRIAL SECTORS BY ONE-YEAR R&D GROWTH IN THE 2016 SCOREBOARD.
Note: The numbers in brackets indicate the relative R&D size of the sector (% of world sector R&D)
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

R&D growth of EU companies is driven by the automobile and high-tech sectors - mostly by German companies – while growth of net sales is held back by low-tech sectors

Within the EU, most of the top R&D investing sectors showed high R&D growth (excepting IT hardware). The highest contribution to R&D growth was shown by Automobiles & Parts (9.2%), driven by Daimler (15.6%) and BMW (13.2%). Pharmaceuticals & Biotechnology was the second highest R&D growth contributor (13.2%) with big pharma companies showing very high R&D growth (excepting GlaxoSmithKline, -0.5%), e.g. Allergan (146.6% due to acquisition), Bayer (20.2%), Boehringer (13.2%), AstraZeneca (12.3%) and Sanofi (9.0%). Other EU sectors showing double-digit R&D growth are Health Care Equipment & Services (20.7% with a large acquisition component), Software & Computer Services (12.2%) and General Industrials (10.6%).

By member state, the companies based in Germany, accounting respectively for 37.6% and 30.0% of the EU's total R&D and net sales, made the largest contribution to the performance of the EU group. The German companies increased R&D by 10.6% and net sales by 8.7%. The other two largest member states of the EU showed a mixed performance. Companies based in the UK increased R&D by 4.1% but reduced sales significantly (-22%), mostly due to the fall in world prices for Oil and Mining companies. Companies based in France increased modestly R&D (2.0%) and reduced net sales (-3.4%) (see Table S.4). R&D of companies based in Ireland (29.5%), made also an important contribution to the EU group, though most of the R&D increase comes from a few American health-related companies with registered offices in Ireland.

Factor	Germany	UK	France	The Netherlands
No. of companies	132	133	83	38
R&D in 2015-2016, €bn	69.8	27.1	28.5	14.1
World R&D share, %	10.0	4.1	4.1	2.0
One year change, %	10.6	4.1	2.0	4.1
Net Sales, €bn	1 714.1	1 069.3	1 015.9	368.5
One year change, %	8.7	-22.0	-3.4	1.1
R&D intensity, %	3.9	2.5	2.8	3.8

TABLE S.4 - PERFORMANCE OF COMPANIES BASED IN THE LARGEST R&D COUNTRIES OF THE EU.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

R&D growth of non-EU companies is dominated by high-tech sectors – mostly by US and Chinese companies – while growth of net sales greatly varied across sectors and countries

The US companies showed a significant increase in R&D in high-tech sectors such as Pharma (13.0%) and Software (11.5%) but presented poor results in terms of net sales (-0.2% in Auto, 1.6% in Software and 4.1% in Pharma).

Japanese companies underperformed EU and US firms in terms of R&D growth (3.3%) but showed better results in terms of net sales growth (0.2%). The performance of Japanese companies is led by the Auto sector that showed an increase of 5.5% in R&D and 6.5% in net sales in 2015.

In the Chinese group of companies, outstanding performance was shown by ICT-related companies Huawei, ZTE and Baidu that grew R&D by more than 30% and also net sales by more than 20%. (see Table S.3).

The EU-US R&D intensity gap has increased over the past 10 years, mostly due to the outperformance of ICT industries in the US

In 2015/16, the US invested almost twice as much of its *Scoreboard* R&D in high tech sectors compared to the EU (75% vs 40%) whereas the EU had more than twice of its *Scoreboard* R&D in medium-high tech sectors (45% vs 20%). This difference in specialisation explains the overall EU-US R&D intensity gap that has widened over the years, especially due to the high R&D growth of US companies in the ICT sector and particularly in Software-related industries. As shown in figure S.4 (page 18), the US software sector has almost doubled its proportion of US R&D from 2006 to 2016. On the other hand, the automotive proportion of total R&D in the US has shrunk while it has increased in the EU.

A statistical analysis on the dynamics of companies' R&D over the last 12 years shows characteristic patterns and persistence of the R&D growth process

Scoreboard companies have heterogeneous growth paths of R&D, even when comparing companies in the same sector. Most firms have a positive but modest growth rate of R&D investment from one year to the next. However, in each year a handful of firms experience rapid growth or decline of R&D. Focusing on large firms that experienced high R&D performance shows that rapid R&D growth is observed across all industries.

Companies' R&D growth reacted to the financial crisis in different ways -some companies even appear to be quite unaffected. Moderate persistence in R&D dynamics means that companies that grew (declined) in one year are likely to continue to grow (decline) in the next.

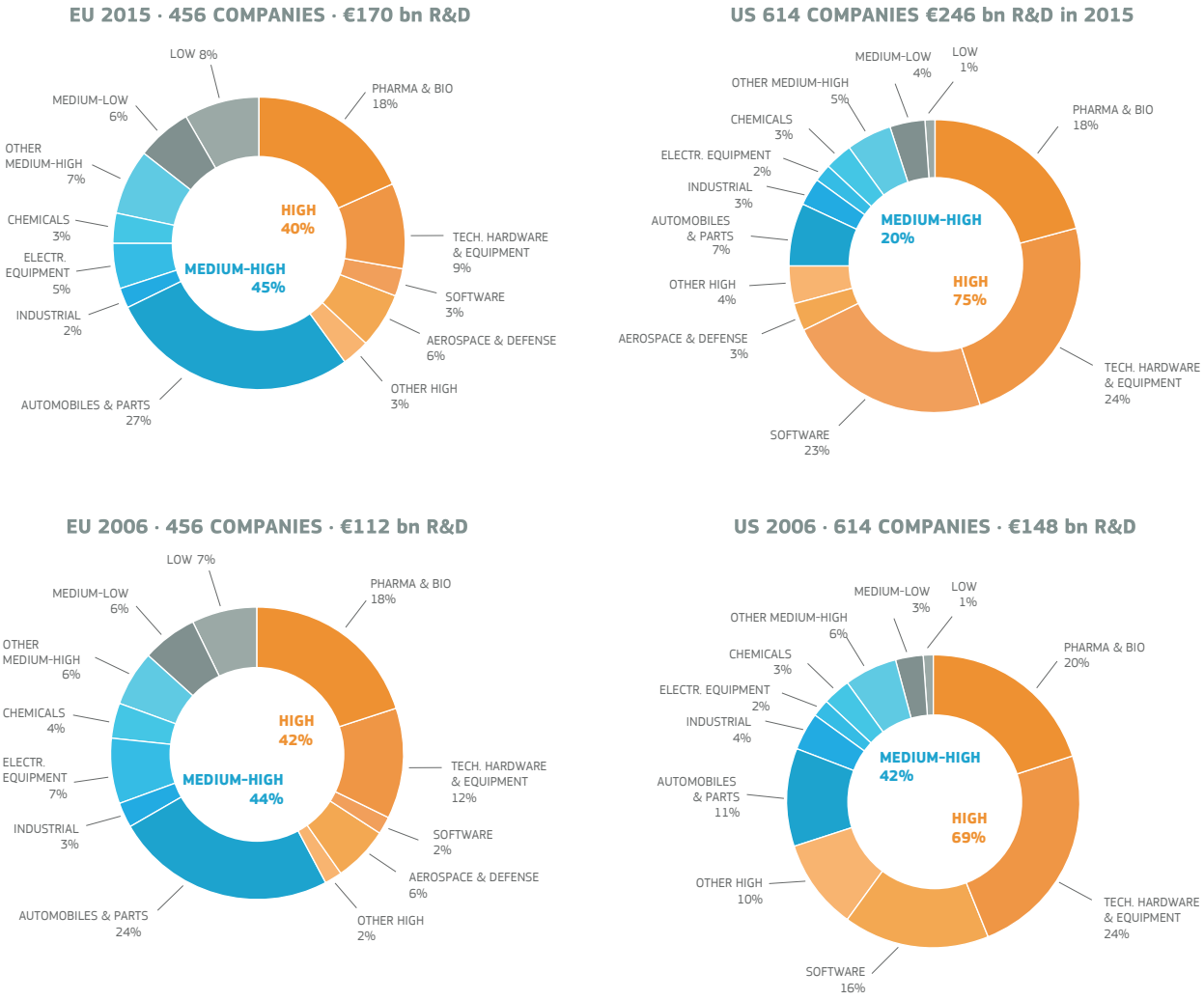

FIGURE S.4 – RELATIVE SECTOR SPECIALISATION OF THE EU VS THE US IN THE 2006 AND 2016 *SCOREBOARDS*.

Note: For the 456 EU and 614 US companies with data available for all the ten years.

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

- ***An analysis combining R&D and patent data on the parent companies and their subsidiaries improves our understanding of the scale and dynamics of industrial R&D flows across territorial borders***

On average, companies headquartered in the EU allocate about 1/4 of their R&D investments outside the EU. The inward R&D from foreign affiliates operating in the EU is slightly lower than the outward R&D by EU companies. The EU-US R&D flows are the largest interregional R&D flows and Switzerland is the second most important source of EU inward R&D. Among EU Member States, the UK shows the highest outward R&D.

The analysis by sector shows that *Health Industries* have the highest volumes of inward and outward R&D flows, while in *Aerospace and Defence and Automobiles* R&D is mostly performed at home. The EU has a small negative R&D balance in the *Automobiles* sector, however representing less than 3% of that sector's R&D investment performed at home (see Table S.5).

SECTOR	EU R&D FLOWS (€M)			EU R&D BALANCE (€M)
	HOME	OUTWARD (O)	INWARD (I)	(I-O)
Aerospace & Defence	7 616	1 514	1 661	146
Automobiles	33 071	5 135	4 217	-918
Chemical	3 630	1 136	1 541	405
Health Industries	19 614	10 036	13 507	3 471
ICT Producers	16 587	7 127	7 439	312
ICT Services	7 266	2 007	2 914	908
Industrials	9 984	3 956	3 959	3
Other Sectors	14 272	8 744	4 194	-4 551
Total	**112 040**	**39 656**	**39 432**	**-224**

TABLE S.5 – ESTIMATED INWARD AND OUTWARD R&D FLOWS FOR MAIN EU INDUSTRIES.
Note: Data for the period 2011-2013 from the Scoreboard and PATSTAT 2016 spring version.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

- ***An analysis of Scoreboard companies' mergers and acquisitions (M&A) activity over the period 2003-2012 shows that the fear that M&A activity transfers EU domestic competencies into foreign hands is excessive***

Results from this analysis show that the majority of M&A deals involve US and EU based companies. While it is true that US companies are the most active acquirers of European firms (particularly from the UK), the same holds for EU companies. However, it is true that different M&A strategies may explain discrepancies in firm performance. In particular, US companies tend to focus their M&A strategy on the acquisition of younger firms, which generally show higher level of productivity and R&D growth. This is a strategy also followed in the case of EU based acquiring firms, though to a lesser extent than observed for US ones. Overall, these results confirm that M&A is an important way for top R&D investors to quickly acquire technology capabilities and new product lines to expand their knowledge base and product range.

Introduction

The 2016 edition of the "EU Industrial R&D Investment Scoreboard" (the *Scoreboard*)[2] comprises the **2500 companies investing the largest sums in R&D in the world** (€21m or more in each case) and an additional number of companies to cover the **top 1000 R&D investing companies based in the EU**[3] (R&D of €6m or more). In total, there are 2909 companies incorporated in the 2016 Scoreboard.

In order to avoid double counting, The *Scoreboard* considers only data from parent or independent companies. Normally, these companies integrate into their consolidated accounts the data of all their subsidiary companies. An analysis of the ownership structure of the parent companies included in the 2015 *Scoreboard* shows that they have about 700.000 subsidiary companies (controlled companies with more than 50% ownership).

Companies' R&D rankings are based on information taken from the companies' latest published accounts. For most companies these correspond to calendar year 2015, but significant proportions have financial years ending on 31 March 2016 (Japanese companies in particular). There are few companies included with financial years ending as late as end June 2016 and a few, usually private, for which only accounts to end 2014 were available.

The 2016 *Scoreboard* includes companies based in 45 countries of which 19 are member states of the EU. A wide range of manufacturing and services sectors is represented, including more than 50 industries with a special focus on the most innovative ones such as ICT, health, transport and engineering related industries. It should be noted that the *Scoreboard* relies on disclosure of R&D investment in companies' published annual reports and accounts and that due to different national accounting and disclosure practices, companies of some countries are less likely than others to disclose R&D investment consistently. For these reasons, companies from some countries such as those in Southern or Eastern Europe might be under-represented while others such as companies from the UK could be over-represented.

The overall coverage in terms of R&D is similar to previous editions. The total amount of R&D investment of companies included in the *Scoreboard* (€696 billion) is equivalent to more than 90% of the total expenditure on R&D financed and performed by the business sector worldwide[4] .

The *Scoreboard* collects key information to enable the assessment of the R&D and economic performance of companies. The main indicators, namely R&D investment, net sales, capital expenditures, operating profits and number of employees are collected following the same methodology, definitions and assumptions applied in previous editions. This ensures comparability so that the companies' economic and financial data can be analysed over a longer period of time.

The capacity of data collection is being improved by gathering information about the ownership structure of the *Scoreboard* parent companies and the main indicators for their subsidiaries. In 2016, we have collected available indicators reported by about 700.000 subsidiary companies involved in this *Scoreboard* edition. This allows a better characterisation of companies, in particular regarding the sectoral and geographic distribution of their research and production activities and the related patterns of growth and employment.

As shown in last year's *Scoreboard*, the analysis of key indicators such as patent data of parent companies and their subsidiaries allows the reassignment of companies to countries where they perform the majority of their actual economic or innovation activity.

In this edition we continue to improve the characterisation of the location of companies' innovation activity. The internationalisation of R&D is analysed by examining the patent activity and the location of the subsidiaries of the *Scoreboard* companies.

The data have been collected by Bureau van Dijk Electronic Publishing GmbH, following thwe same approach and methodology applied since the first *Scoreboard* edition in 2004. For background information please see Annex 1.

[2] The EU Industrial R&D Investment Scoreboard is published annually by the European Commission (JRC-IPTS/DG RTD) as part of its Industrial Research and Innovation Monitoring and Analysis activity (IRIMA).

[3] In this report, the term EU company refers to companies whose ultimate parent has its registered office in a Member State of the EU. Likewise, non-EU company applies when the ultimate parent company is located outside the EU (see also the glossary and definitions in Annex 2 as well as the handling of parent companies and subsidiaries).

[4] According to the latest figures reported by Eurostat, i.e. BERD financed by the business enterprise sector in 2014 compared with R&D figures in the 2015 Scoreboard (see Figure I.1 below).

Description of the company dataset

This edition of the *Scoreboard* contains data on the world's top 2500 companies ranked by their investments in R&D. These companies each invested more than €21 million in 2015/16, accounting together for total R&D of €696.0 billion.

The amount of R&D investment by these 2500 companies is equivalent to more than 55% of the total expenditure on R&D worldwide (GERD) and about 90% of the R&D expenditure financed by the business sector worldwide (BERD). This is illustrated in figure I.1 where the latest 2014 territorial statistics are compared with the corresponding figures of the 2015 *Scoreboard* (*Scoreboard* €607.2bn; GERD €1086.9bn; BERD €679.7bn).

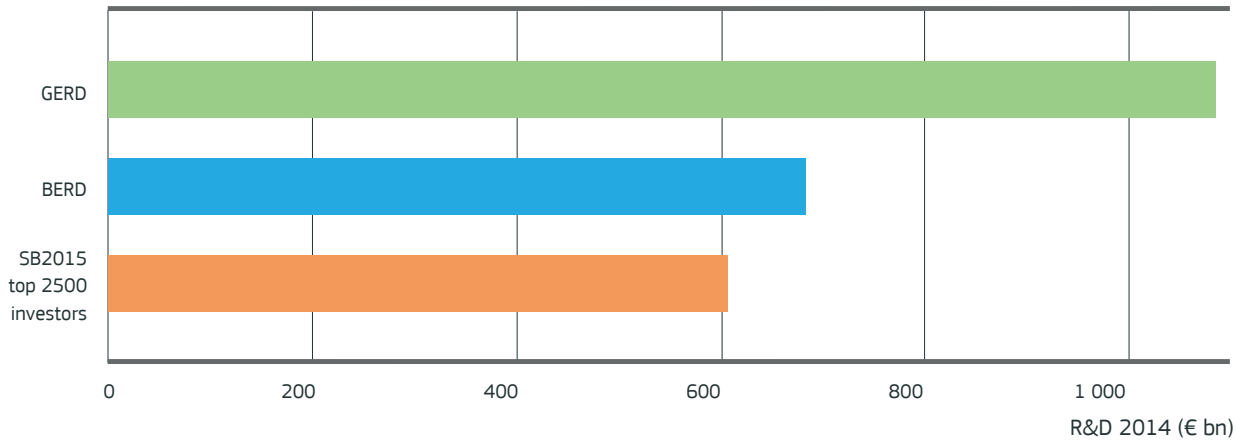

FIGURE I.1 – COMPARISON OF R&D FIGURES OF THE SCOREBOARD AND TERRITORIAL STATISTICS.
Note: Total R&D expenditure (GERD) and total business R&D expenditure (BERD) funded by the business sector in 2014.
Sources: Adapted from latest figures reported by Eurostat on 30 November 2016, including most countries reporting R&D. The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The dataset is complemented with additional companies in order to cover the top 1000 R&D investing companies based in the EU, all of them having invested more than R&D €6 million in 2015/16. This additional sample is analysed separately in chapter 4.

The main methodological limitations are summarised in Box I.1 (see further description of the dataset in Annex 2).

Companies' distribution by country and industry

The 2016 *Scoreboard* comprises 2500 companies with headquarters in 45 countries of which 19 are member states of the EU. The sample includes companies based in the EU (590), the US (837), Japan (356), China (327), Taiwan (111), South Korea (75), Switzerland (58), Canada (32), India (25) and a further 18 countries. See Table I.1 and Figure I.4. A wide range of manufacturing and services sectors is represented in the *Scoreboard*, including more than 50 industries with a special focus on the most innovative ones such as the ICT, health, transport and engineering related industries. See the number of EU and non-EU companies by country in Table I.1, by sector in Table I.2 and the top 3 companies by level of R&D investment for the main industrial sectors in Table I.3.

NUMBER OF COMPANIES BY COUNTRY			
EU		NON-EU	
UK	133	US	837
Germany	132	Japan	356
France	83	China	327
Sweden	40	Taiwan	111
The Netherlands	38	South Korea	75
Denmark	29	Switzerland	58
Italy	29	Canada	32
Ireland	21	India	25
Finland	19	Israel	20
Spain	17	Australia	14
Austria	15	Norway	12
Belgium	14	Brazil	9
Luxembourg	9	Singapore	7
Portugal	4	Turkey	6
Greece	3	Malaysia	4
Slovenia	1	New Zealand	3
Czech Republic	1	Russia	3
Hungary	1	Mexico	2
Malta	1	Further 8 Countries	9
TOTAL	**590**	**TOTAL**	**1910**

TABLE I.1 – DISTRIBUTION OF COMPANIES BY COUNTRY.
Note: 2500 companies with R&D investment above €21.1 million.
Source: The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

NUMBER OF COMPANIES IN THE 10 MOST NUMEROUS INDUSTRIES			
EU		NON-EU	
Pharmaceuticals & Biotechnology	78	Pharmaceuticals & Biotechnology	291
Industrial Engineering	69	Technology Hardware & Equipment	268
Software & Computer Services	47	Software & Computer Services	231
Electronic & Electrical Equipment	42	Electronic & Electrical Equipment	186
Automobiles & Parts	35	Industrial Engineering	130
Technology Hardware & Equipment	30	Automobiles & Parts	121
Banks	28	Chemicals	104
Chemicals	22	Health Care Equipment & Services	76
Health Care Equipment & Services	22	General industrials	69
Aerospace & Defence	19	Construction & Materials	50

TABLE I.2 – DISTRIBUTION OF COMPANIES BY INDUSTRIAL SECTOR.
Source: The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

PHARMACEUTICALS & BIOTECH.		AUTOMOBILES & PARTS		TECHNOLOGY HARDWARE & EQUIP.	
NOVARTIS	Switzerland	VOLKSWAGEN	Germany	INTEL	US
ROCHE	Switzerland	TOYOTA MOTOR	Japan	HUAWEI	China
JOHNSON & JOHNSON	US	GENERAL MOTORS	US	APPLE	US
SOFTWARE & COMPUTER SERVICES		**ELECTRONIC & ELECTRICAL EQUIPMENT**		**INDUSTRIAL ENGINEERING**	
ALPHABET	US	SAMSUNG	South Korea	CATER PILLAR	US
MICROSOFT	US	SIEMENS	Germany	VOLVO	Sweden
ORACLE	US	HITACHI	Japan	CRRC CHINA	China
CHEMICALS		**AEROSPACE & DEFENCE**		**GENERAL INDUSTRIALS**	
BASF	Germany	AIRBUS	The Netherlands	GENERAL ELECTRIC	US
DUPONT	US	BOEING	US	TOSHIBA	Japan
DOW CHEMICAL	US	UNITED TECHNOLOGIES	US	PHILIPS	The Netherlands
LEISURE GOODS		**HEALTH CARE EQUIPMENT & SERVICES**		**BANKS**	
SONY	Japan	MEDTRONIC	Ireland	BANCO SANTANDER	Spain
PANASONIC	Japan	BOSTON SCIENTIFIC	US	BARCLAYS	UK
LG ELECTRONICS	South Korea	THERMO FISHER SCIENTIFIC	US	DEUTSCHE BANK	Germany

TABLE I.3 – TOP 3 COMPANIES BY R&D FOR THE MAIN INDUSTRIES INCLUDED IN THE 2016 SCOREBOARD.
Source: The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Concentration of R&D investment by company, sector and country

Industrial R&D is highly concentrated. A small subset of companies, industries and countries accounts for a large share of the total R&D investment of the whole sample of 2500. For example, the top 100 companies account for 53.1% of the R&D, the companies based in the three largest countries (US, Japan and Germany) account for 63.2% and the four largest industries (Pharmaceuticals & Biotechnology, Automobiles & Parts, Technology Hardware & Equipment, Software & Computer Services) account for 61.7% of the total R&D investment. This is illustrated in Figures I.2 and I.3.

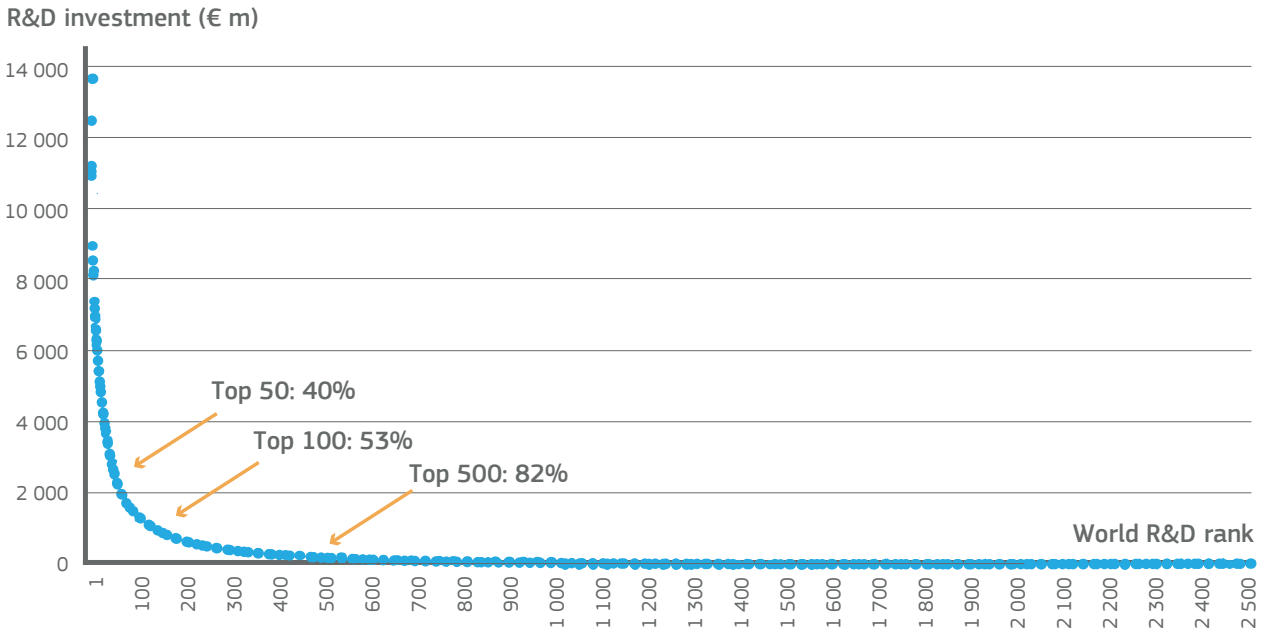

FIGURE I.2 - COMPANIES OF THE 2016 SCOREBOARD RANKED BY R&D.
Source: The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

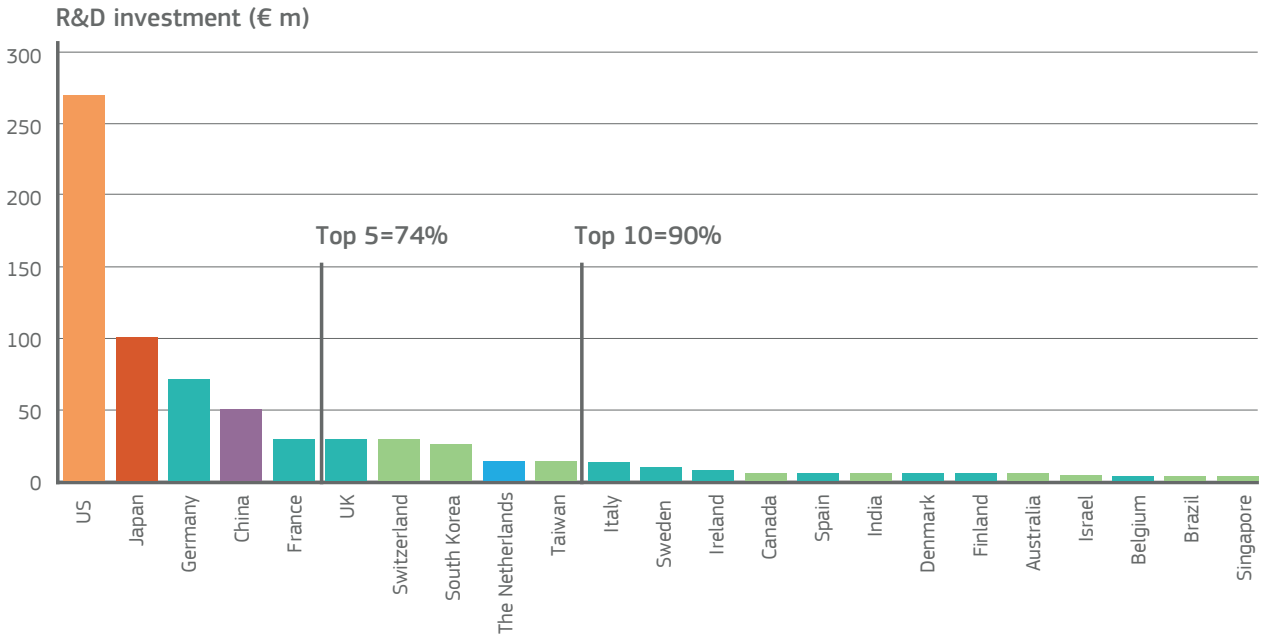

FIGURE I.3 - R&D INVESTMENT OF THE 2015 SCOREBOARD AGGREGATED BY COUNTRY.
Source: The 2015 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

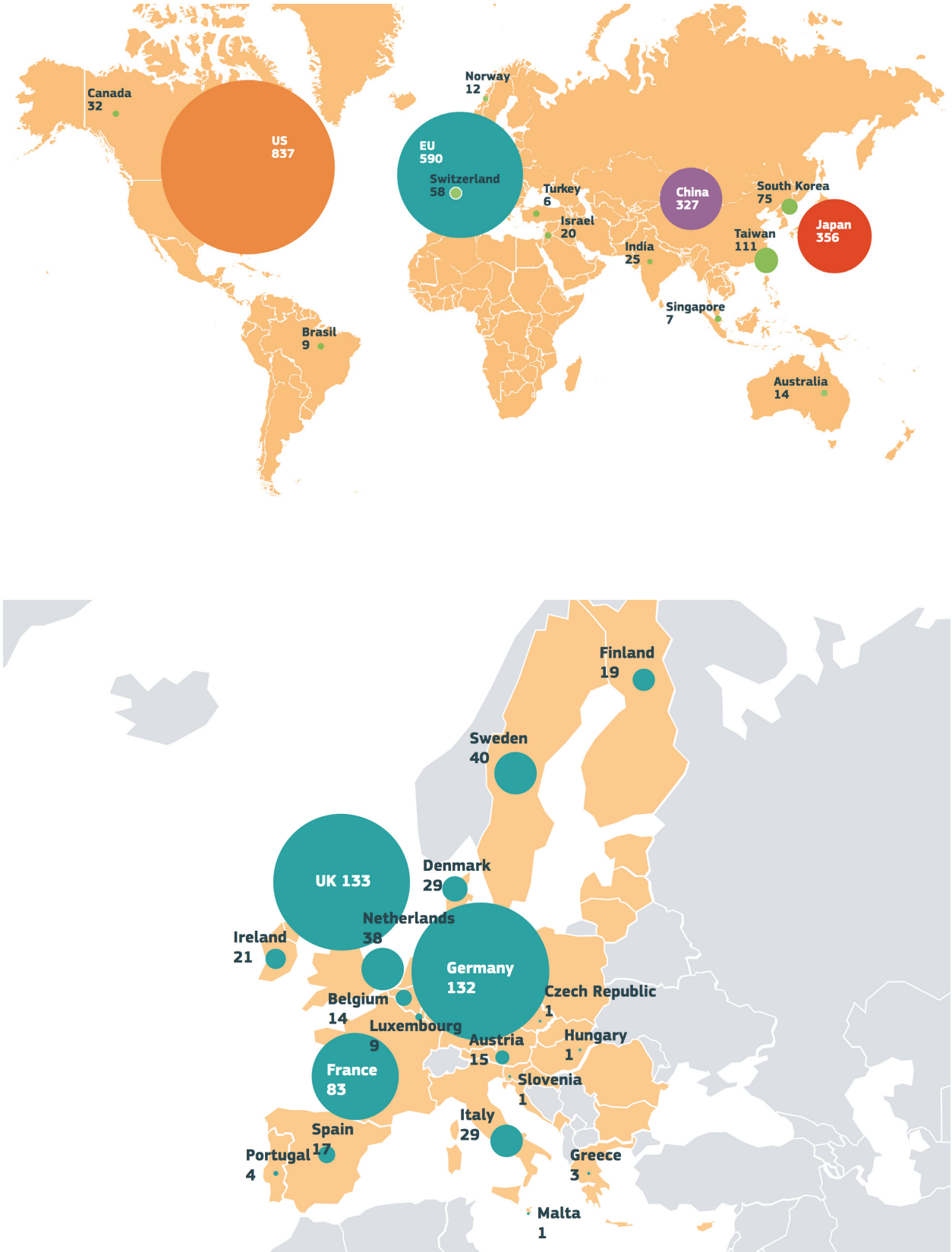

FIGURE I.4 - DISTRIBUTION OF THE 2500 COMPANIES IN THE 2016 SCOREBOARD BY HEADQUARTERS COUNTRY.

Note 1: Number of companies indicated besides the country code (includes only countries with at least one company).

Note 2: R&D for countries with more than 10 companies is represented with a bubble whose size is proportional to R&D in 2015/16

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Box I.1 –
Methodological caveats

Users of *Scoreboard* data should take into account the methodological limitations summarised here, especially when performing comparative analyses (a full description of the methodology is found in Annex 2):

A typical problem arises when comparing data from different currency areas. The *Scoreboard* data are nominal and expressed in Euros with all foreign currencies converted at the exchange rate of the year-end closing date (31.12.2015). The variation in the exchange rates from the previous year directly affects the ranking of companies, favouring those based in countries whose currency has appreciated with respect to the other currencies. In this reporting period, the exchange rate of the Euro depreciated by 10 % against the US dollar and the Japanese Yen, and by 5.8 % against the pound sterling.

The growth rate of the different indicators for companies operating in markets with different currencies is affected in a different manner. In fact, companies' consolidated accounts have to include the benefits and/or losses due to the appreciation and/or depreciation of their investments abroad. The result is an 'apparent' rate of growth of the given indicator that understates or overstates the actual rate of change. For example, this year the R&D growth rate of companies based in the Euro area with R&D investments in the US is partly overstated because the 'benefits' of their overseas investments due to the depreciation of the Euro against the US dollar (from $1.21 to $1.09). Conversely, the R&D growth rate of US companies is partly understated due to the 'losses' of their investments in the Euro area. Similar effects of understating or overstating figures would happen for other indicators, e.g. for net sales.

When analysing data aggregated by country or sector, be aware that in many cases, the aggregate indicator depends on the figures of just a few firms. This is due, either to the country's or sector's small number of firms in the *Scoreboard* or to the indicator dominated by a very few large firms.

The different editions of the *Scoreboard* are not directly comparable because of the year-on-year change in the composition of the sample of companies, i.e. due to newcomers and leavers. Every *Scoreboard* comprises data of several financial years allowing analysis of trends for the same sample of companies.

In most cases companies' accounts do not include information on the place where R&D is actually performed; consequently the approach taken in the *Scoreboard* is to attribute each company's total R&D investment to the country in which the company has its registered office or shows its main economic activity. This should be borne in mind when interpreting the *Scoreboard*'s country classification and analyses.

Growth in R&D can either be organic, the outcome of acquisitions or a combination of the two. Consequently, mergers and acquisitions may sometimes underlie sudden changes in specific companies' R&D or sales growth rates and/or positions in the rankings.

Other important factors to take into account include the difference in the various countries' (or sectors') business cycles which may have a significant impact on companies' investment decisions, and the initial adoption or stricter application of the International Financial Reporting Standards (IFRS)[5].

[5] Since 2005, the European Union requires all listed companies in the EU to prepare their consolidated financial statements according to IFRS (see: EC Regulation No 1606/2002 of the European Parliament and of the Council of 19 July 2002 on the application of international accounting standards at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32002R1606:EN:HTML).

Report structure

1

Chapter 1 presents the worldwide trends of industrial R&D. It provides an overview of the main indicators for the top 2500 companies ranked by level of R&D investment and the main changes that took place over the last year. An analysis of the main indicators of the company data aggregated by world regions is included together with the performance of companies over the past 10 years.

2

The performance of individual companies among the top R&D investors is provided in **Chapter 2**. The list of the top 50 and top 100 R&D companies is examined highlighting those companies showing remarkable R&D and economic results and improvement in their R&D ranking over the last 12 years. It also includes an analysis of the ranking of large companies by R&D intensity.

3

Chapter 3 presents an analysis of the main R&D and economic indicators of companies aggregated by industrial sector, including comparisons of EU companies with their main worldwide counterparts.

4

Chapter 4 discusses the trends on R&D and economic performance of the companies included in the extended sample comprising the top 1000 R&D investors based in the EU, focussing on the largest R&D countries of the EU accounting for more than 97% of the total R&D of the sample of 1000 companies based in the EU.

5

Chapter 5 examines the dynamics of R&D of the Scoreboard companies over the last 12 years. The objective is to investigate the patterns and persistence of the R&D growth process.

6

An analysis combining R&D and patent data on the parent companies and their subsidiaries is presented in **Chapter 6**, aimed at improving the knowledge about the geographic distribution of R&D activities across territorial borders.

7

Finally, **Chapter 7** analyses trends of mergers and acquisitions (M&A) activities involving *Scoreboard* companies over the period 2003-2012. The aim is to assess the effects of transferring companies' ownership and control across countries and industries and to characterise strategies of acquiror companies and the effects of M&A on company performance.

ANNEXES

Annex 1 provides background and methodological information about how the *Scoreboard* is prepared. The methodological approach of the *Scoreboard*, its scope and the limitations are described in **Annex 2**. The sector and country composition of the EU 1000 sample is found in **Annex 3**. The access to the full dataset is shown in **Annex 4.**

The complete data set is freely accessible online at:
http://iri.jrc.ec.europa.eu/scoreboard16.html

1 WORLDWIDE TRENDS IN CORPORATE R&D

1 Worldwide trends in corporate R&D

This chapter provides an overview of the main trends in R&D and economic indicators for the world's top 2500 companies (those that invested more than €21 million in R&D in 2015/16). It includes the analysis of the long-term performance of companies aggregated by main world regions.

The 2500 companies are grouped into four main sets: the top 590 companies based in the EU, 837 companies from the US, 356 companies from Japan, 327 companies based in China and 390 companies from the rest of the world (RoW group, comprising companies based in Taiwan (111), South Korea (75), Switzerland (58), Canada (32) and a further 19 countries).

R&D investments and economic results of companies in 2015 show important variations across countries and industries. Companies in aggregate increased significantly their R&D investments while showing an important decline in revenues. However, the increase of R&D was driven by high-tech industries whereas the decrease of sales was dominated by low-tech sectors, mainly oil- and mining-related industries.

As observed in past years, this reflects continued and persistent market and economic uncertainties in 2015. Box 1.1 below summarises the economic background in 2015 and early 2016 in which global R&D companies have been operating.

To interpret these results, it is important to remember the effects of the exchange rates, especially on rankings and growth rates. In this reporting period, the exchange rate of the Euro depreciated by 10 % against the US dollar and the Japanese Yen, and by 5.8 % against the pound sterling. The main effects of this is that companies based in the Euro area are penalised in terms of R&D rankings; however, in terms of growth rates, their results are overstated due to the revaluation of their foreign R&D and sales (see Box I.1).

Key findings

- The top 2500 *Scoreboard* companies invested in R&D €696.0bn in 2015/16, an increase of 6.6% respect to 2014/15, a similar growth rate to the year before (6.8%). On the contrary, the net sales *declined (-3.6%), compared with an increase of 2.2% in 2014/15. The growth in R&D was driven by companies operating in the largest R&D-investing industries (ICT, health and auto), that also increased significantly net sales, while the overall fall in net sales was mostly due to oil- and mining-related companies.*

- The 590 EU companies increased R&D investment at higher rate than the world average, at 7.5% (*mostly due to Auto and High-tech companies*) while decreasing net sales by 3.6% (*mostly due to oil-related companies*). The 837 US companies reported a significant increase in R&D (5.9%) but also an important decline in net sales (-4.0%). The 356 Japanese companies showed a more modest R&D increase (3.3%) while net sales remained practically unchanged (0.2%). As in the past few years, companies based in China continued to show the best performance in terms of R&D growth (24.7%) but presented also a significant decrease in net sales (-6.2%).

- Outside of the EU, the US, Japan and China (the Rest of the World group comprising 390 companies), the largest increases in R&D investment were reported by companies based in Taiwan (7.1%) and South Korea (3.7%). The net sales of companies from the RoW group decreased in the largest countries (e.g. Switzerland -3.3% and South Korea -1.7%).

- Trends over the past 10 years show a worldwide but hesitant recovery of companies' net sales following the financial crisis. On the contrary, companies' R&D growth has been positive all over the world since 2010. Recovery of R&D growth has been more pronounced for the US and EU companies, the latter showing the best performance in the last year.

Box 1.1 – Economic environment for the *Scoreboard* companies in 2015/16.

From mid-2015 companies and investors were watching the US central bank (the Fed) closely to see when it would start raising interest rates to more normal levels from the near zero they had remained at since the financial crisis. The first rate rise for nearly 10 years eventually came in December 2015 when rates moved from zero to 0.25%. The Fed indicated that it expected the US economy to be strong enough to enable it to make four more rate rises during 2016. The Bank of England was expected to follow the Fed since UK growth was also strong. The US and UK were expected to raise rates first since their World Bank GDP growth rates in 2015 at 2.4% and 2.3% respectively were higher than other major developed economies such as the Eurozone (1.7%) and Japan (0.5%). The growth rate of the second largest economy – China - has also been dropping sharply from 12% in early 2010 to about 6.7% in early 2016 and this has contributed to the lower world growth rate.

However, US/UK rate rises were not what happened in 2016. Up to the end of November 2016, the US had still not raised rates at all during 2016 and the uncertainty ushered in by the Brexit vote in June 2016 led to the Bank of England reducing rates to 0.25% and restarting quantitative easing (QE). The low growth outlook in the Eurozone with high unemployment in many Eurozone countries led to the ECB cutting rates to 0% (with the overnight deposit rate negative) and increasing QE in March 2016. The Bank of Japan found it ever harder to find bonds to purchase in its efforts to fight deflation and implemented a negative interest rate of -0.1% in February 2016. This all meant that the interest rate environment remained low throughout 2015/16 with negative rates in the Eurozone, Denmark, Sweden, Switzerland and Japan in 2016. According to Bloomberg, by June 2016 about $10 trillion of government bonds worldwide (mainly Japan and Europe) offered yields below zero. In summary, despite central bank actions, developed economies have a current combination of low interest rates, low growth and low inflation so concerns remain about how to ensure that deflation is avoided.

Companies have adjusted to this low interest rate environment with recent debt from large multinationals in stable sectors (e.g. Sanofi, Unilever) issued as zero coupon securities and short-term paper sold by General Electric and Johnson & Johnson now trading below zero in the secondary market. Some companies have used the current low interest rates to grow their earnings per share (eps) even though their revenue is growing slowly or not at all. They have done this by increasing borrowings either to make share buybacks (which increase earnings per share though not earnings) or to take on debt to fund large acquisitions (which increase eps by adding to earnings but not to the number of shares). This contrasts with many companies in the *Scoreboard* which invest in R&D for new and improved products to drive increases in revenue, profits and eps. This is particularly true for companies with global positions in growing markets (see Alphabet, Gilead and Facebook in the Scoreboard's top 50 for example).

Another major influence on company performance in 2015/16 has been the continuing low level of oil and commodity prices. The oil price fell below $50 in January 2015 and remained in the $40-50 range up to late 2016 with the exception of excursions to $60 in spring 2015 and to around $30 in early 2016. The prices of commodities such as iron ore have also fallen and remained low as demand from China reduced. These trends have reduced the sales of oil and mining companies and of the wide range of companies supplying these industries and are evident in the Scoreboard sales and profitability figures for companies in these sectors.

1.1 | Indicator changes over the last year

The main economic and financial indicators for the year 2015 for the set of 2500 companies are summarised in Table 1.1.

- Overall R&D investment continued to increase in 2015/16 for the fifth consecutive year. The 2500 *Scoreboard* companies invested €696.0 billion in R&D, 6.6% more than in 2014/15, following an increase of 6.8% in the year before. Seventy per cent of the companies showed positive R&D growth in 2015/16.

- For the fourth consecutive year, the net sales of the 2500 companies underperformed with respect to R&D, decreasing by 3.6%, compared with an increase of 2.2% over the previous period. Operating profits of the companies also decreased significantly compared with the previous year, although a large proportion (79%) of companies made profits, similar to the proportion of companies (80%) that made profits in the previous period.

- Company investments in fixed capital decreased slightly by 0.8%, compared with last year's stagnation. Capital expenditure as a percentage of net sales, at 7.1% remained practically the same as that of the previous year.

- The number of employees of the 2500 companies in the slightly increased (by 1.3%), compared with an increase of 1.5 % in 2014/15.

Factor	Top 100 R&D investors	World 2500
R&D in 2015, € bn	369.4	696.0
One-year change, %	6.9	6.6
CAGR 3yr, %	6.4	6.3
Net Sales, € bn	5 512.1	17 686.8
One-year change, %	2.6	-3.6
CAGR 3yr, %	3.0	0.3
R&D intensity, %	6.7	3.8
Operating profits, € bn	629.4	1 517.7
One-year change, %	4.0	-12.3
Profitability, %	11.8	8.7
Capex, € bn	362.7	1 127.5
One-year change, %	6.3	-0.8
Capex / net sales, %	7.1	7.1
Employees, million	11.8	47.4
One-year change, %	2.5	1.3

TABLE 1.1 – OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2016 *SCOREBOARD*.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

1.2 | R&D trends by world region

This section analyses the overall R&D and economic performance of the *Scoreboard* companies according to the location of their registered offices in the main world regions. The 2500 companies are grouped into four main sets: the top 590 companies from the EU, 837 companies from the US, 356 from Japan, 327 from China and 390 from others contries (RoW). The RoW group includes companies from China (327), Taiwan (111), South Korea (75), Switzerland (58) and companies based in a further 20 countries.

Figure 1.1 (page 35) and table 1.2 (page 36) summarise the companies' indicators aggregated by main world region. Table 1.3 shows the main indicators for countries included in the RoW group and Table 1.4 presents the main indicators for the 4 largest R&D countries of the EU.

Overall trends in the EU

The R&D investment of the top 590 companies based in the EU substantially increased in 2015/16, by 7.5%, compared with 3.2% in 2014/15. On the other hand, the net sales of these EU companies decreased by 3.6%, more than the slight 0.7% decline shown in 2014/15.

The companies based in Germany, accounting respectively for 37.6% and 30.0% of the EU's total R&D and net sales, made the largest contribution to the performance of the EU-590 group. The 132 German companies increased R&D by 10.6% and net sales by 8.7%. These results reflect to a large extent the results in the Automobiles & Parts and also good performance in ICT and health related sectors. The Automobiles & Parts sector, accounting for 53% of R&D and 36% of net sales of the group of German companies increased R&D by 9.6% and net sales by 15.2%, e.g. double digit R&D growth was shown by Daimler, BMW and ZF. German companies showed also good performance in other sectors, namely double-digit R&D and net sales growth in health and ICT-related industries. In particular, outstanding double-digit R&D growth was shown by the largest German Pharmaceutical companies Bayer and Boehringer Sohn. (see further details in Chapter 4 where an extended sample of the top 1000 EU R&D investors is analysed).

The other two largest member states of the EU showed a mixed performance. Companies based in the UK increased R&D by 4.1% but decreased sales significantly by 22% (The UK's sales decrease was mostly due to the decline in Oil and Mining companies, -37% and -26% respectively). Companies based in France increased R&D modestly by 2.0% and decreased net sales by 3.4%.

Companies based in Ireland made an important contribution to the R&D of the EU group increasing R&D by 29.6%, though, most of the R&D increase comes from a few American health-related companies with headquarters in Ireland that made acquisitions during 2015/16.

Other world regions

The group of US companies increased R&D investment by 5.9% and decreased sales by 4.0%. The R&D results of the US companies mainly reflect the good performance of companies from the Pharmaceuticals & Biotechnology (13.3%) and Software & Computer Services (11.5%) and the fall of net sales is mostly due to oil-related sectors but also due to poor sales in sectors such as Industrial Engineering and Automobiles.

Japanese companies underperformed EU and US firms in terms of R&D (up by 3.3%) but showed better results in terms of net sales growth (+0.2%) mainly because there are no sizeable Japanese oil companies. As in the case of German companies, the average performance of Japanese companies is strongly dependent on the results of the Automobiles & Parts sector (accounting for 29.4% and 27.1% of the Japanese R&D and net sales respectively). This sector showed an increase of 5.5% in R&D and 6.5% in net sales in 2015.

Companies based in China reported again the largest increase in R&D investment (up by 24.7%) but also

showing a significant decrease in net sales (-6.2%). In the Chinese group of companies, outstanding performance was shown by ICT-related companies Huawei, ZTE and Baidu that grew R&D by more than 30% and also net sales by more than 20%.

Companies based outside of the EU, US, Japan and China (the RoW group) showed a modest R&D investment growth (2.4%) and a significant decrease in net sales (-4.8%). Companies in the RoW group that showed the largest increase in R&D are those based in Taiwan (up by 7.1%). The companies based in Switzerland, the largest R&D investor in this group showed decreases in R&D and net sales of 1.5% and 3.3% respectively (with Novartis's divestments contributing significantly to this).

Compared with last year's *Scoreboard*, the EU companwies' share of global R&D investment decreased by 1.0 percentage point (from 28.1% to 27.1%), *mostly due to the depreciation of the Euro with respect to the main currencies (see exchange rates applied in Table A3.1 in Annex 2).* The R&D share of Japanese companies remained

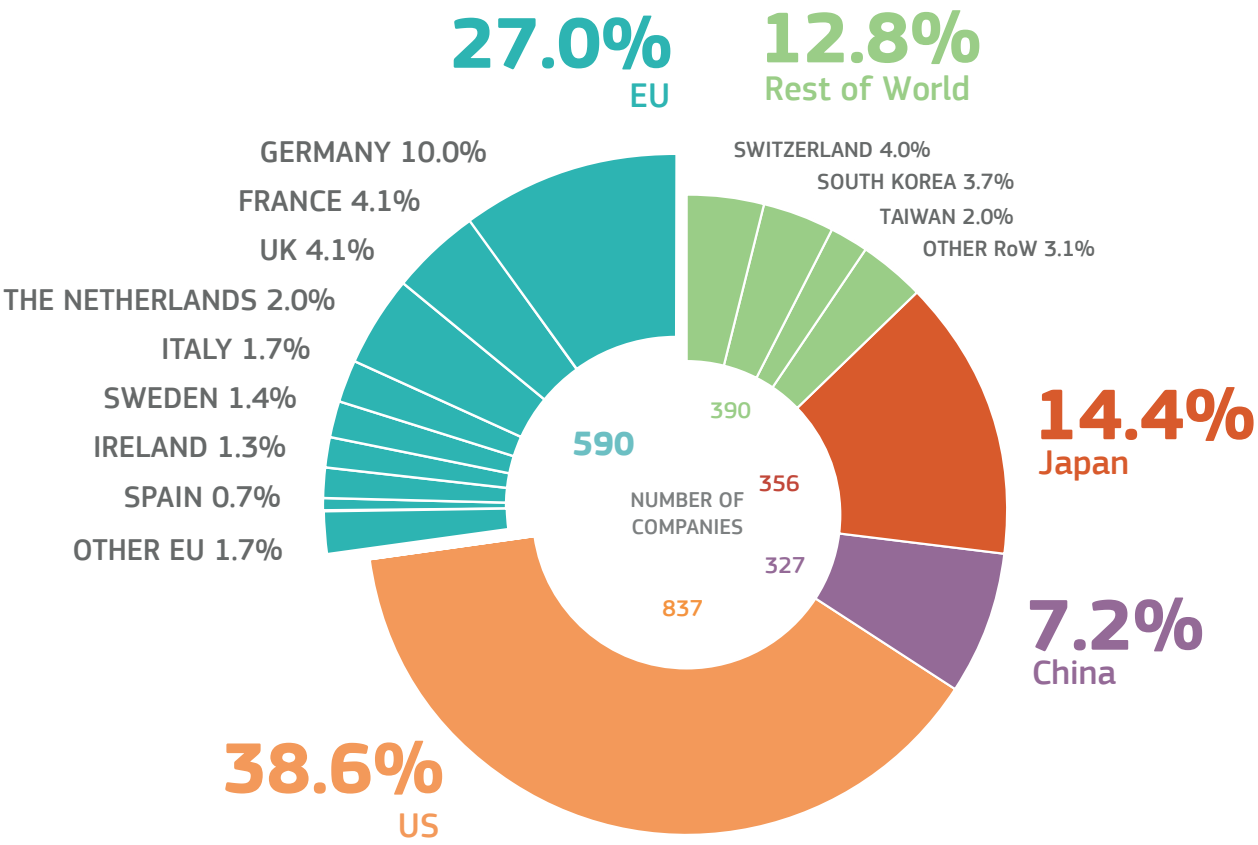

FIGURE 1.1 - R&D INVESTMENT BY THE TOP 2500 COMPANIES, BY MAIN WORLD REGION (% OF TOTAL €696.0BN)
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

practically unchanged and that of the US increased by 0.5 percentage points. The Chinese companies showed the largest increase in R&D share, from 5.9% to 7.2%.

The average R&D intensity of the sets of companies based in the EU, the US and China increased due to the higher growth of R&D investments compared with the growth rate of net sales. For the second consecutive year, the R&D intensity for companies based in Japan remained practically unchanged.

In 2015/16, average company capital expenditure decreased for the third consecutive year for EU companies (-1.2%), US companies (-3.0%) and Chinese companies (-11.1%). Companies based in Japan increased capex significantly by 6.1%.

The average operating profits of companies decreased in 2015/16 for most of the groups of companies (EU -21.2%; US -7.6% and China -15.8%), except for Japan (5.8%).

The profitability (operating profits as percentage of net sales) changed according to the difference between the growth rate of sales and profits. Consequently, the average profitability decreased for EU companies (from 8.3% to 6.8%), US companies (from 13.5% to 12.9%) and Chinese companies (from 6.8% to 6.1%). And for Japanese companies the profitability increased slightly from 6.5% to 6.8%.

The sales/employee figure for the EU at €328k is significantly lower than that for the US (€400k) or Japan (€386k). This is somewhat surprising given the number of oil and mining companies included in the EU set of companies but reflects differences in sector mix between world regions combined with exchange rate effects. In particular, EU sales per employee are lowered vs. the US by the EU's much smaller set of high R&D intensity companies but raised by the EU's much larger number of low R&D intensity companies such as oil companies that have high sales per employee.

As underlined in previous *Scoreboard* reports, most of the differences in R&D intensity and profitability between regions and countries are related to differences in sector mix. The US is by far the strongest region in the group of high R&D intensity sectors including pharmaceuticals, health, software, and technology hardware whereas the EU and Japan are stronger in medium R&D intensity sectors such as the automotive and industrial engineering sectors (see chapter 3).

Factor	EU	USA	JAPAN	CHINA	RoW
No. of companies	590	837	356	327	390
R&D in 2015/2016, € bn	188.3	268.6	99.9	49.8	89.4
World R&D share, %	27.0	38.6	14.4	7.2	12.8
One year change, %	7.5	5.9	3.3	24.7	2.4
CAGR 3yr, %	4.5	6.5	3.9	20.5	6.4
Net Sales, € bn	5 678.4	4 518.8	2 859.6	1 978.9	2 651.2
One year change, %	-3.6	-4.0	0.3	-6.2	-4.8
CAGR 3yr, %	-2.5	-0.1	5.8	3.1	-0.1
R&D intensity, %	3.2	5.8	3.3	2.5	3.3
Operating Profit, € bn	376.5	581.5	183.0	120.4	256.2
One year change, %	-21.2	-7.6	5.8	-15.8	-16.5
Profitability (1)	6.8	12.9	6.8	6.1	9.7
Capex, € bn	317.2	293.8	169.3	124.2	223.1
One year change, %	-1.2	-3.0	6.1	-11.1	4.5
Capex intensity, %	6.8	6.6	6.4	6.7	9.7
Employees, million	17.3	11.3	7.4	7.5	3.9
One year change, %	1.0	1.0	1.0	2.9	0.7

TABLE 1.2 - OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2016 *SCOREBOARD*.

Note : The RoW group comprises companies based in Taiwan, South Korea, Switzerland, Canada and a further 19 countries.

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	Switzerland	South Korea	Taiwan	Canada
No. of companies	58	75	111	32
R&D in 2015/2016, € bn	28.0	25.4	14.0	4.7
World R&D share, %	4.0	3.7	2.0	0.7
One year change, %	-1.5	3.7	7.1	-2.3
CAGR 3yr, %	2.5	10.4	8.8	-1.0
Net Sales, € bn	377.6	822.5	511.9	115.1
One year change, %	-3.3	-1.7	-0.3	1.7
CAGR 3yr, %	-0.2	0.8	1.7	4.7
R&D intensity, %	7.4	3.1	2.7	4.1
Operating Profit, € bn	54.4	62.2	35.0	19.1
One year change, %	-10.1	18.7	5.4	-16.9
Profitability, %	14.4	7.6	6.8	16.6
Employees, million	1.3	N.A	0.6	0.2
One year change, %	1.2		-2.5	17.2

TABLE 1.3 - PERFORMANCE OF COMPANIES BASED IN THE LARGEST COUNTRIES OF THE ROW GROUP.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	Germany	UK	France	The Netherlands
No. of companies	132	133	83	38
R&D in 2015/2016, € bn	69.8	28.2	28.5	14.1
World R&D share, %	10.0	4.1	4.1	2.0
One year change, %	10.6	4.1	2.0	4.1
CAGR 3yr, %	7.5	3.1	0.0	0.7
Net Sales, € bn	1 714.1	1 069.3	1 015.9	368.5
One year change, %	8.7	-22.0	-3.4	1.1
CAGR 3yr, %	2.8	-10.0	-3.0	-0.7
R&D intensity, %	3.9	2.5	2.8	3.8
Operating Profit, € bn	85.2	80.5	63.0	38.4
One year change, %	-21.7	-36.8	-20.5	11.4
Profitability, %	5.2	7.6	6.5	10.4
Employees, million	5.6	2.8	3.0	1.2
One year change, %	4.4	0.4	-1.4	1.5

TABLE 1.4 - PERFORMANCE OF COMPANIES BASED IN THE LARGEST R&D COUNTRIES OF THE EU.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

1.2.1 | Long-term performance of companies by world region

The annual growth rates of R&D investment and net sales and the profitability of companies based in the EU, the US and Japan is provided respectively in figures 1.2, 1.3 and 1.4 for the period 2006-2015. These figures are based on our history database comprising R&D and economic indicators over the 10 years period 2006-2015[6] period (EU 377, US 544 and Japan 311).

The trends observed in these figures show the behaviour of these companies including the effects of the crisis that began in 2008. The following points are observed:

- Companies based in the EU reversed the negative trends of the last three years, showing a modest recovery of R&D investment but the losses in net sales observed in the previous period increased further (driven by low oil and commodity prices). The profitability of the EU companies decreased over the last year and remained substantially lower than that of the US companies.
- The US companies continued to show significant R&D investment growth, similar to the level prior to the crisis and show a further fall in in net sales growth, but well below the level of R&D growth. The US-based companies continued to show a very high level of profitability characteristic of the well-represented R&D-intensive sectors that has been stable since recovery from the crisis in 2010. The profitability of the US companies is higher than their EU counterparts and especially higher than the Japanese ones.
- Japanese companies, hit hard by the crisis in 2008-2009 and by the earthquake and tsunami in 2011, continued the recovery, in R&D with positive growth in net sales, observed in the past period but at a more moderate pace. The profitability of Japanese companies also continued to recover in 2015/16 but remained at relatively low levels comparable to the EU but well below that of the US companies.

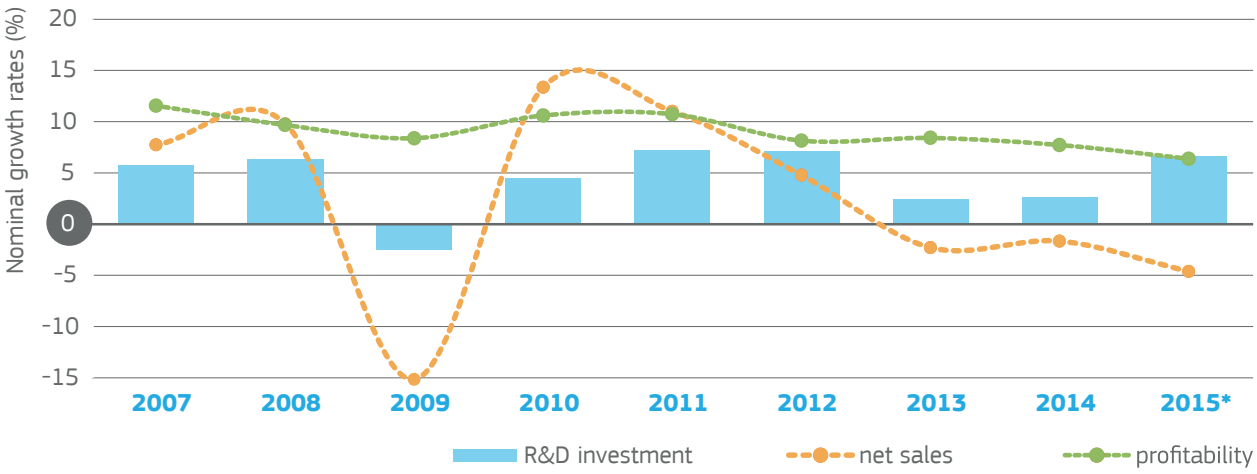

FIGURE 1.2 - ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE EU COMPANIES.
Note: * Figures for 2015 for the whole sample of 590 EU companies were 7.5% for R&D, -3.6 for net sales and 6.6% profitability.
The figure is for 377 out of the 2500 companies for which R&D and net sales are available for the full 10 years period.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[6] The profitability in Figures 1.1, 1.2 and 1.3 refer to the ratio of operating profits over net sales.

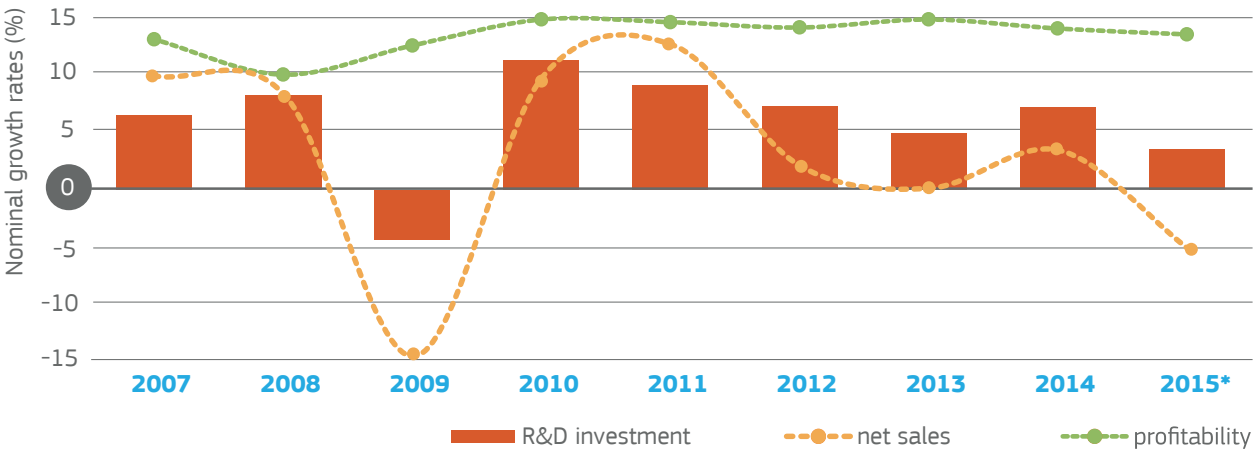

FIGURE 1.3 – ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE US COMPANIES.
Note: * Figures for 2015 for the whole sample of 837 US companies were 5.9% for R&D, -4.0 for net sales and -7.6% profitability.
The figure is for 544 out of the 2500 companies for which R&D and net sales are available for the full 10 years period.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

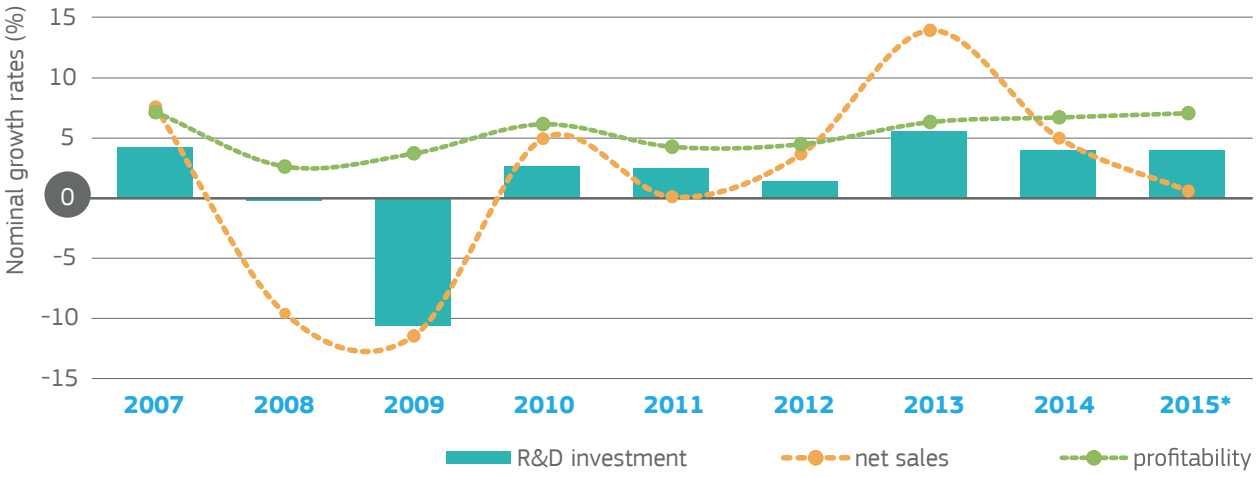

FIGURE 1.4 – ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE JAPANESE COMPANIES.
Note: * Figures for 2015 for the whole sample of 356 Japanese companies were 3.3% for R&D, 0.2 for net sales and 6.8% profitability. The figure is for 311 out of the 2500 companies for which R&D and net sales are available for the full 10 years period.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

1.2.2 | R&D trends by world regions and sector groups over the last 10 years

Trends in R&D over the long-term are presented in figure 1.5 for the main world regions. The figures refer to a set of companies that reported R&D over the whole 10 years period 2006-2015 (EU-456, US-614, Japan-343 and other countries-420). The R&D data are broken down into groups of industrial sectors, each with a characteristic range of R&D intensities (see definition in Box 1.1)

The following points can be observed regarding the overall R&D changes in the period 2006-2015 (figure 1.6):

- Worldwide, companies increased R&D by 59.1% (EU by 52.7 %; US by 65.0% and Japan by 12.5%) over the ten years.
- For the 456 EU companies, the largest percentage R&D increases were in low R&D-intensive sectors (65.2%) and medium-high sectors (56.5%).
- For the 614 US companies, the largest percentage R&D increases were in high R&D-intensive sectors (78.1%) and medium-low sectors (70.8%).
- For the 343 Japanese companies, the largest percentage R&D increases were in medium-high R&D-intensive sectors (19.5%) and medium-low sectors (3.8%).

Box 1.2 -

Grouping of industrial sectors according to R&D intensity *(R&D as % of net sales)**

High R&D intensity sectors include mainly Pharmaceuticals & biotechnology; Health care equipment & services; Technology hardware & equipment; Software & computer services, Aerospace & defence and Leisure Goods.

Medium-high R&D intensity sectors include mainly Electronics & electrical equipment; Automobiles & parts; Industrial engineering; Chemicals; Personal goods; Household goods; General industrials; Support services.

Medium-low R&D intensity sectors include mainly Food producers; Beverages; Travel & leisure; Media; Oil equipment; Electricity; Fixed line telecommunications.

Low R&D intensity sectors include mainly Oil & gas producers; Industrial metals; Construction & materials; Food & drug retailers; Transportation; Mining; Tobacco; Multi-utilities.

**This classification takes into account the R&D intensity of all companies aggregated by ICB 3-digits sectors: High above 5%; Medium-high between 2% and 5%; Medium-low between 1% and 2% and Low below 1%. Some sectors are adjusted to compensate the insufficient representativeness of the Scoreboard in those sectors using the OECD definition of technology intensity for manufacturing sectors[7].*

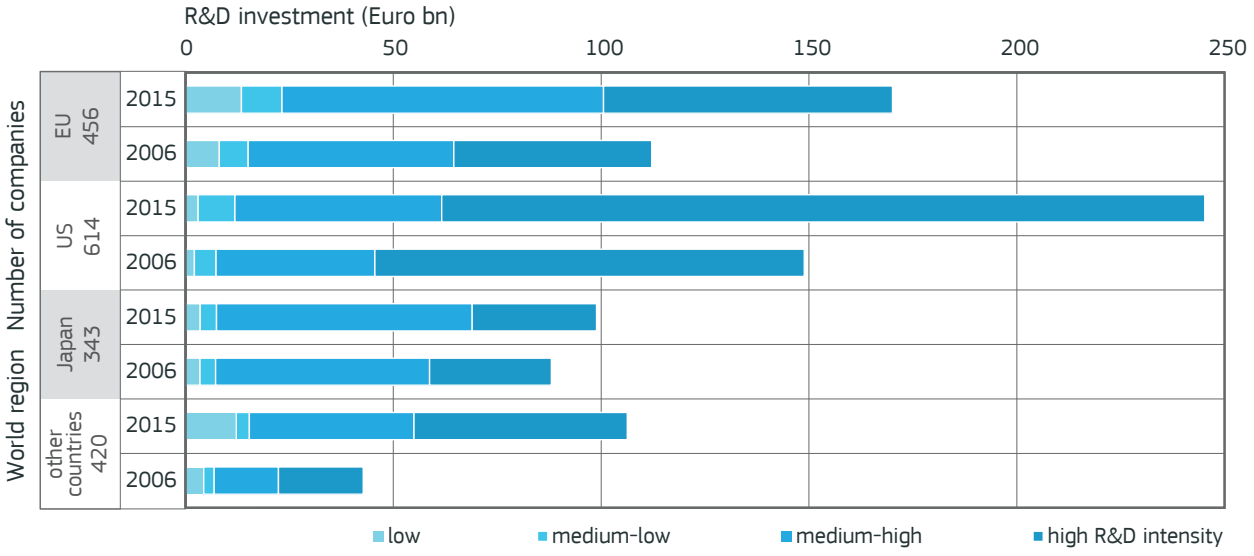

FIGURE 1.5 - R&D INVESTMENT TRENDS BY THE SCOREBOARD COMPANIES FOR MAIN WORLD REGIONS.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[7] ISIC REV 3. Technology intensity definition, OECD, 7 July, 2011.

1.2.3 | Employment trends by regions and sector groups

Among the 2500 companies in this year's *Scoreboard*, 2031 companies reported number of employees. In total these companies employed 47.4 million people in 2015, 1.3% more than the previous year.

The distribution of employees by region was 17.3 million for companies based in the EU, 11. 3 million for US companies, 7.4 million for the Japanese companies, 7.5 million for the Chinese companies and 3.9 million for the rest of countries.

Trends on employment over the long-term are presented in figure 1.6 for the main world regions. The figures refer to a set of companies that reported number of employees over the whole 10 year period 2006-2015 (EU-393, US-515, Japan-303 and other countries-290) and are broken down into groups of industrial sectors with characteristic R&D intensities (see definition in Box 1.2).

The following points can be observed regarding the changes in number of employees in the period 2006-2015 (figure 1.6):

- Overall worldwide employment increased by 23.9% from 2006 to 2015 led by increases in high R&D-intensive sectors (32.1%) and medium-high sectors (31.2%).
- For the EU companies, the overall employment growth was 17.1 %, increasing by 40.3% in high R&D-intensive sectors, by 28.4% in medium-high and by 0.3 % in low sectors.
- For the US companies, the overall employment growth (17.9%) greatly varies by sector group: a strong increase for high R&D-intensive sectors (25.8%) and a sharp decrease in low sectors (-23.6%).
- For the Japanese companies, the overall employment increase of 21.2% corresponded to an increase of 41.0% in medium-low R&D-intensive sectors and of 25.6% in medium-high sectors.
- The ratio of employment in high to medium-high R&D intensity sectors for companies based in Japan fell from 33.2% to 27.3%, rose for EU companies, from 38.8% to 42.4%, and significantly increased for US companies from 90.0% to 97.3%.

It is important to remember that data reported by the *Scoreboard* companies do not inform about the actual geographic distribution of the number of employees. A detailed geographic analysis should take into account the location of subsidiaries of the parent *Scoreboard* companies (see for example in the 2015 *Scoreboard* report, an analysis of the location of companies' economic and innovation activities).

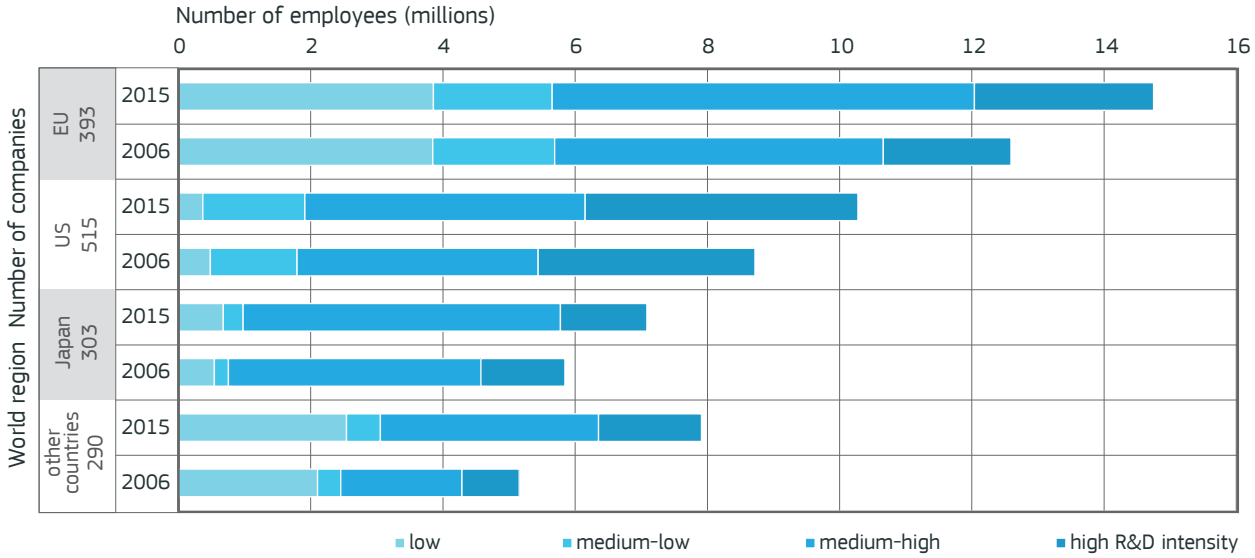

FIGURE 1.6 - EMPLOYMENT TRENDS BY THE SCOREBOARD COMPANIES FOR MAIN WORLD REGIONS.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2

TOP R&D
INVESTING COMPANIES

2 Top R&D Investing Companies

This chapter describes the performance of individual companies, with a focus on the results of top R&D investors, highlighting those companies that show considerable changes in economic performance, in particular from an R&D viewpoint. *Due to data availability, R&D figures for some companies may be under- or over-stated (see explanations in Box 2.1).*

The world's top 100 R&D companies account for 53.1% of the R&D of the whole set of 2500 and are analysed, highlighting those presenting important changes from the previous year and those showing the best performance in terms of R&D and economic growth over the last 10 years.

The group of top R&D investors includes major industrial players in key sectors such as IT hardware & software, pharmaceuticals and automobiles & parts. Key technological and market trends explain to a large extent changes observed in the *Scoreboard* indicators for these companies. Examples of such developments are illustrated in Box 2.2

The R&D ranking of the top 50 companies is presented in figure 2.1 and table 2.1 shows changes in such ranking since the first *Scoreboard* in 2004. A ranking of the top R&D investors by R&D intensity is shown in Table 2.2, indicating the reasons for main changes observed over the last period.

Key findings

- For the third consecutive year, the two top R&D investors remain the same: Volkswagen from Germany in the 1st place and Samsung Electronics from South Korea in the 2nd position.

  The other companies in the top-ten are Intel, Alphabet (previously Google), Microsoft and Johnson & Johnson from the US; Novartis and Roche from Switzerland; Huawei from China and Toyota Motor from Japan.

- The top 100 companies, accounting for 53.1% of the total R&D performed by all the 2500 companies, showed growth of R&D and net sales (6.9% and 2.5%) above the world average. Of these 100 companies, 68 increased R&D investment (vs. 71 in 2014), including 33 companies with double-digit R&D growth and 32 companies that decreased R&D. Regarding net sales, 61 companies reported an increase (vs. 71 in 2014), including 29 companies with double-digit sales growth.

- The top 100 group includes:
  - 30 EU companies of which 23 have increased R&D (17 by more than 10%),
  - 35 US companies of which 20 increased R&D (8 by more than 10%),
  - 16 from Japan of which 8 increased R&D (2 by more than 10%) and
  - 19 companies from the RoW group of which 14 increased R&D (7 by more than 10%).

- The 5 companies showing the largest increase in R&D are Allergan, Ireland (146.6% due to acquisition); CRRC China (92.0%); Facebook, US (80.6%); Celgene, US (60.7%) and Telecom Italia (53.8%). The companies with the largest decrease in R&D are Fujitsu, Japan (-11.3%); Novartis, Switzerland (-9.5%, partly due to divestments); Takeda Pharmaceutical (-9.5%); Petrochina (-9.4%) and NTT, Japan (-8.7%).

2.1 | General trends

In the 2016 *Scoreboard* 136 companies have an R&D investment of more than € 1.0bn (42 from the EU and 45 from the US) while 61 have R&D exceeding € 2.0bn (20 from the EU and 25 from the US).

The top 10 companies invested more than € 5.0bn in R&D and account for 14.8 % of the total R&D investment by the 2500 *Scoreboard* companies.

The two top R&D investors are the same as in last year's *Scoreboard*: In the 1st place the German company Volkswagen (€13.6bn) and in the 2nd position from South Korea Samsung Electronics (€12.5bn). The other companies in the top-ten are Intel, Alphabet and Microsoft (€11bn) from the US; Novartis (€9.0bn) and Roche (€8.6bn) from Switzerland; Huawei (€8.4bn) from China; Johnson & Johnson (€8.3bn) from the US and Toyota Motor (€8.0bn) from Japan.

The top 100 companies invested €369.4bn, accounting for 53.1% of the total R&D investment and 30.0% of the total net sales by all the 2500 *Scoreboard* companies. The EU has 30 companies among the top 100 R&D investors, one company more than it had in the 2015 *Scoreboard*, however, two of these companies (Allergan and Medtronic) are US companies with operational headquarters in the US but registered offices in Ireland.

The US has 35 companies, two less than it had last year and Japan has 16, same number than in last year's *Scoreboard.*

The EU companies in the top 100 are mainly from the Automobiles & Parts (8), Pharmaceuticals & Biotechnology (8), ICT sectors (4) and Aerospace & Defence (2). The US companies are mainly from the ICT (13), Pharmaceuticals & Biotechnology (10), and Chemicals (3) sectors. The Japanese companies operate mainly in the Automobiles & Parts (4) and Pharmaceuticals (4) sectors.

Sixty-eight companies in the top 100 have shown positive R&D investment growth. Among them, 33 companies had double-digit R&D growth, and of these, 21 companies also showed double-digit growth in net sales.

Most of the top 100 companies showing double-digit R&D increases are in the Pharmaceuticals & Biotechnology (7), ICT (5) and Automobiles & Parts (5) sectors. The 5 companies showing the largest increase in R&D are Allergan, Ireland (146.6% due to acquisition); CRRC China (92.0%); Facebook, US (80.6%); Celgene, US (60.7%) and Telecom Italia (53.8%).

As mentioned above, 21 companies had double-digit growth in R&D and net sales, the top 5 companies among them are Facebook, Medtronic, Huawei, Baidu and Apple.

Amongst the top 100 companies only four made losses (Allergan, Bombardier, Toshiba and Volkswagen) with 12 showing profitability of only 5% or less but 24 showing profitability of over 20%. All but two of the 24 were from the very high R&D intensity sectors of biopharma, software and technology hardware; the other two were Procter & Gamble and Monsanto. There are currently no profitability data for four of the top 100.

Thirty-two companies in the top 100 have experienced a decrease in R&D investment. The companies with the largest decrease in R&D are Fujitsu, Japan (-11.3%); Novartis, Switzerland (-9.5%); Takeda Pharmaceutical (-9.5%); Petrochina (-9.4%) and NTT, Japan (-8.7%).

The R&D intensity of companies in the top 100 (6.8%) increased, as in the previous year, due to R&D growth (6.9%) being higher than net sales growth (2.5%). The EU companies in the top 100 have the same R&D intensity as that of non-EU companies (6.7%).

Box 2.1 – Understatement or overstatement of R&D figures

The *Scoreboard* relies on consistent disclosure of R&D investment in published annual reports and accounts. However, due to different national accounting standards and disclosure practices, in some cases, R&D costs cannot be identified separately in companies' accounts, e.g. appearing integrated with other operational expenditures such as engineering costs. To avoid overstatement of R&D figures, the *Scoreboard* methodology excludes R&D figures that are not disclosed separately (see methodological notes in Annex 2). Inevitably, the strict application of this criterion may lead to understating the actual R&D effort of some companies.

An example of a possible large understatement of R&D figures is the US company Amazon. This company reported a combined figure of $12.54bn for 'R&D and content' investment in its latest annual report together with capitalised R&D of $642m which, following the methodology, is the figure mentioned in the *Scoreboard.* With this R&D figure, Amazon appears in position 215th in the R&D ranking whereas according to its large overall 'innovation' investment it should be in a much higher position in the R&D ranking (Amazon also reported a 35% increase in R&D and content from last year). For example, the best estimate from the information available of Amazon's R&D is in the range of €8bn and this would place the company at #11 or higher in the top 50 (below Toyota but above Apple).

Box 2.2 – Key technological trends affecting the top R&D investing companies

There are two main types of technological advance. **Sustaining technological innovations** that bring better products and services to an established market and can provide opportunities for companies to improve their competitive positions and **disruptive technological innovations** which bring to market completely new products and services. These disruptive technologies may well be developed by companies new to a sector as well as innovative companies within a sector. New entrant companies with disruptive technologies can grow quickly and even supplant the established leading companies. A classic example of this is the way in which the advent of digital photography led to Kodak, the global market leader in film photography, filing for bankruptcy in 2012.Examples of important current **sustaining technological innovations** are:

- **Monoclonal antibodies** which are now the basis of an increasing range of modern drugs. Many pharmaceutical companies have partnered with biotech companies such as MorphoSys and Regeneron to access new antibodies and hence bolster their clinical pipelines.

- **Low power, high performance chip designs** by ARM now dominate smartphones and other mobile devices and are likely to be very important for the IoT (internet-of-things). ARM kept improving its designs and thus built up a share of over 95% of the global smartphone market from its origins as a supplier for early simple mobile phones. This was achieved despite Intel's dominant position in chips for PCs and servers.

- **Standard sustaining technologies** for individual companies include new model ranges from car makers, new generation smartphones (Samsung S7 Edge, Apple iPhone 7), improved IT applications in healthcare (Cerner and Craneware), improved drugs (e.g. Gilead's improved antivirals for HIV and Hepatitis C) and higher performance semiconductor chips enabled by each new generation of precision lithography systems (from ASML).

But **disruptive technological innovations** tend to have much greater effects on existing markets and companies. The technologies underlying the most likely medium-term disruptions are drawn from **ICT** [e.g. big data, AI (artificial intelligence), IoT], **biotechnology** [low cost genomic sequencing, gene editing, immunotherapy, stem cells], **new materials** [nanotechnology, graphene, biomaterials] and systems [robotics, self-driving cars, renewable energy]. A recent example of disruption is the way **online advertising** has grown rapidly to the point that it is predicted by eMarketer to overtake TV advertising for the first time in 2016. And it is dominated by just two relatively new companies - Google and Facebook - with 64% of the large US market. Examples of other potential areas for disruption are:

- **Transport industry.** Both **self-driving technology** and zero emissions **electric cars** may well disrupt the automotive industry while Uber is disrupting the taxi business. Tesla, a new company, has tripled its R&D in the last two years, sells the best performing electric car on the market in terms of range and acceleration and is building a giga-factory for substantially lower cost lithium batteries. Then there are self-driving car developments led by Alphabet and Tesla, some in association with conventional automotive companies. Tesla announced that all its production vehicles will be equipped with the hardware for full self-driving capability with features for full autonomy predicted to be activated by end 2017. The 2016 Paris Motor Show demonstrated that existing automotive companies are now responding to these developments with Daimler and Volkswagen both demonstrating electric concept cars – the EQ and ID respectively. Both companies plan to have full ranges of many electric models on the market by 2025. And Daimler is setting up a new digital division to develop connected and autonomous cars. Robotic ships are now possible although they will initially be led in convoys by a manned lead ship. Robotic aircraft in the form of armed military drones are already in service and there are proposals to use smaller drones for parcel deliveries.

- **Both medicine and agriculture** (genetically modified plants and farm animals) look set to be profoundly influenced by **gene editing** (insertion, deletion or replacement of DNA at a specific site in the genome of an organism or cell using the latest CRISPR/Cas9 technique). For example, the successful gene editing treatment of a one-year old girl with leukaemia was reported in November 2015. Then Genus (UK) reported in December 2015 that it had used gene editing to develop pigs resistant to porcine reproductive & respiratory syndrome virus, a disease that can be fatal. Gene editing to treat inherited diseases is one example of **personalised medicine**. Lower cost next generation genomic sequencing, e.g. from Illumina (US) and probably Oxford Nanopore (UK) will be important in determining whether a person is at risk of a particular disease and then informing personal treatment decisions. Gene editing holds the promise of curing many inherited diseases.

- **Medicine** is a field where there are many potential disruptions with **stem cells**

being an important example. They have been used for bone marrow transplants (to treat leukaemia) but early work suggests their use might be expanded to treat a range of serious diseases such as heart disease, cancer, type 1 diabetes and retinal diseases. Success with these applications could well disrupt companies providing the current treatments for these diseases.

- **Other health sector technological trends**. Technological developments are likely to change many other aspects of the health sector with **robot-assisted surgery** developing fast (Intuitive Surgical's da Vinci system from the US is the market leader) and likely to require less and less human intervention in the future. Then there are more and more **health diagnostic and electronic products** being launched such as the world's smallest pacemaker that can be implanted inside the heart through the femoral vein (launched by Medtronic in 2016). And cures are on the horizon for some of the most serious diseases. These include **immunotherapy** which enables the body's immune system to attack a growing range of cancers (AstraZeneca, Bristol-Myers Squibb, Merck and Roche). Then there is progress with treatments for some of the most serious neurological diseases where late stage clinical trials are showing promise for Alzheimer's (Biogen and Eli Lilly) with other trials for **Parkinson's** (Prothena and Roche). Last but not least collaborations between ICT and health companies and institutes are starting with medical big data analytics exemplified by the partnership between Alphabet's Verily Life Sciences and GlaxoSmithKline. This partnership is called Galvani Life Sciences and aims to treat a **wide range of chronic diseases** using miniaturised, implantable devices that can modify the electrical signals that pass along nerves in the body.

Thirteen of the aforementioned innovative companies are in the *Scoreboard*'s world top 50 R&D companies (Alphabet, Apple, AstraZeneca, Bristol-Myers Squibb, Eli Lilly, Facebook, Gilead, GSK, Merck, Roche, Samsung, Daimler and VW), two more in the top 70 (Biogen, Medtronic) and seven more in the top 550 (ARM, ASML, Cerner, Illumina, Intuitive Surgical, Regeneron and Tesla). Many other smaller R&D companies in the *Scoreboard* are working to make important advances in technologies of growing importance such as fintech, gene editing, IoT, big data, cybersecurity, next generation batteries (beyond lithium) and nanotechnology.

2.2 | Long-term performance of top R&D companies

This section analyses the behaviour of the top companies over the long-term based on our history database containing company data for the period 2002-2015. Results of companies showing outstanding R&D and economic results are underlined.

Ranking of the top 50

Table 2.2 shows the evolution of the R&D rankings of the top 50 companies since the first *Scoreboard* in 2004 and most significant changes are highlighted. It is important to note, as stated in the previous section and in past reports, that the reported growth of companies is often partly due to mergers and acquisitions.

There are 14 EU companies (18 in 2004) and 36 non-EU companies (32 in 2004) in the top 50.

In the EU group, seven companies left the top 50 (Alcatel, Istituto Finanziario Industriale, Philips, Renault, BAE Systems, Peugeot and Nokia) and three companies joined the top 50 (Boehringer Ingelheim, Fiat Chrysler and SAP).

In the non-EU group, ten companies left the top 50 (Fujitsu, Canon, Matsushita Electric, NEC, Motorola, Nortel Networks, Wyeth, Delphi, Sun Microsystems and Toshiba) and fourteen companies joined the top 50 (Abbvie, Amgen, Apple, Denso, Nissan, Gilead Sciences, Alphabet, Huawei, LG Electronics, Oracle, Panasonic, Qualcomm, Takeda Pharmaceuticals, Facebook).

The distribution of the top 50 companies by main industrial sector and region changed from 2004 to 2014 as follows:

- Automobiles & Parts, from 13 (EU 7) to 11 (EU 5)
- Pharma & Biotech, from 11 (EU 3) to 17 (EU 4)
- ICT industries, from 13 (EU 3) to 13 (EU 2)

The EU companies that improved by at least 20 places are Bayer (now ranked 28th) and SAP (now 49th).

There are 12 non-EU companies that gained more than 20 places. They include Samsung Electronics (now 2nd), Alphabet (now 4th), Huawei (now 8th), Apple (now 11th), Oracle (now 19st), Qualcomm (now 25th), Takeda (now 50th), LG Electronics (now 48th), Gilead Sciences (now 46th), Bristol-Myers Squibb (now 20th), Celgene (now 41st), Facebook (29th).

Two companies dropped twenty or more places but remained within the top 50: Sony (now 39th) and Panasonic (now 40th).

There are 14 companies within the top 50 that have reduced R&D but only one of these is from the EU. There are also two with losses in 2015/16 (one from the automotive sector) and six whose profitability is below 5% (three from the automotive sector).

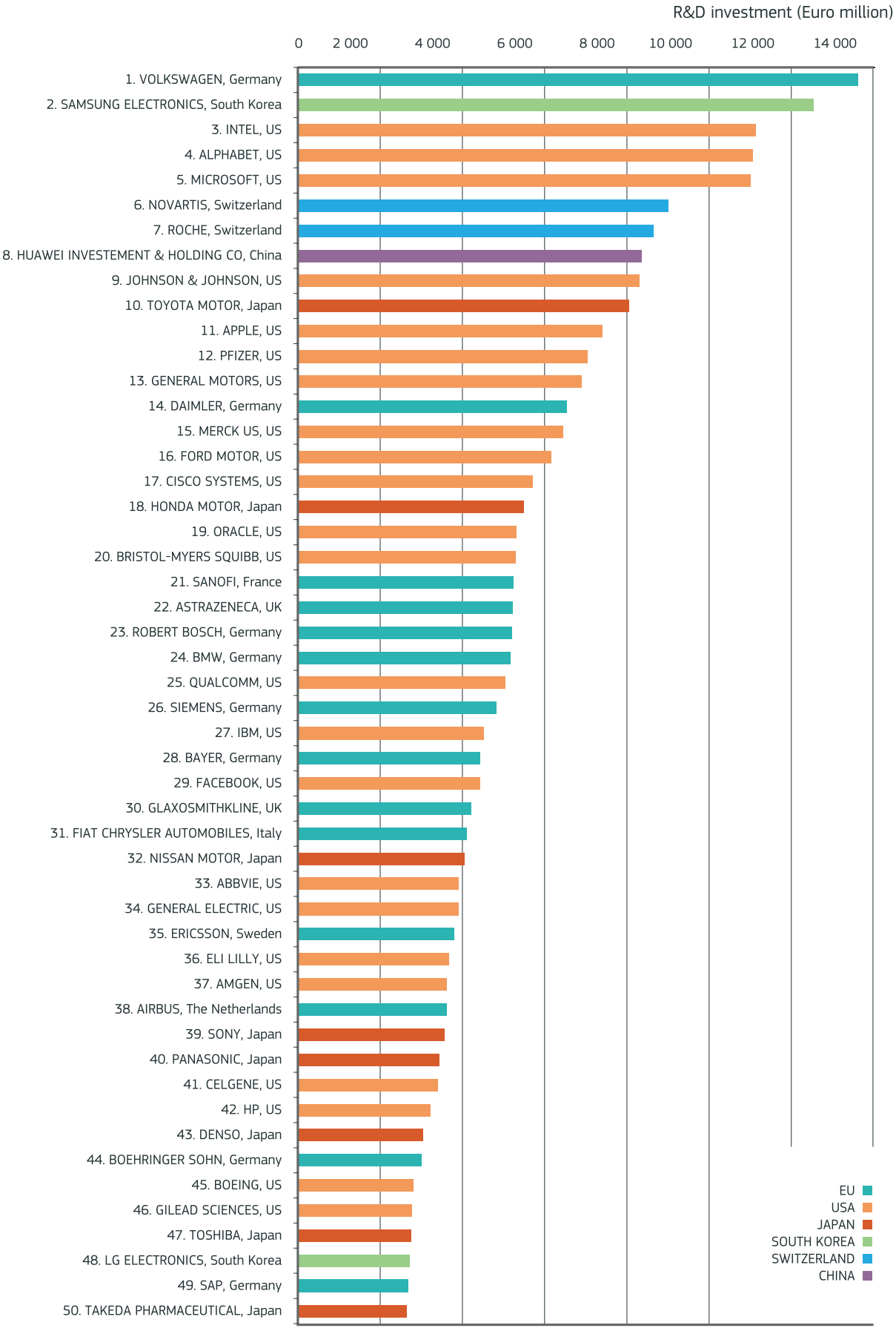

FIGURE 2.1 – THE WORLD'S TOP 50 COMPANIES BY THEIR TOTAL R&D INVESTMENT (€M) IN THE 2016 SCOREBOARD.

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

RANK ON 2016	COMPANY	COUNTRY	R&D IN 2015 (€BN)	R&D INTENSITY (%)	RANK CHANGE 2004-2016
1	VOLKSWAGEN	Germany	13.6	6.4	up 7
2	SAMSUNG ELECTRONICS	South Korea	12.5	8.0	up 31
3	INTEL	US	11.1	21.9	up 11
4	ALPHABET	US	11.1	16.0	up > 200
5	MICROSOFT	US	11.0	14.1	up 8
6	NOVARTIS	Switzerland	9.0	19.4	up 14
7	ROCHE	Switzerland	8.6	19.4	up 11
8	HUAWEI	China	8.4	15.0	up > 200
9	JOHNSON & JOHNSON	US	8.3	12.9	up 3
10	TOYOTA MOTOR	Japan	8.0	3.7	down 5
11	APPLE	US	7.4	3.5	up 93
12	PFIZER	US	7.0	15.7	down 10
13	GENERAL MOTORS	US	6.9	4.9	down 7
14	DAIMLER	Germany	6.5	4.4	down 11
15	MERCK US	US	6.4	17.7	up 14
16	FORD MOTOR	US	6.2	4.5	down 15
17	CISCO SYST EMS	US	5.7	12.6	up 13
18	HONDA MOTOR	Japan	5.5	4.9	down 7
19	ORACLE	US	5.3	15.6	up 27
20	BRISTROL-MYERS SQUIBB	US	5.3	34.8	up 22
21	SANOFI	France	5.2	15.2	down 5
22	ASTRAZENECA	UK	5.2	23.0	up 3
23	ROBERT BOSCH	Germany	5.2	7.4	up 5
24	BMW	Germany	5.2	5.6	up 5
25	QUALCOMM	US	5.0	21.7	up 67
26	SIEMENS	Germany	4.8	6.4	down 21
27	IBM	US	4.5	6.0	down 17
28	BAYER	Germany	4.4	9.4	up 32
29	FACEBOOK	US	4.4	26.9	up > 200
30	GLAXOSMITHKLINE	UK	4.2	12.9	down 19
31	FIAT CHRYSLER	Italy	4.1	3.7	new
32	NISSAN MOTOR	Japan	4.1	4.4	up 2
33	ABBVIE	US	3.9	18.6	new
34	GENERAL ELECTRIC	US	3.9	3.6	up 3
35	ERICSSON	Sweden	3.8	14.2	down 18
36	ELI LILLY	US	3.7	20.0	up 5
37	AMGEN	US	3.6	18.2	unchanged
38	AIRBUS	The Netherlands	3.6	5.6	down 3
39	SONY	Japan	3.6	5.8	**down 24**
40	PANASONIC	Japan	3.4	6.0	**down 33**
41	CELGENE	US	3.4	39.9	up >200
42	HP	US	3.2	3.4	down 19
43	DENSO	Japan	3.0	8.8	down 8
44	BOEHRINGER SOHN	Germany	3.0	20.3	up 18
45	BOEING	US	2.8	3.2	up 12
46	GILEAD SCIENCES	US	2.8	9.2	up 320
47	TOSHIBA	Japan	2.8	6.4	
48	LG ELECTRONICS	South Korea	2.7	6.1	up 62
49	SAP	Germany	2.7	12.9	up 21
50	TAKEDA PHARMA	Japan	2.6	19.1	up 23

TABLE 2.1 – THE TOP 50 COMPANIES IN 2016 SCOREBOARD: RANK CHANGE 2004-2016 *(ON PREVIOUS PAGE)*
Note: companies in "blue" went up more than 20 ranks and in "red" lost more than 20 ranks
Source: The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

2.3 | Ranking of large companies by R&D intensity

This section examines the subset of the 50 highest R&D intensity large companies. These are companies where R&D is a very substantial component of sales and profits and the selected companies are therefore almost all drawn from the R&D-intensive ICT and biopharma sectors. The criteria for compiling the list are:

- R&D should be over €1bn so we are choosing companies from the top 137 companies in the world by size of R&D investment and
- R&D intensity (R&D to sales ratio) should be 10% or more so that R&D is a major investment and significant driver of growth

The top 50 are shown in Table 2.2 which lists the companies with their sectors and R&D intensities together with the number of places they have moved up or down compared to the top 50 drawn from the 2015 *Scoreboard.* Six new companies appear in the top 50 this year: Allergan, Baidu, Electronic Arts, Seagate Technology, SK Hynix and Syngenta. Two of the six (Electronic Arts and Allergan) had R&D below €0.9bn last year while the other four all had R&D intensity below 10%. These six replace Bosch, Broadcom, eBay, Gilead Sciences, Marvell Technology and Texas Instruments which do not meet one or both of the criteria this year.

The main general conclusions are:

- 25 of the companies in the table are also in the top 50 by amount of R&D (all 25 therefore have R&D>€2.6bn)
- The US contributes 23 of the top 50, the EU 15, Japan 4 and others 8 (3 from Switzerland, 3 from China and one each from S. Korea and Taiwan). Two of the EU companies have their operational centres in the US but are headquartered in Ireland (Allergan and Seagate Technology) and are classed as EU companies under the Scoreboard's standard methodology. Allergan was acquired by Actavis Inc of the US in 2015 and then changed the name of the combined company from Actavis back to Allergan plc with registered office in Ireland.
- Biopharmaceuticals accounts for 22 of the 50 companies (of which 6 can be classed as biotech – Amgen, Biogen, Celgene together with AstraZeneca, Bristol-Myers and Merck US; the last three having built up their biotech pipelines)), IT hardware (including telecom equipment) for 16 companies, software/ internet 9 and just 3 others (two agri-science firms classed as chemicals and one aerospace). The biopharmaceuticals companies are drawn from the US (10), EU (6), Japan (4) and Switzerland (2) but five of the six biotech companies are from the US.
- The US strength in high technology sectors such as biotech, software and hardware (ex telecom equipment) means that it contributes 8 of the top 10 companies in the table and 19 of the total of 28 companies in these three sectors (including Seagate). Japan, on the other hand, has no top 50 companies in these three sectors with all its four entries all being pharmaceuticals firms.

There are twelve sizeable changes in rankings from last year where companies have moved up or down by five or more places. Four of these were big increases in ranking with three of them caused by double-digit increases in R&D (AbbVie, AstraZeneca and Mediatek). The fourth was Novartis where sales were down more than R&D as it sold off smaller, less R&D-intensive divisions and bought in cancer treatments from GSK. Of the eight large falls in ranking, four were driven by decreases in R&D while the others increased sales faster than R&D.

A number of companies have shown very big increases in R&D and/or R&D intensity since last year. These include four pharma/biotech companies (Allergan, AstraZeneca, Bristol-Myers Squibb and Celgene), Baidu and Facebook from software and Huawei and ZTE in hardware. The largest increases in R&D are by Allergan (146.6% by

acquisition), Facebook (80.6%), Celgene (60.7%), Baidu (46.2%), Huawei (46.1%), Bristol-Myers Squibb (38.5%), ZTE (34.1%), AbbVie (29%), SK Hynix (23.8%) and Alphabet (22.4%). These are very large increases for companies with high R&D intensities. Note that three of the ten are from China where large technological companies are now realising the importance of R&D investment for growth.

AstraZeneca and Bristol-Myers Squibb are two of the top companies working on cancer immunotherapy in which biotech drugs are used to enable the body's immune system to attack cancer cells. They are putting substantial R&D investment into developing their pipelines of such drugs with AstraZeneca's R&D intensity up from 19.4% last year to 23% this year and BMS's up from 26.2% to 34.6%. Other companies active in cancer immunotherapy include Merck US (R&D intensity 17.7%), Roche and Novartis (both with 19.4%). Roche's acquisition of US biotech Genentech gave it biotech and immunotherapy expertise. Celgene has the largest R&D intensity in the table at 39.9%; this reflects its extensive pipeline of 55 clinical trials of potential drugs with 37 of these aimed at a range of cancers.

Facebook has increased its R&D by 80.6% to €4.4bn and its R&D intensity from 21.4% last year to 26.8% this year as it develops its leading social media platform. Alphabet and Facebook together account for 64% of the growing US digital advertising market with Alphabet's share nearly four times Facebook's. Alphabet's share of the global digital ad market for 2016 is put at 31% by eMarketer. Baidu, the Chinese equivalent of Google search, Google maps, Wikipedia and other web services, was founded by two Chinese experts who had worked in the US. The company has a large market share in China since it accepts government censorship which many western web companies will not. Baidu increased its R&D by 46.2% this year to €1.44bn. However, Alphabet's R&D is nearly eight times larger at €11.1bn and its R&D intensity is somewhat higher (16% vs. 15.4%).

EU companies are represented in the top 50 by six from biopharma (AstraZeneca, Boehringer Ingelheim, GlaxoSmithKline, Merck (DE), Novo Nordisk and Sanofi), five from technology hardware/telecom equipment (Alcatel-Lucent, ASML, Ericsson, Nokia, ST Microelectronics) with one each from software (SAP) and aerospace (Finmeccanica). ASML is the clear world leader in precision lithography, the key step in making all semiconductor chips, Novo Nordisk is world leader in treatments for diabetes, the world's fastest-growing major disease, and AstraZeneca is one of the four world leaders in immuno-oncology.

TABLE 2.2 *(ON NEXT PAGE)* – RANKING OF LARGE COMPANIES BY R&D INTENSITY

Note1: Colour of names of companies indicate country/world region as in Figure 2.1, except Mediatek (n black) from Taiwan.
Note 2: EMC was acquired by Dell in 2016 and is now part of Dell Technology; the acquisition of EMC is the largest ever acquisition of a tech company.
Source: The 2016 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

RANK BY R&D INT.	RANK BY R&D 2015	COMPANY	SECTOR	R&D INT. 2015 (%)	RANK CHANGE	REASONS FOR BIG CHANGES (UP OR DOWN 5 PLACES OR MORE)
1	41	CELGENE	Biotech	39.9	0	
2	20	BRISTOL-MYERS SQUIBB	Pharma	34.8	3	
3	29	FACEBOOK	Internet	26.9	4	
4	111	NVIDIA	IT hardware	26.6	-2	
5	131	ELECTRONIC ARTS	Software	25.2	NEW	Sales down >R&D up
6	124	YAHOO!	Internet	24.3	-2	
7	94	MEDIATEK	IT hardware	23.2	5	Sales level, R&D up
8	22	ASTRAZENECA	Pharma	23.0	8	R&D up 12.3, sales -6.9%
9	3	INTEL	It hardware	21.9	2	
10	25	QUALCOMM	IT hardware	21.7	-1	
11	81	DAIICHI SANKYO	Pharma	21.2	-2	
12	44	BOEHRINGER SOHN	Pharma	20.3	2	
13	36	ELI LILLY	Pharma	20.0	0	
14	6	NOVARTIS	Pharma	19.4	9	Sales -15%, R&D -9.5% (GSK deal)
15	7	ROCHE	Pharma	19.4	2	
16	50	TAKEDA PHARMA	Pharma	19.1	-10	R&D -9.5%, sales +5.1%
17	68	BIOGEN IDEC	Biotech	18.7	-2	
18	33	ABBVIE	Pharma	18.6	7	R&D up more than sales
19	54	NOKIA	IT hardware	18.4	-1	
20	37	AMGEN	Biotech	18.2	-12	R&D down, sales up
21	119	STMICROELECTRONICS	IT hardware	18.1	0	
22	60	ALLERGAN	Pharma	15.0	NEW	Merger Actavis & Allergan
23	15	MERCK US	Pharma	17.7	-3	
24	57	ALCATEL-LUCENT	IT hardware	16.9	1	Controlled by Nokia since 01/2016
25	129	ASML HOLDING	IT hardware	16.6	-6	
26	74	ASTELLAS PHARMA	Pharma	16.4	-2	
27	4	ALPHABET	IT services	16.0	2	
28	12	PFIZER	Pharma	15.7	-6	
29	19	ORACLE	Software	15.6	2	
30	92	BAIDU	Internet	15.4	NEW	R&D +46.2%, sales +35.3%
31	21	SANOFI	Pharma	15.2	3	R&D up more than sales
32	103	APPLIED MATERIALS	IT hardware	15.0	-4	R&D up 1.6% but sales up 6.5%
33	8	HUAWEI	IT hardware	15.0	3	
34	35	ERICSSON	IT hardware	14.2	-7	R&D down, sales up
35	5	MICROSOFT	Software	14.1	5	R&D level, sales down 8.8%
36	85	OTSUKA	Pharma	13.9	-1	
37	64	ZTE	IT hardware	13.8	4	R&D +34.1%, sales up 23%
38	76	MERCK DE	Pharma	13.3	-8	R&D level, sales up
39	30	GLAXOSMITHKLINE	Pharma	12.9	-2	
40	49	SAP	Software	12.9	-1	
41	9	JOHNSON & JOHNSON	Pharma	12.9	3	R&D + 6.5%, sales -5.75%
42	17	CISCO SYSTEMS	IT hardware	12.6	-1	
43	86	WESTERN DIGITAL	IT hardware	12.5	2	
44	72	NOVO NORDISK	Pharma	12.0	-13	R&D level, sales up 21.5%
45	121	SEAGATE TECHNOLOGY	IT hardware	11.1	NEW	Sales fell more than R&D
46	55	EMC	IT hardware	10.7	-15	
47	98	FINMECCANICA	Aerospace	10.6	2	
48	91	MONSANTO	Chemicals	10.5	-2	
49	84	SK HYNIX	IT hardware	10.5	NEW	R&D +23.8%, sales +9.8%
50	107	SYNGENTA	Chemicals	10.2	NEW	Sales down more than R&D

3

R&D DISTRIBUTION **BY INDUSTRIAL SECTOR**

3 R&D Distribution by Industrial Sector

This chapter presents the main R&D trends among the 2016 Scoreboard companies aggregated by industrial sectors[8]. It comprises the ranking of sectors by their level of R&D investment, R&D intensities, rates of R&D growth and the comparison of such trends across world regions.

Key findings

- Companies from Software & Computer Services, driven by the US companies, showed the highest R&D growth (12.3%). The top two R&D investing sectors achieved a fair increase of R&D and are Pharmaceuticals & Biotechnology (9.8%) and Technology Hardware & Equipment (7.6%). The Automobile & Parts sector grew R&D at a rate similar to the all-sector average rate (6.6%). All the other large sectors increased R&D below the world average, e.g. Electronic & Electric Equipment (5.5%) and Health Care Equipment and Services (5.0%); and those showing the poorest performance were Chemicals (2.3%) and Aerospace & Defence (1.2%).

- In the Pharmaceuticals & Biotechnology sector, companies operating in biotechnology increased R&D by 23.8% whereas the traditional pharmaceutical companies increased it only by 7.2%. As observed in previous editions, this is due to the rapid development of biotechnology, illustrated by an outstanding performance of the top biotechnology companies, most of the world's large biotechs being based in the US.

- Among the top 5 sectors, companies based in the EU had the highest R&D growth in Pharmaceuticals & Biotechnology (13.2%) and Software & Computer Services (12.2%). The highest R&D growth in the EU was showed by the Health Care Equipment and Services (20.7%), mainly due to the largest company in that sector, Medtronic (a US company headquartered in Ireland), that increased R&D by 35.5% due to its acquisition of Covidien (another US company with registered office in Ireland).

- Trends observed in the *Scoreboard* over the last 12 years show a characteristic, but very different industrial specialisation of the EU and US companies that persists after the financial crisis and appears to have been reinforced over the past few years:

    - Concentration of the EU companies in medium-high R&D intensity sectors (total domestic and sector world R&D shares of 44.7% and 33.7% respectively). In particular in Automobiles & Parts with domestic and world R&D shares of 27.0% and 46.5% respectively.

    - Dominance of US companies in high R&D-intensity sectors (total domestic and sector world R&D shares of 75.7% and 54.5% respectively). In particular in ICT industries with total domestic and sector world R&D share of 45.8% and 67.1% respectively.

[8] According to the Industry Classification Benchmark (ICB) applied in the Scoreboard.

3.1 | General R&D trends

Figure 3.1 shows the R&D rankings of companies from the main industrial sectors including the relative R&D share by main world region. The specialisation of the main world regions, represented by the share of sectors within the regions' total R&D investment, is given in figure 3.2.

- R&D investment in the *Scoreboard* remains highly concentrated by sectors: out of 38 industrial sectors, the top three –Pharmaceuticals & Biotechnology, Automobiles & Parts and Technology Hardware & Equipment– account for 49.0% of the total R&D investment by all the Scoreboard companies.

  The top 6 and top 15 sectors constitute, respectively, 72.0% and 91.6% of the total R&D in the *Scoreboard*. A similar concentration of R&D in a relatively small number of industrial sectors has been observed over the last 13 years.

- The ranking by R&D investment of the top 15 sectors remained unchanged.

- The Pharmaceuticals & Biotechnology sector keeps its first position in the R&D ranking, increasing its share of the total R&D investment to 19.1%. It is followed by the Automobile & Parts (15.6%) and Technology Hardware & Equipment (14.4%) sectors.

- The R&D specialisation (share of R&D investment) of the main regions in the top 3 sectors are:

  - In the EU, Automobiles & Parts (27.0%), Pharmaceuticals & Biotechnology (19.6%), and Technology Hardware & Equipment (6.9%);

  - In the US, Technology Hardware & Equipment (23.3%), Pharmaceuticals & Biotechnology (22.9%) and Software & Computer Services (22.8%);

  - In Japan, Automobiles & Parts (29.4%), Electronic & Electrical Equipment (13.0%) and Pharmaceuticals & Biotechnology (10.6%).

- The contribution to the total *Scoreboard* R&D:

  - by EU companies is 46.5% to Automobiles & Parts, 46.2% to Aerospace & Defence, and 32.0% to the Industrial Engineering sectors;

  - the US contributes 77.2% to Software & Computer Services, 57.7% to Technology Hardware & Equipment and 55.1% to Health Care Equipment & Services;

  - Japan contributes 61.4% to Leisure Goods, 30.0% to Chemicals, and 29.6% to General Industrials.

3.2 | R&D growth by industrial sector

The actual contribution of an industrial sector to the overall R&D growth of a region depends on both its rate of R&D change and the sector's share of the total R&D of the region. Figures 3.1 and 3.2 show the shares of the main industrial sectors and table 3.1 shows their ranking by R&D growth worldwide for the *Scoreboard* companies based in the main world regions.

The following points are observed for the top 11 sectors accounting for 91.5% of the total R&D investment of the *Scoreboard* companies:

- Worldwide, the Software & Computer Services sector shows the highest one-year growth rate (12.3%) followed by Pharmaceuticals & Biotechnology (10.0%) and Technology Hardware and Equipment (7.6%) sectors. *The R&D growth rate of the Software & Computer Services sector is mostly due to the R&D growth of US companies such as Alphabet (22.4%) and Facebook (80.6%) and Chinese companies such Baidu (46.2%). The German company SAP (16.6%) is the fourth contributor to the R&D growth of this sector*[9].

- Among the companies based in the EU, most of the top R&D investing sectors showed high R&D growth (excepting Technology Hardware and Equipment). The highest contribution to R&D growth was shown by Automobiles & Parts (9.2%), *driven by German companies such as*

[9] Taking into account the R&D weight of the company within the sector and its R&D growth in 2015.

Daimler (15.6%) and BMW (13.2%). Pharmaceuticals & Biotechnology was the second R&D growth contributor (13.2%) with big pharma companies showing very high R&D growth (excepting GlaxoSmithKline, -0.5%), e.g. Allergan (146.6% through acquisition), Bayer (20.2%) and AstraZeneca (12.3%). Other EU sectors showing double-digit R&D growth are Health Care Equipment & Services (20.7% driven by acquisition), Software & Computer Services (12.2%). Most large EU software companies had double-digit R&D growth, e.g. SAP, UBISOFT ENTERTAINMENT, EYGS, DASSAULT SYSTEMES, MICRO FOCUS INTERNATIONAL, PLAYTECH, GAMELOFT, AVG TECHNOLOGIES AND COMPUTATIONAL DYNAMICS. Sectors showing the lowest R&D growth in 2015 were Industrial Engineering (-1.7%) and Aerospace & Defence (-0.8%).

- Among the companies based in the US, the Pharmaceuticals & Biotechnology and Leisure Goods sectors show the highest one-year growth rate (13.0%) followed by Software & Computer Services (11.5%). Sectors showing the lowest one-year R&D growth are Chemicals (-3.8%) and Health Care Equipment & Services (-3.1%).

- For Japanese companies, the highest one-year growth rate is shown by Health Care Equipment & Services (10.9%) followed by Industrial Engineering (9.6%). The poorest performance was shown by Software & Computer Services (-8.3%) and Leisure Goods (0.2%).

- For the Chinese companies, all the top 11 sectors showed double-digit R&D growth, including the largest R&D industries such as Software & Computer Services (38.3%), Technology Hardware & Equipment (35.0%) and Industrial Engineering (24.8%).

Apart from the top 11 industries, there were important R&D changes in some other sectors:

- In the smaller sectors in terms of R&D, significant R&D growth was shown by Banks (15.1%) mainly due to double-digit R&D growth reported by EU banks such as BANCO SANTANDER, BARCLAYS and DEUTSCHE BANK. Also the Construction & Materials sector showed an important R&D increase (20.7%), mostly due to Chinese companies.

- Oil and mining related sectors, on the other hand, decreased R&D as oil and commodity prices fell: Oil & Gas Producers (-14.5%), Oil Equipment, Services & Distribution (-12.1%) and Mining (-19.7%).

- The Alternative Energy sector reversed the negative trend of the past few years showing an increase of 7.7% in 2015.

- In 2015, the Industrial Transportation sector continued the positive trend of the past year, increasing significantly R&D (18.2%).

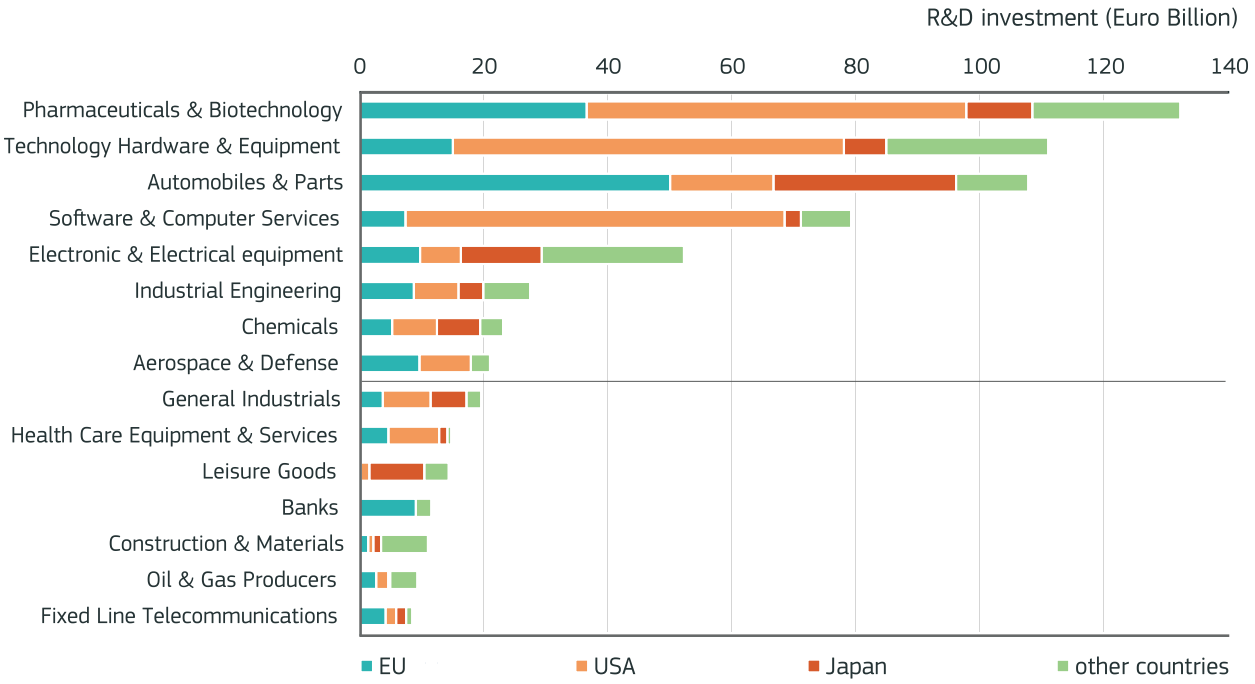

FIGURE 3.1 - R&D RANKING OF INDUSTRIAL SECTORS AND SHARE OF MAIN WORLD REGIONS FOR THE WORLD'S TOP 2500 COMPANIES.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

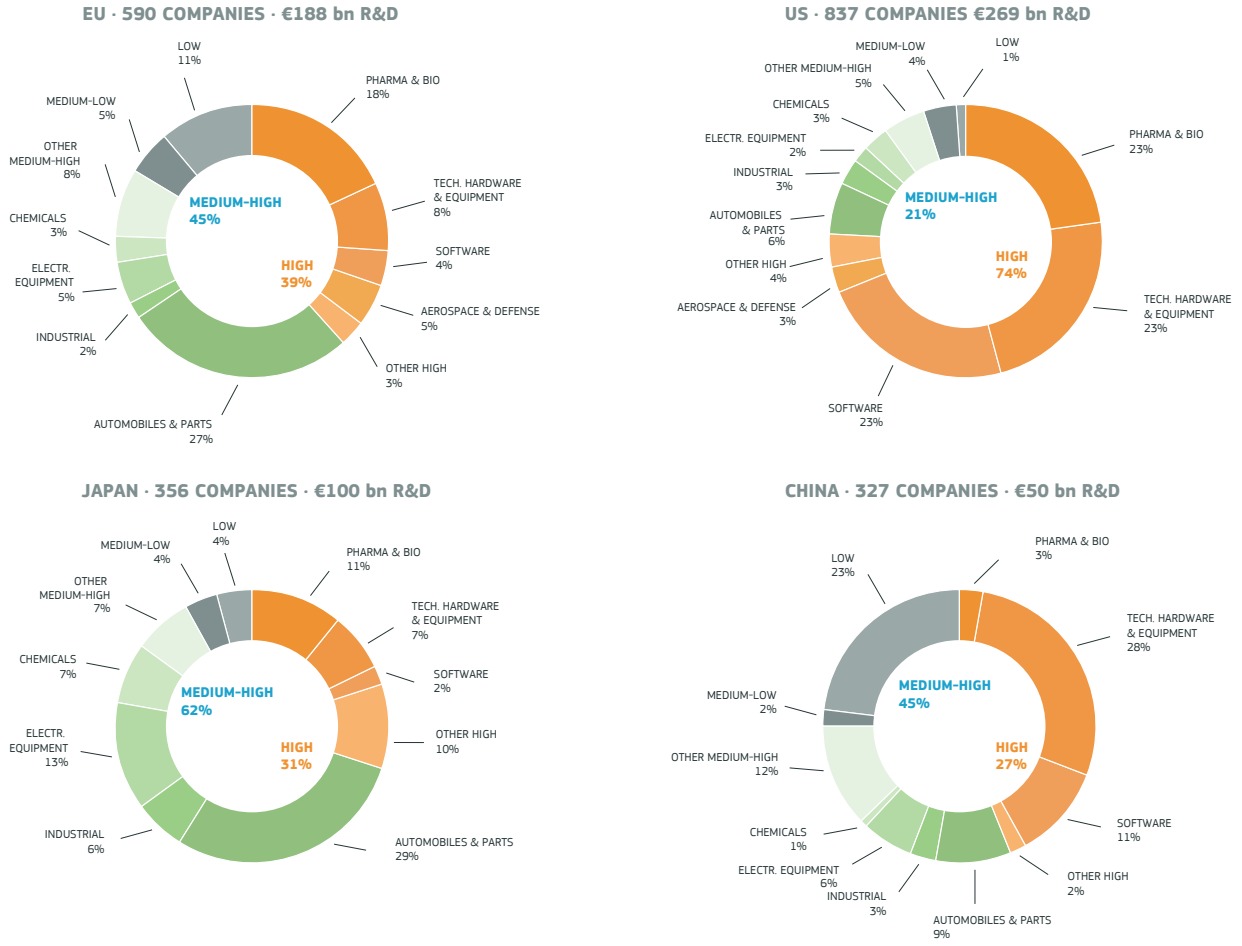

FIGURE 3.2 - R&D SHARES OF SECTORS OF THE MAIN WORLD REGIONS

SECTOR	GLOBAL R&D GROWTH (%)	EU	USA	JAPAN	CHINA
Software & Computer Services	12.3	12.2	11.5	-.8.3	38.3
Pharma & Biotechnology	9.8	13.2	13.0	2.3	27.5
Technology Hardware & Equip.	7.6	0.0	5.1	.47	35.0
Automobiles & Parts	6.7	9.2	-0.6	5.5	14.2
Electronic & Electrical Equipment	5.5	9.6	3.1	3.7	23.7
Health Care Equip. & Services	5.0	20.7	-3.1	10.9	14.1
General Industrials	3.7	10.6	0.5	0.6	14.7
Industrial Engineering	3.3	-1.7	-1.4	9.6	24.8
Leisure Goods	2.9	7.5	13.0	0.2	15.8
Chemicals	2.3	6.7	-3.8	5.0	28.0
Aerospace & Defense	1.2	-0.8	2.8	2.0	44.7
Top 11 Industriles	**7.3**	**8.2**	**7.0**	**3.7**	**28.6**
Other Industries	1.8	4.6	-.68	-0.1	15.4
All Industries	**6.6**	**7.5**	**5.9**	**3.3**	**24.7**

TABLE 3.1. RANKING OF TOP 11 INDUSTRIAL SECTORS BY OVERALL ONE-YEAR R&D GROWTH IN THE 2016 *SCOREBOARD*.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

3.3 | R&D intensity by sector

Table 3.2 provides the list of industrial sectors ranked by worldwide R&D intensity of the main industrial sectors for the 2500 *Scoreboard* companies grouped by main world region.

The following points are observed:

- Most industrial sectors increased their R&D intensity as R&D investment increased more than net sales in 2015/16, e.g. Pharmaceuticals & Biotechnology (14.8 % vs. 14.4%) and Technology Hardware & Equipment (8.3% vs. 8.0%). The opposite happened for Health Care Equipment & Services (3.6% vs. 3.8%).

- Four sectors have an R&D intensity of more than 5.0%: Pharmaceuticals & Biotechnology, IT sectors (Software & Computer Services and Technology Hardware & Equipment) and Leisure Goods (mainly electronic leisure). The sector with the lowest R&D intensity is Oil & Gas Producers (0.3%).

- Among the top 11 sectors, the R&D intensity of EU companies is larger than that of the US and Japan in 5 sectors (Electronic & Electrical Equipment, Technology Hardware & Equipment, General Industrials, Automobiles & Parts and Aerospace & Defence). Japanese companies show higher R&D intensity than the EU and the US in sectors such as Leisure Goods, Health Care Equipment & Services and Chemicals. The R&D intensity of US companies is higher than that of the EU and Japan in Pharmaceuticals & Biotechnology, Software & Computer Services and Industrial Engineering.

- As observed in previous *Scoreboards*, the overall lower average of R&D intensity of the EU companies is due to their large share of low R&D-intensive sectors with very large sales such as Oil & Gas, Mining, Banks, as compared to a similar group of non-EU companies. Conversely, the high average R&D intensity of the US companies is due to their considerable weight in high R&D-intensive sectors (see Figures 3.1 and 3.2 and Table 3.4).

SECTOR	GLOBAL R&D INTENSITY (%)	EU	USA	JAPAN	CHINA
Pharmaceuticals & Biotechnology	15.0	13.8	18.7	11.8	2.7
Software & Computer Services	10.6	10.2	14.7	1.9	10.2
Technology Hardware & Equip.	8.4	15.1	9.3	5.2	6.7
Leisure Goods	5.9	2.7	5.8	5.9	5.1
Electronic & Electrical Equipment	4.7	5.3	4.2	4.5	4.3
Automobiles & Parts	4.3	5.4	4.1	4.0	2.4
Aerospace & Defence	4.3	5.4	3.1	1.4	3.1
Health Care Equipment & Services	3.6	5.1	2.8	8.0	7.8
Industrial Engineering	3.2	3.1	3.3	3.0	3.8
Chemicals	2.9	2.2	3.6	3.9	2.0
General Industrials	2.8	4.8	3.1	3.0	2.2
Top 11 Industries	**6.0**	**6.3**	**7.6**	**4.3**	**4.5**
Other Industries	1.1	1.0	1.5	1.1	1.2
All Industries	**3.8**	**3.2**	**5.8**	**3.3**	**2.5**

TABLE 3.2 – RANKING OF THE TOP 11 INDUSTRIAL SECTORS BY OVERALL R&D INTENSITY IN THE 2016 *SCOREBOARD*

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

3.4 | Growth of net sales by industrial sector and main world region

Table 3.3 shows the ranking of the top 11 industrial sectors by overall one-year growth of net sales for the companies based in the EU, the US, Japan and the RoW group. These sectors account for 86.7% of the total R&D and 51.8% of the total net sales. The following points are observed:

- The majority of large R&D investing sectors increased net sales. Worldwide, the Automobiles & Parts shows the highest one-year growth rate of net sales (7.9%) followed by Health Care Equipment & Services (7.5%) and Software & Computer Services (5.4%).

- Among the small R&D investing sectors (but large in terms of net sales), a significant decrease in net sales was driven by the fall of oil and commodity prices. Oil-related industries reduced net sales by almost 30% and mining industries by more than 20%.

- Among the companies based in the EU, the highest growth rates of net sales are in Health Care Equipment & Services (21.2%) and Leisure Goods (20.7%). The sector showing the lowest one-year sales growth is Industrial Engineering (-4.7%) and Chemicals (-3.8%). *Among the largest sectors in the EU, the highest profitability is shown in Pharmaceuticals & Biotechnology (17.9%) followed by and Health Care Equipment & Services (14.2%) and Software & Computer Services (13.6%).*

- Among the companies based in the US, Technology Hardware & Equipment shows the highest one-year growth rate for sales (5.9%) followed by Pharmaceuticals & Biotechnology (4.1 %). Sectors showing the lowest one-year R&D growth are Industrial Engineering (-10.4%) and Chemicals (-8.3%). *The US-based companies have the highest profitability in Pharmaceuticals & Biotechnology (26.3%), Technology Hardware & Equipment (19.8%) and Software & Computer Services (18.1%).*

- For Japanese companies, the highest one-year growth rate for sales is shown by Pharmaceuticals & Biotechnology (9.1%) and Automobiles & Parts (6.5%). The poorest performance is shown by General Industrials (-6.3%). The profitability of companies based in Japan is generally lower than their counterparts in the EU and the US, for example 10.5% for Pharmaceuticals & Biotechnology. The highest profitability sector for Japanese companies is Health Care Equipment & Services (15.5%).

SECTOR	OVERALL SALES CHANGE (%)	EU SALES CHANGE	US SALES CHANGE	JAPAN SALES CHANGE	CHINA SALES CHANGE
Automobiles & Parts	7.9	13.4	-0.2	6.5	10.0
Health Care Equipment & Services	7.5	21.2	3.8	6.4	20.1
Software & Computer Services	5.4	12.6	1.6	2.6	28.2
Technology Hardware & Equipment	4.9	1.6	5.9	0.1	13.6
Pharmaceuticals & Biotechnology	4.9	7.3	4.1	9.1	9.2
Aeropace & Defence	2.8	5.8	1.5	5.6	-4.5
Electronic & Electrical equipment	2.8	4.8	2.0	1.8	15.5
Leisure Goods	-0.7	20.7	2.7	-1.2	7.5
General Industrials	-2.8	3.9	-3.2	-6.3	-1.3
Industrial Engineering	-5.4	-4.7	-10.4	4.2	-2.0
Chemicals	-7.2	-3.8	-8.3	-1.4	4.7
Top 11 Industries	**2.7**	**6.9**	**0.7**	**2.5**	**8.3**
Other Industries	-10.4	-9.7	-13.6	-4.2	-13.8
All Industries	**-3.6**	**-3.6**	**-4.0**	**0.3**	**-6.2**

TABLE 3.3 - RANKING OF TOP 11 INDUSTRIAL SECTORS BY SALES GROWTH IN THE 2016 *SCOREBOARD.*
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

3.5 | Changes in indicators by region and sector groups

It is interesting to see the distribution of R&D investment of the *Scoreboard* companies across regions and sectors using an aggregation of the 38 industrial sectors into four groups of high-, medium-high-, medium-low- and low-R&D intensity (see Box 1.1 in chapter 1).

The worldwide and domestic distribution of the R&D investment by the 2500 *Scoreboard* companies shows clear differences by world region, illustrating respectively the weight of the region in the world and its specialisation (See Table 3.4):

- Companies based in the EU specialise in medium-high R&D-intensive sectors (44.7% of total R&D of the EU companies) and contribute 33.7% of the total world R&D of that sector group (compared to the EU's 27.0% of total world R&D). EU Industrial sectors accounting for a large share of total world R&D of their sector are Automobiles & Parts (46.5%), Aerospace & Defence (46.2%) and Industrial Engineering (32.1%).

- Those based in the US specialise in high R&D intensive sectors (75.7% of total R&D of the US companies) and contribute 54.5% of the world R&D of that sector group. Industrial sectors accounting for a large share of total world R&D of these sectors are Software & Computer Services (77.2%), Technology Hardware & Equipment (57.7%) and Health Care Equipment & Services (55.1%) compared to the US's 38.6% of total world R&D.

- Japanese companies specialise in medium-high R&D intensive sectors (61.9% of total domestic R&D) while contributing 24.8% of the world R&D of that sector group. The industrial sectors with highest weight in the total world R&D are Leisure Goods (61.4%), General Industrials (29.5%) and Chemicals (30.0%) compared to Japan's 14.4% share of total world R&D.

Region	Sector								
	High share (%)		Medium-high share (%)		Medium-low share (%)		Low share (%)		Region's world share (%)
	World	Domestic	World	Domestic	World	Domestic	World	Domestic	
EU	19.8	39.3	33.7	44.7	36.8	5.4	44.0	10.6	27.0
US	54.5	75.7	20.8	19.4	33.9	3.5	8.4	1.4	38.6
Japan	8.1	30.2	24.8	61.9	14.7	4.1	8.3	3.8	14.4
China	5.9	44.1	6.2	31.0	2.7	1.5	25.7	23.4	7.2

TABLE 3.4 - WORLD AND DOMESTIC R&D DISTRIBUTION OF THE 2016 *SCOREBOARD* COMPANIES BY SECTOR GROUPS FOR THE MAIN REGIONS

Note : Sector groups as defined in Box 1.1.

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

4

THE TOP 1000 R&D **INVESTORS IN THE EU**

4 The top 1000 R&D Investors in the EU

This chapter discusses the R&D and economic trends of companies based in Member States of the EU. This specific analysis is based on an extended sample of companies representing the top 1000 R&D investors in the EU, i.e. the 590 EU *companies included in the world top 2500 sample and 410 additional companies based in the EU, all of which have R&D of €6m or more. The main questions addressed are firstly about the one-year changes in R&D and economic indicators of companies based in the top 10 Member States by level of R&D investment. The second question regards the long-term trends of company results, namely the rate of growth of R&D and net sales and profitability for companies based in the three largest Member States of the EU.*

Key findings

- Companies based in Germany, the top R&D investor, continued to increase considerably R&D in 2015, at 10.5%, above the world (6.6%) and EU (7.4%) averages. Companies based in the UK showed a significant increase of R&D (4.1%), and French companies a more modest R&D growth rate (1.9%).
- Apart from the three top Member States, among the group of largest EU countries, those whose companies increased R&D above the EU average were Ireland (29.6% due to acquisitions), Italy (10.5%) and Denmark (8.6%). Among the large countries, only the companies based in Finland decreased R&D (-3.8%).
- The analysis of 10-year trends of R&D and economic results for companies based in Germany, the UK and France show the effects of the crisis in 2008-2009 and a recovery over 2010-2012, especially for the German companies. However over the past year the recovery seems to be stalling with companies from the three countries showing a fall in net sales. The latter is mostly due to the decrease of net sales of large companies in terms of sales but with relatively small R&D, e.g. oil companies (Total, Shell,BP, ENI) and banks (HSBC).

4.1 | Overview of the EU 1000 companies

The composition of the sample of the EU 1000 companies across industrial sectors and countries is found in Annex 3. This sample, as well as the global 2500, shows a high concentration of companies by sector and country. The 15 largest sectors in terms of R&D account for 78% of the companies. The distribution of companies for these sectors and for countries including more than 5 companies is shown in Table 4.1 (page 41).

SECTOR	R&D 2015 (€ BN)	Nr FIRMS	AT	BE	DE	DK	ES	FI	FR	IE	IT	LU	NL	SE	UK
Automobiles & Parts	50.3	47	4		18			1	6		5		2	2	9
Pharmaceuticals & Biotechnology	37.3	133	1	5	14	11	4	1	20	8	4	1	8	9	43
Technology Hardware & Equipment	15.2	41	2	1	6	1		2	6	1			6	5	10
Electronic & Electrical equipment	10.2	69	3	3	14	2		4	9	1	4	1	5	4	19
Aerospace & Defence	9.8	24			2		1		7		2		1	1	9
Industrial Engineering	9.2	104	5	2	37	3	3	7	7	2	7	2	4	11	14
Banks	9.2	33		2	7	2	2		2	2	2		2	2	7
Software & Computer Services	8.2	112	2		20	2	2	5	17	1		1	3	5	53
Chemicals	5.6	42	2	3	14	1		3	3				3	3	10
Health Care Equipment & Services	5.0	44		2	13	3			3	2			2	5	13
Fixed Line Telecommunications	4.3	10	1		1	1	1		1		1			1	2
Geneal Industrial	4.0	35		1	10	1	1	1	2	1	2	2	2	7	5
Oil & Gas Producers	2.8	8	1				1	1	1		1				2
Food Producers	2.7	26	1		2	1		2	3	2			5		8
Support Services	2.1	49			12				3	1			1	6	26
Top 15	**175.9**	**777**	**22**	**19**	**170**	**28**	**15**	**27**	**90**	**21**	**28**	**7**	**44**	**61**	**230**
Others	17.3	223	7	11	47	6	7	12	27	4	15	8	5	22	44
Total	**193.2**	**1000**	**29**	**30**	**217**	**34**	**22**	**39**	**117**	**25**	**43**	**15**	**49**	**83**	**274**

TABLE 4.1- DISTRIBUTION OF THE EU 1000 COMPANIES ACROSS MAIN SECTORS AND COUNTRIES*.
* INCLUDING ONLY COUNTRIES WITH MORE THAN 5 COMPANIES
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

4.2 | Trends of companies in the top 10 Member States of the EU

There are 906 companies based in the top 10 Member States accounting for 97.4 % of the total R&D of the 1000 EU sample (see table 4.2).

The overall performance of the EU group is largely driven by the performance of companies based in Germany, France and the UK, accounting for 66.7% of the total R&D and 65.6% of total net sales (see Tables 4.2 and 4.3).

In 2015, by far, the 217 German companies made the largest contribution to the results of the EU 1000 sample. These companies, accounting respectively for 36.7% and 29.6% of the total R&D and net sales, increased R&D by 10.5% and net sales by 8.5%. These results reflect to a large extent the performance of the German companies in the Automobiles & Parts sector (9.6% in R&D and 15.2% in net sales). This sector accounts for 52.3% of R&D and 35.0% of net sales of the group of German companies. *Among the large companies in this sector, double-digit R&D growth was shown by automotive sector companies Daimler, BMW and ZF. German companies showed also good performance in other sectors, namely double-digit R&D and net sales growth in health and ICT-related industries. In particular, double-digit R&D growth was shown by large German companies such as Bayer, Boehringer Sohn, SAP and Siemens.*

The 276 companies from the UK, accounting for 15.4% and 19.2% of the total R&D and net sales of the EU 1000 sample, increased R&D by 4.1% but showed a very large decrease in net sales (-20.9%). *The largest contribution to R&D growth was made by the Pharmaceuticals (7.7%) and Banks (17.9%) sectors. The negative figure on net sales is mostly due to Oil and Mining related companies (e.g. Shell, BP, Rio Tinto and Anglo American).*

The 117 companies based in France, accounting respectively for 15.0 % and 17.0% of the total R&D and net sales of the EU 1000 sample, slightly increased R&D investment (1.9%) and decreased net sales 3.1%. The largest contribution to the R&D growth was made by the Automobiles & Parts (9.1%) and Pharmaceuticals & Biotechnology (6.3%) and the poorest performance was shown by the Industrial Engineering sector (-45.0%). The latter had also the worst performance in terms of net sales (-47.2%).

Apart from the group of the three top countries, among the group of largest EU countries, those whose companies increased R&D above the EU average were Ireland (29.6% in R&D and 2.0% in sales), Italy (10.5% in R&D and 0.2% in sales), Denmark (8.6% in R&D and 8.8% in sales) and Spain (8.1% in R&D and -1.4% in sales). The outstanding R&D growth of the Irish group was largely due to the R&D growth of two US companies with headquarters in Ireland, both of which grew substantially through making large acquisitions. *These companies made also the largest contribution to the R&D growth of their sectors: From the Pharmaceuticals sector, Allergan (146.7% after Actavis combined with Allergan) and from the Health Care Equipment sector, Medtronic (35.6% after Medtronic acquired Covidien).*

Companies based in Finland continued to decrease R&D in 2015 (-3.8%), but a lower pace compared with 2014 (-15.7%), mostly due to Nokia (-7.9%), which accounts for 63.9% of the total R&D of Finnish companies.

In term of net sales, several countries showed negative results, the poorest figures in net sales were for companies based in the UK (-20.9%), as mentioned above, mostly due to oil and mining related companies as the prices of these commodities fell. All the countries except Finland showing negative or near zero sales growth have large oil companies (UK –BP & Shell; France – Total; Spain – Repsol; Italy – ENI).

It is important to remember that in many countries, the aggregate country indicators depend to a large extent on the figures of a very few firms. This is due, either to the country's small number of companies in the *Scoreboard* or to the concentration of R&D in a few large firms. For example:

- Ericsson and Volvo account for 57.0% of the total R&D of the Swedish companies and therefore largely determined the overall R&D growth of their group (1.4%). Both decreased R&D (Ericsson by 3.5% and Volvo by 2.4%) offsetting the good R&D figures of smaller companies such as Sandvik, Hexagon, Atlas Copco and Electrolux.

- The Automobiles & Parts sector accounts for 52.3% of the R&D of companies based in Germany. Four companies in this sector, accounting for 37.6 % of the German companies' R&D, contributed a large part of that country's R&D growth: Daimler (515.6%), ZF (55.9%), BMW (13.2%) and Volkswagen (3.8%).

COUNTRY	NO. OF COMPANIES	R&D IN 2015/16 (€ BN)	R&D SHARE WITHIN EU (%)	R&D ONE YEAR GROWTH (%)	NET SALES ONE YEAR GROWTH (%)
Germany	217	70.8	36.7	10.5	8.5
UK	276	29.8	15.4	4.1	-20.9
France	117	28.9	15.0	1.9	-3.1
The Netherlands	49	14.3	7.4	4.2	1.1
Italy	45	12.4	6.4	10.5	0.2
Sweden	83	10.0	5.2	1.4	7.6
Ireland	24	8.8	4.6	29.6	2.0
Spain	22	4.7	2.5	8.1	-1.4
Denmark	34	4.4	2.3	8.6	8.8
Finland	39	3.9	2.0	-3.8	-4.0
Top 10 countries	**906**	**188.2**	**97.4**	**7.4**	**-2.9**
Other countries	94	5.0	2.6	6.9	-9.4
Total EU	**1 000**	**193.2**	**100.0**	**7.4**	**-3.2**

TABLE 4.2 - R&D TRENDS FOR COMPANIES BASED IN THE TOP 10 EU MEMBER STATES

Note: For the sample of 1000 EU companies.

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

INDUSTRY	EU 1000 R&D (€BN)	GERMANY 1-YEAR CHANGE (%)		FRANCE 1-YEAR CHANGE (%)		UK 1-YEAR CHANGE (%)	
		R&D	SALES	R&D	SALES	R&D	SALES
Automobiles & Parts	50.3	9.6	15.2	9.1	8.8	-4.0	-0.6
Pharmaceuticals & Biotechnology	37.3	13.6	11.4	6.3	3.5	7.7	0.1
Technology Hardware & Equipment	15.2	20.7	28.3	5.6	5.3	0.9	9.4
Electronic & Electrical Equipment	10.2	10.1	5.8	7.6	6.7	10.2	8.6
Aerospace & Defence	9.8	6.8	11.1	-3.4	14.6	4.6	2.5
Industrial Engineering	9.2	11.2	8.6	-45.0	-47.2	0.7	-12.5
Banks	9.2	22.7	3.1	8.9	6.6	17.9	-11.9
Software & Computer Services	8.2	14.5	13.6	15.6	15.6	9.7	7.9
Chemical	5.6	4.1	-0.7	22.4	12.9	10.2	4.4
Health Care Equipment & Services	5.0	12.5	15.9	28.4	18.5	4.5	4.7
Fixed Line Telecommunications	4.3	10.9	10.5	-0.8	2.0	-38.8	6.0
General Industrials	4.0	1.7	-11.2	11.8	13.6	0.9	3.3
Top 12 industries	**168.3**	**10.6**	**10.6**	**5.3**	**4.3**	**5.9**	**-4.5**
Other industries	24.9	9.4	4.2	-10.0	-8.0	-2.9	-27.3
Total	**193.2**	**10.5**	**8.5**	**1.9**	**-3.1**	**4.1**	**-20.9**

TABLE 4.3 - GROWTH OF R&D AND NET SALES FOR THE FOR GERMAN, FRENCH AND UK COMPANIES BREAK DOWN BY INDUSTRIAL SECTOR.

Note: For the sample of 1000 EU companies

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD

4.3 | Performance of companies based in the 3 top EU Member States

The annual growth rates of R&D investment, net sales and profitability of companies based in Germany, France and the UK is provided respectively in figures 4.1, 4.2 and 4.3 for the period 2006-2015. These figures are based on our history database comprising R&D and economic indicators over the whole 2006-2015 period from the EU 1000 data-set, including 159 from Germany, 87 from France and 165 from the UK.

The trends observed in these figures show the behaviour of these companies including the effects of the crisis that began in 2008. The following points are observed:

- Companies based in Germany showed a good performance over the period 2010-2012, recovering the levels of growth prior to the crisis, especially in terms of R&D. In the last period, they continued to increase R&D at a rapid pace, maintaining a stable but low level of profitability and showing an outstanding recent recovery in term of net sales since Germany has no large oil or mining companies.

- Companies based in France showed a recovery in R&D and net sales in 2010-2011, however, over the period 2012-2014 they presented an important decline in R&D growth and also an important decrease in the growth rate of net sales. Over the last period French companies show a modest recovery of R&D growth but with the rate of growth of net sales still declining. The average profitability of the French companies shows a decreasing trend since 2011 that seems to stabilise over the last period.

- Companies based in the UK showed a strong recovery of R&D and net sales in 2010-2011 that was broken up in 2012. In 2012-2013 their R&D investment resumed to grow at significant pace but with a level of net sales practically unchanged. In 2014, the R&D level remained practically unchanged but with significant decrease of net sales. Over the last period, the R&D investment of the companies based in the UK resumed to grow but along a strong decrease in net sales (as explained above, due to the fall in commodity prices). The average profitability of the UK companies, like their French counterparts, shows a high but decreasing trend in the period 2010-2014 that seems to be stabilised over 2014-15.

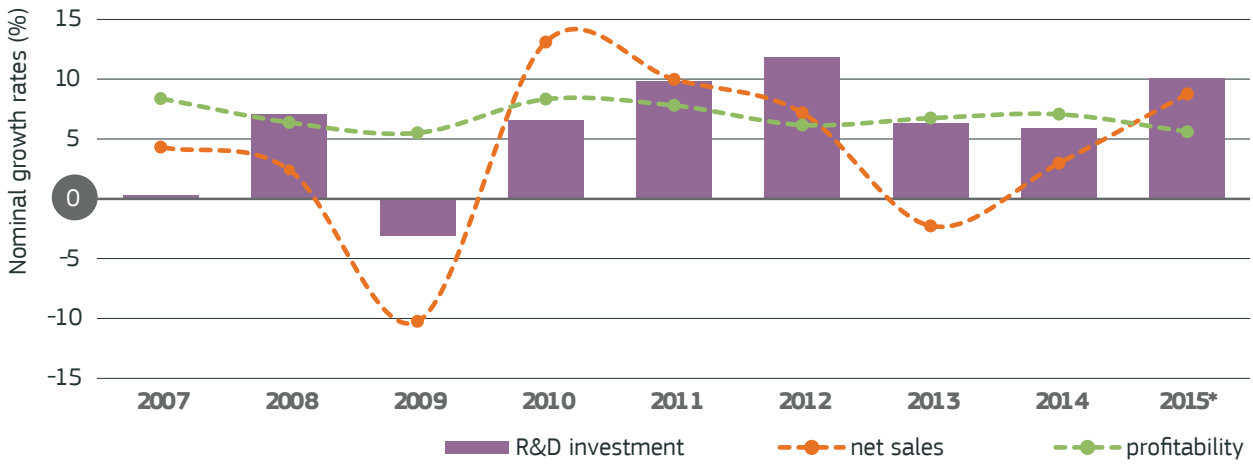

FIGURE 4.1. ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE GERMAN COMPANIES.
Note 1: * Figures for 2015 for the whole sample of 217 German companies were 10.5% for R&D, 8.4 for net sales and 5.2% profitability.
The diagram represents 124 companies for which R&D and net sales are available for the 10 years period.
Note 2: Profitability defined as the ratio of operating profits over net sales.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

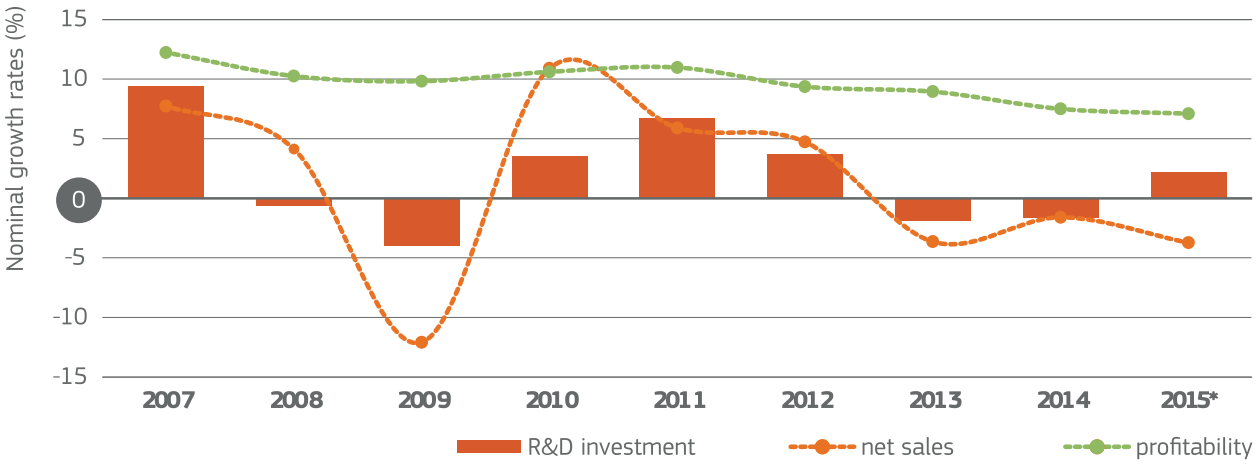

FIGURE 4.2. ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE FRENCH COMPANIES.
Note1 : * Figures for 2015 for the whole sample of 117 French companies were 1.9% for R&D, -3.1% for net sales and 6.4% profitability.
The diagram represents 74 companies for which R&D and net sales are available for the 10 years period.
Note 2: Profitability defined as the ratio of operating profits over net sales.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

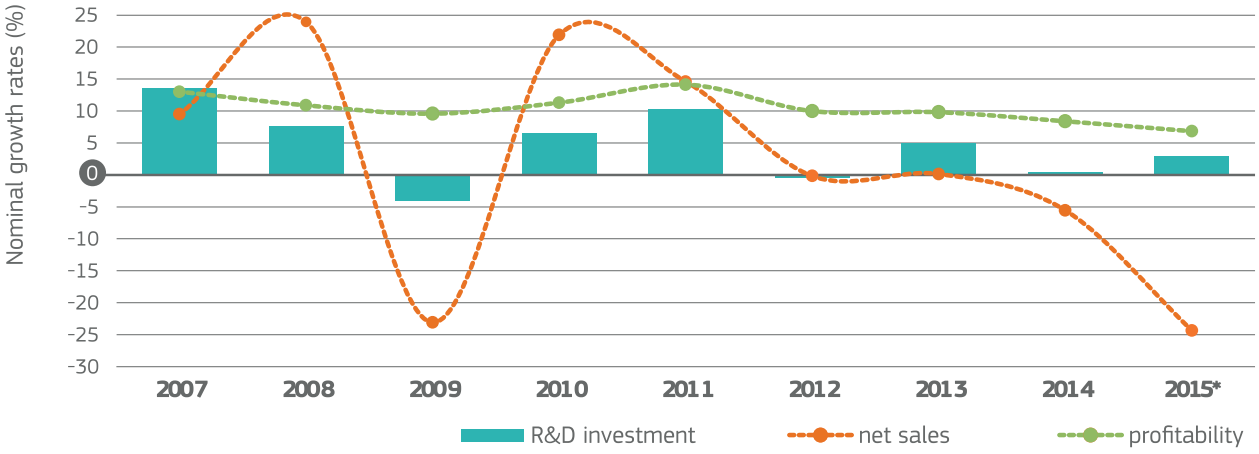

FIGURE 4.3. ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE UK COMPANIES.
Note 1: * Figures for 2015 for the whole sample of 276 UK companies were 4.1% for R&D, -20.9 for net sales and 7.5% profitability.
The diagram represents 112 companies for which R&D and net sales are available for the 10 years period.
Note 2: Profitability defined as the ratio of operating profits over net sales.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

4.4 | R&D intensity trends by companies based in selected Member States

In 2015/16, for the third consecutive year, the average R&D intensity of the EU-1000 companies increased because of the higher increase of R&D investments compared to that of net sales, 7.4% vs. -3.2% (see Figure 4.4).

It is important to remember that a few large but low R&D intensity sectors have a big effect on some country average R&D intensities. One example is Oil & Gas Producers and Banks for the UK. In the 2015/16, these sectors contributed 52.0% of the UK's *Scoreboard* company sales, so if these two sectors had been left out, the average R&D intensity of UK companies would have substantially increased.

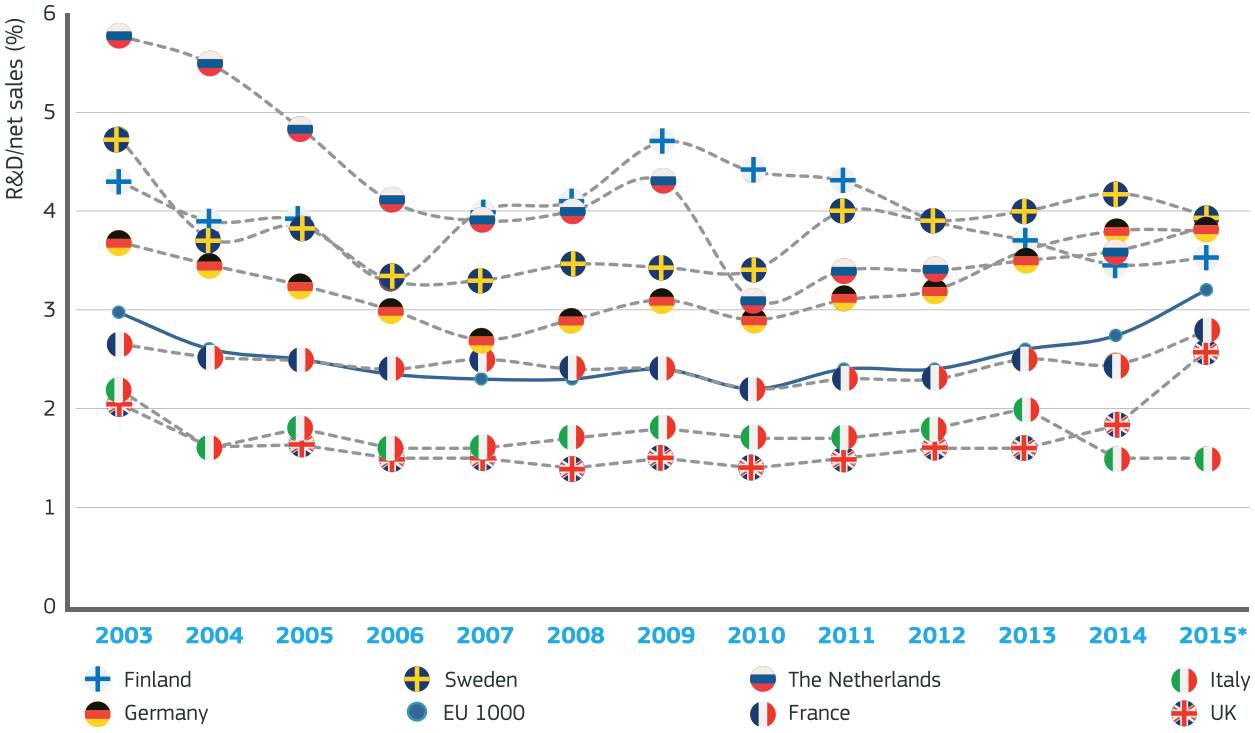

FIGURE 4.4. TRENDS IN R&D INTENSITIES FOR EU SCOREBOARD COMPANIES IN SELECTED MEMBER STATES.

Note: * Figures for 2015 for the current sample of EU 1000 companies from the respective countries and for previous years for samples of each Scoreboard.

Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

5

PERSISTENCE AND PATTERNS **OF R&D GROWTH**

5 Persistence and Patterns of R&D Growth

Policymakers seeking to encourage companies to increase their R&D investments require a sound understanding of the realities of the dynamics of firm-level R&D investment. Improving our knowledge of growth processes of R&D investment can help to improve the effectiveness of policies aimed at stimulating R&D investment. This chapter describes the R&D growth paths of firms by presenting new evidence from the *Scoreboard* dataset, and discusses some policy implications.

The objective of this chapter is to provide a clear and coherent picture of the growth of R&D investment in companies, to have a better understanding of the broad features of the dynamics of R&D investment. To this end, we focus on the total R&D investment data, reported at the company level, for the *Scoreboard* companies, and track their R&D dynamics over time, for the period 2000-2014. Different quantitative techniques are used to highlight different facets of R&D investment dynamics.

Key findings

- Most firms have a positive but modest growth rate of R&D investment from one year to the next. However, in each year a handful of firms experience rapid growth or decline of R&D.
- Focusing on a selection of large firms that experienced rapid R&D growth, and identify the names and R&D growth rates of these 'superstar' performers. Rapid R&D growth is not confined to certain industries: instead we see that these firms are observed in all sectors.
- We also investigate the time profiles of R&D investment over the last dozen years, for leading firms in selected sectors, using longitudinal company-level line-plots. These plots underline the heterogeneity of R&D paths, even for firms in the same sector. Some firms have rapid growth, alongside their rivals who may have stagnating R&D. For example, in the ICT services sector, Microsoft and Google boosted their R&D investment while Fujitsu experienced decline in R&D. Hence, not all firms in the same sector have the same R&D investment strategies.

5.1 | Introduction

A longitudinal dataset for Scoreboard companies was constructed by merging cross-sectional data for individual years, covering the period 2000-2014, although data coverage varies across years. This allowed us to track the evolution of key variables (in particular, R&D investment and total sales) for each company in the database.

Annual growth rates of R&D investment are calculated in the usual way (Tornqvist et al., 1985)[10] as follows: Growth rate of $R\&D_{it} = \log(R\&D)_{it} - \log(R\&D)_{it-1}$, for company i in year t. Amounts are converted into Euros for all companies, and statistics for R&D and sales are presented in millions of Euros (unless otherwise stated)[11].

5.2 | Growth rates distribution

We begin our analysis by looking at the distribution of growth rates, to better appreciate the variation across companies in terms of the rates of R&D growth that they can achieve. Figure 5.1 below plots the growth rates distribution for the years 2014, 2013 and 2012. Instead of a normal or 'Gaussian' distribution, we observe a heavy-tailed 'tent-shaped' distribution, the form of which is stable across years. While most firms have positive but modest

[10] Tornqvist L., Vartia P., Vartia Y.O. (1985). How Should Relative Changes Be Measured? American Statistician 39(1), 43-46.

[11] Data cleaning involves focusing only on firms with positive sales, with R&D intensity less than 100%, and where R&D investment is non-missing and positive.

R&D growth rates, a handful of firms have growth of R&D expenditure that is either very fast (for large positive values of the log growth rate) or that is large and negative, indicating rapid decline (for large negative values of log growth rate). While most firms do not experience much change in R&D from year to year, a significant minority of rapid R&D growth firms have a disproportionately large effect on the overall R&D landscape.

For the year 2014, the interquartile range (i.e. the 50% of observations that are in the centre) runs from -1.5% to +18.9%[12]. This indicates that most firms have mildly positive growth rates of R&D. Most firms in our sample tend to increase, rather than decrease, their R&D investments from one year to the next (although this is probably due to how firms are selected for inclusion in our Scoreboard sample). 10% of firms have an R&D growth rate of 48.6% or more, and 1% of firms have an R&D growth rate of 228% or more.

Figure 5.1 shows that a handful of companies experience very fast growth of R&D from one year to the next. But what are the identities of the fastest-growing R&D companies? What are their names, their sectors of activity, their sizes? To investigate this, we present some details on the top growth companies.

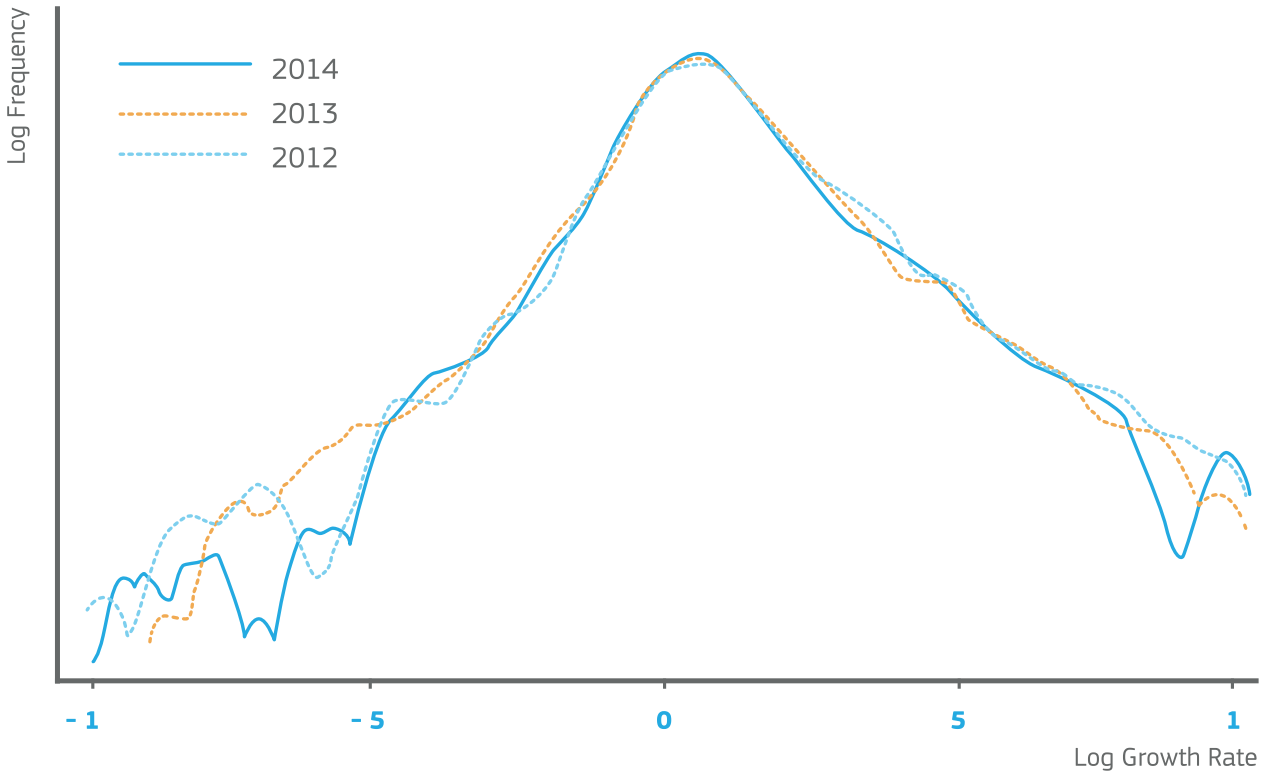

FIGURE 5.1 - DISTRIBUTION OF GROWTH RATES OF R&D INVESTMENT, FOR RECENT YEARS.

Selection of large companies with rapid R&D growth

Table 5.1 below shows a selection of 34 companies that experience rapid growth of R&D investment in 2014. Inclusion in the selection of firms in Table 5.1 requires that a firm have a relatively fast growth rate of R&D investment (log growth higher than 0.5) and with net sales in 2014 greater than 1000, and with R&D investment in 2013 of at least 20 (to avoid emphasizing fast R&D growth that is due to starting from a low base level for R&D investment).

[12] In terms of log growth rates, the values are -0.0155 to 0.1887, with 10% of firms having an R&D growth rate of 0.3964 or more, and 1% having a growth rate of 1.1870 or more.

The companies are found in all sectors: whether they be high-tech sectors such as ICT services, ICT producers and Pharmaceuticals, or even relatively mature technology sectors such as Services or Transport. The largest company (in terms of sales) from this selection of companies is Softbank Group, from the ICT services sector, whose R&D investment jumped up from 24m EUR in 2013 to 74m EUR in 2014. Tesla motors, and Tata motors, both from the 'Automobiles and parts' sector, also more than doubled their R&D investment during this period. Other well-known companies in this selection of fast-growing R&D investors include Lenovo and Facebook.

The following points are observed:

- Most firms hardly change their R&D investment from one year to the next.
- In each year, a handful of firms experience rapid decline in R&D or growth in R&D.
- These latter firms make a disproportionate contribution to industrial dynamics, because they are often large firms with a large, and rapidly growing, share of R&D.
- Firms experiencing rapid R&D growth rates are found in all sectors.

Table 5.1 (page 73 and 74) shows that some firms are able to increase their R&D investment remarkably quickly in the space of one year. But what about the longer-term performance of these companies? Are there any patterns in the longer-term growth profiles of R&D investment? Do firms in the same sector share the same trends in R&D investment? Which firms are growing and which firms are stagnating?

To investigate these questions, we now take a sector-by-sector approach that provides a more detailed view on the time profiles of R&D investment.

BVD COMPANY NAME	COUNTRY	NET SALES (€M)	SECTOR GROUP	R&D IN 2014 (€M)	21R&D IN 2013 (€M)	R&D GROWTH RATE (%)
SOFTBANK GROUP CORP	JP	59 195	ICT SERVICES	74	24	207.2%
LENOVO GROUP LIMITED	HK	38 132	ICT PRODUCERS	958	581	65.1%
TATA MOTORS LIMITED	IN	33 190	AUTOMOBILES & PARTS	2 346	1 123	108.9%
COMMONWEALTH BANK OF AUSTRALIA	AU	15 666	SERVICES	370	211	75.3%
SHANGHAI CONSTRUCTION GROUP CO., LTD	CN	14 879	OTHER	140	73	91.1%
THERMO FISHER SCIENTIFIC INC.	US	13 911	HEALTH	569	326	74.7%
ALLERGAN PLC	IE	10 759	PHARMACEUTICALS & BIOTECHNOLOGY	894	508	76.0%
FACEBOOK, INC.	US	10 268	ICT SERVICES	2 196	1 165	88.4%
CHINA RAILWAY ERJU CO., LTD (CREC)	CN	9 336	OTHERS	64	36	78.4%
CHINA GEZHOUBA GROUP CO., LTD	CN	9 272	OTHERS	105	43	146.7%
BRF S.A.	BR	8 997	OTHERS	60	21	181.1%

TABLE 5.1 - DETAILS ON A SELECTION OF 34 LARGE COMPANIES WHICH HAD THE FASTEST GROWTH RATES OF R&D INVESTMENT OVER 2013-2014.
TABLE CONTINUES ON NEXT PAGE →

BVD COMPANY NAME	COUNTRY	NET SALES (€M)	SECTOR GROUP	R&D IN 2014 (€M)	21R&D IN 2013 (€M)	R&D GROWTH RATE (%)
MAHINDRA & MAHINDRA LIMITED	IN	8 306	AUTOMOBILES & PARTS	199	88	127.3%
BAIDU INC.	CN	6 603	ICT SERVICES	940	553	69.9%
ISRAEL CORPORATION LIMITED	IL	5 033	INDUSTRIALS	138	82	67.0%
BOE TECHNOLOGY GROUP CO., LTD	CN	4 774	ELECTR. & ELECTRICAL EQUIPMENT	137	76	80.5%
ANHUI JIANGHUAI AUTOMOBILE CO., LTD	CN	4 235	AUTOMOBILES & PARTS	340	164	107.0%
CHINA CSSC HOLDINGS LIMITED	CN	3 703	INDUSTRIALS	103	53	94.1%
AVAGO TECHNOLOGIES LIMITED	SG	3 516	ICT PRODUCERS	572	273	109.3%
GEELY AUTOMOBILE HOLDING LIMITED	KY	2 926	AUTOMOBILES & PARTS	89	51	74.2%
TOFAS TÜRK OTOMOBIL FABRIKASI A.S.	TR	2 640	AUTOMOBILES & PARTS	148	39	274.9%
TESLA MOTORS	US	2 634	AUTOMOBILES & PARTS	383	191	100.3%
SHENZHEN O-FILM TECH COMPANY LIMITED	CN	2 586	ELECTR. & ELECTRICAL EQUIPMENT	115	65	76.8%
INTERCONTINENTAL EXCHANGE, INC	US	2 547	SERVICES	64	37	73.3%
DMG MORI AG	DE	2 229	INDUSTRIALS	91	52	76.1%
CHINA ZHONGWANG HOLDINGS LIMITED	KY	2 150	INDUSTRIALS	44	24	81.2%
CHINA LESSO GROUP HOLDING LIMITED	KY	1 995	INDUSTRIALS	62	33	87.3%
YINGLI GREEN ENERGY HOLDING COMPANY LIMITED	KY	1 740	ELECTR. & ELECTRICAL EQUIPMENT	76	39	94.0%
GOERTEK INCORPORATED COMPANY	CN	1 670	ELECTR. & ELECTRICAL EQUIPMENT	104	62	69.2%
SCIENTIFIC GAMES CORP	US	1 471	TRANSPORT	136	53	158.1%
ZEBRA TECHNOLOGIES CORP	US	1 376	ELECTR. & ELECTRICAL EQUIPMENT	124	75	65.8%
GOPRO, INC	US	1 148	OTHERS	125	61	105.9%
MITAC HOLDING CORPORATION	TW	1 093	ICT PRODUCERS	75	21	256.4%
N BROWN GROUP PLC	GB	1 070	OTHERS	62	22	184.0%
HANERGY THIN FILM POWER GROUP LIMITED	BM	1 021	ALTERNATIVE ENERGY	55	21	163.5%

TABLE 5.1 – DETAILS ON A SELECTION OF 34 LARGE COMPANIES WHICH HAD THE FASTEST GROWTH RATES OF R&D INVESTMENT OVER 2013-2014.
Note: Selection criteria: we include only firms with a relatively fast growth rate of R&D (log growth higher than 0.5), with net sales in 2014 of more than 1000, and with R&D investment in the base year of at least 20. Growth rates g in the last column calculated as g = [R&D(2014)-R&D(2013)]/R&D(2013). Sales and R&D are expressed in million of Euros.
Source: The 2016 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

5.3 | R&D trajectories of the largest R&D investors in specific sectors

In what follows, we consider the R&D trajectories of the largest investors in specific sectors[13].

Automobiles and parts sector

Figure 5.4 below shows that Volkswagen has invested heavily in R&D since around 2010, while its competitors in the automobiles & parts industry have increased their R&D investments only gradually (Robert Bosch, BMW) or else have stagnated (GM, Ford, Daimler).

Our focus on the world's largest R&D investors (sorted according to R&D investment in the year 2014) makes us potentially vulnerable to sample selection bias, because firms with stagnating or declining R&D are likely to exit the dataset and hence be excluded from the analysis. Despite this possible bias, however, we still find much heterogeneity in growth paths, with fast-R&D-growth firms operating alongside stagnating or declining R&D investors. Without this sample selection bias, we would expect to find even more firms experiencing rapid decline in R&D investments.

R&D investment of some firms seems to have suffered from the 2008 financial crisis (in particular, Toyota, GM, and Ford). For other firms, however, the financial crisis does not appear to strongly interrupt the trend of stagnating R&D investment levels. Our results do not suggest that the 2008 financial crisis, by itself, is to blame for stagnating R&D levels. The crisis may have hit some companies relatively hard (e.g. US companies), but these firms have also recovered to some extent.

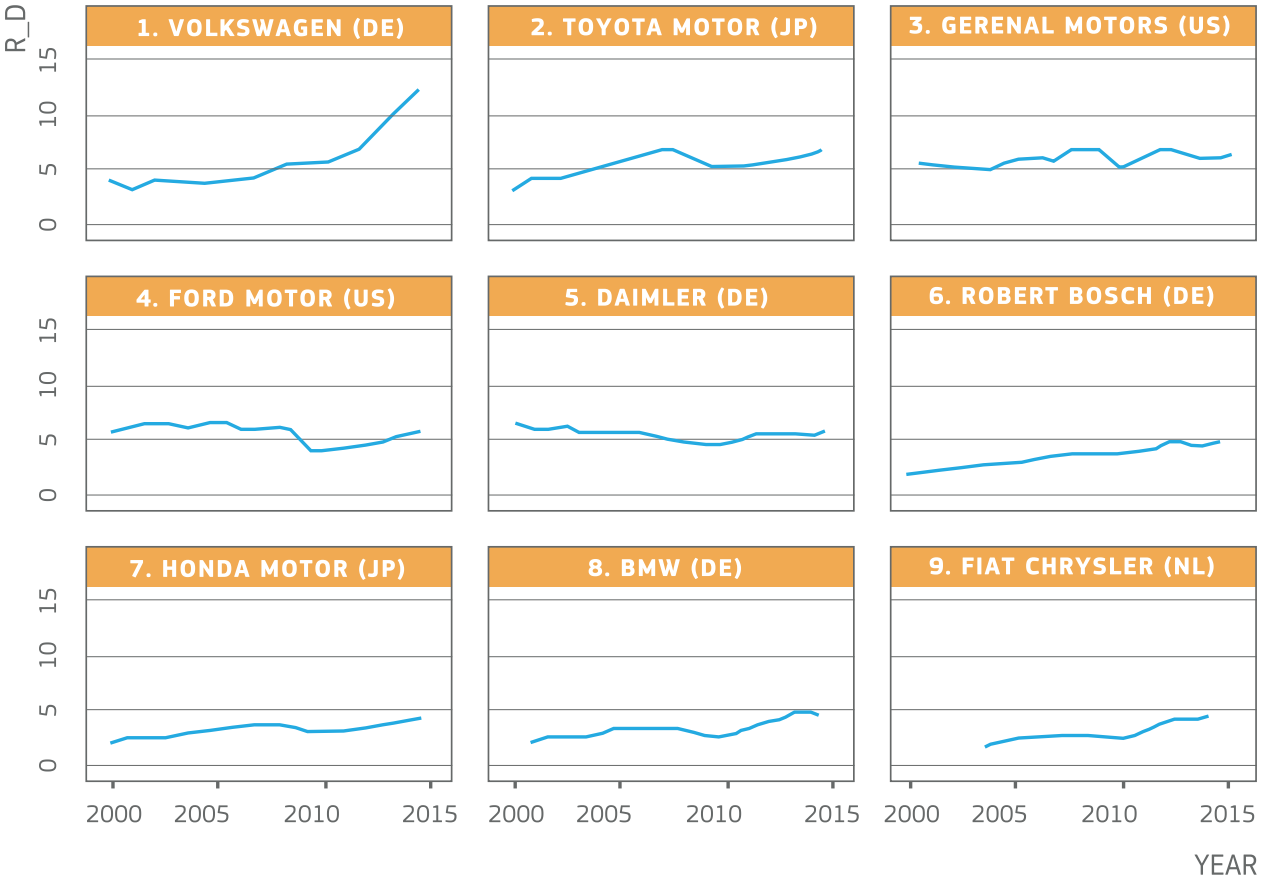

FIGURE 5.4 - LINE PLOT OF R&D INVESTMENT OVER TIME, BY COMPANY, FOR THE LARGEST R&D INVESTING COMPANIES IN THE "AUTOMOBILES AND PARTS" SECTOR.
Note : Firms sorted by R&D investment in 2014, in billions of Euros.

[13] Sectors are defined in a rather broad way, following a typical classification applied in the Scoreboard.

Electronic and Electrical Equipment sector

Figure 5.5 vividly illustrates how R&D growth in the "Electronics and Electrical equipment" industry has been dominated by Samsung. Similarly to the case of Volkswagen among automobile companies, Samsung's meteoric increases in R&D investing have set it apart from its rivals, perhaps because Samsung has exploited opportunities in the emerging smartphone sector. Hon Hai, Danaher, and Schneider have steadily increased their R&D investments (although starting from a low base): the R&D investment of Danaher has increased tenfold over the period 2000-2014, and Hon Hai has had even faster growth of R&D investment (from 0.06m EUR in 2001 to 1.27m EUR in 2014). Other firms, such as Siemens and Hitachi, experienced stagnating R&D levels. Again, it is not always the case that the 2008 financial crisis interrupts any previous trend in R&D investment. Instead, companies have considerable heterogeneity in their R&D investment dynamics, even if they are within the same sector.

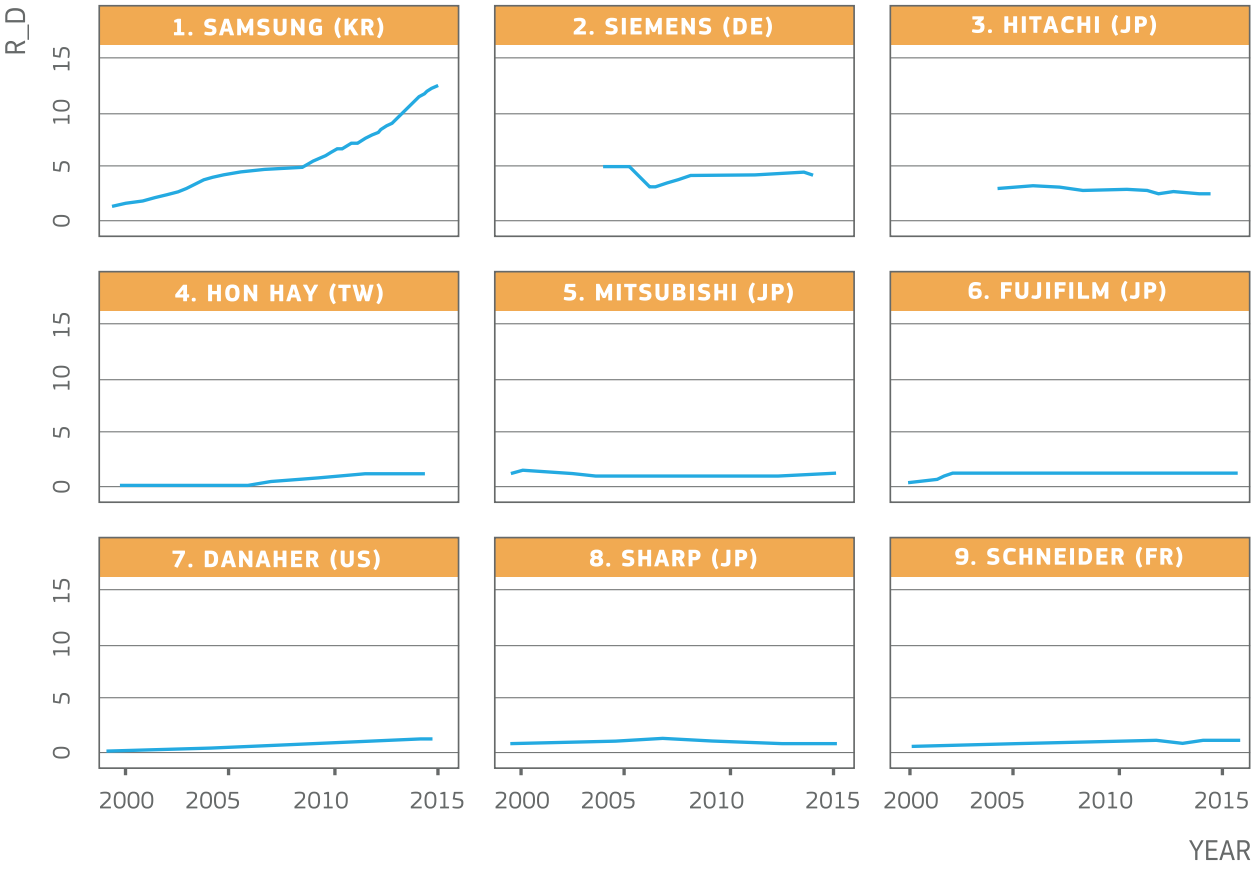

FIGURE 5.5 - R&D INVESTMENT OVER TIME, BY COMPANY, FOR THE LARGEST R&D INVESTING COMPANIES IN THE "ELECTRONIC AND ELECTRICAL EQUIPMENT" SECTOR.

Note : Firms sorted by R&D investment in 2014, in billions of Euros.

ICT producers sector[14]

We now turn to the ICT producers sector (see Figure 5.6). Intel, Apple, Qualcomm and EMC all increased their R&D investments, while some other firms had a bumpier ride. In Europe, Alcatel-Lucent, Nokia and Ericsson have had

[14] Comprising companies which are also engaged in the ICT services sector, e.g. Apple.

stagnating R&D investment levels in the recent decade (Alcatel-Lucent has been recently merged with Nokia). These changes don't appear to be entirely attributable to the financial crisis – note that Alcatel and Nokia actually seem to have increased their R&D investments at the time of the 2008 crisis. Apple's smooth increase in R&D investment appears to be particularly unaffected by the onset of the financial crisis.

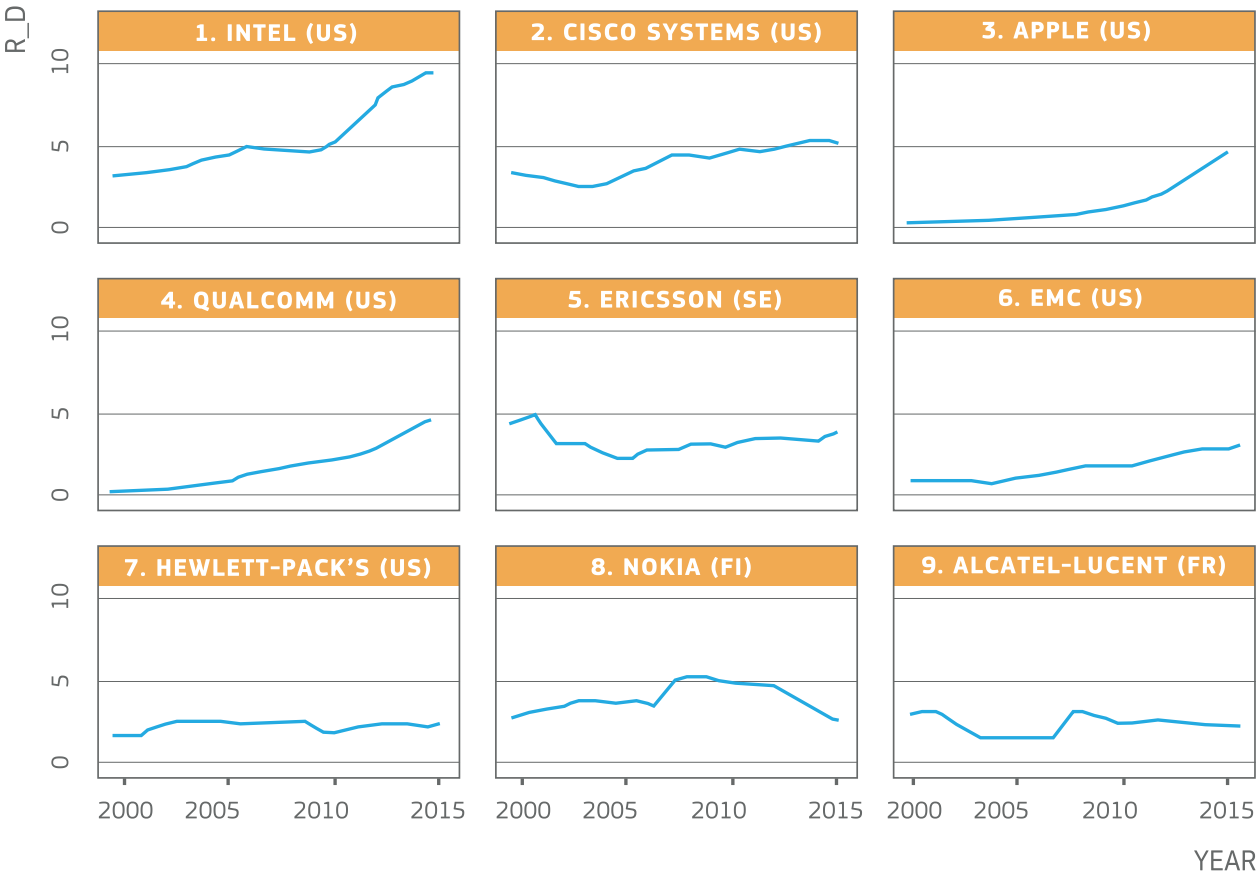

FIGURE 5.6 – R&D INVESTMENT OVER TIME, BY COMPANY, FOR THE LARGEST R&D INVESTING COMPANIES IN THE "ICT PRODUCERS" SECTOR.
Note : Firms sorted by R&D investment in 2014, in billions of Euros.

ICT services sector

Figure 5.7 shows that several companies in the ICT services sector have had a bullish growth of R&D investments: in particular Microsoft, Google and Oracle. Meanwhile Japanese company Fujitsu experienced a decline, while SAP and IBM had more mediocre R&D investment performances. Baidu, the Chinese web services company, which appeared in our selection of fast-growing R&D investors in Table 1, experienced a prolonged growth in R&D investment, from 0.002m EUR in 2004 to 0.94m EUR in 2014.

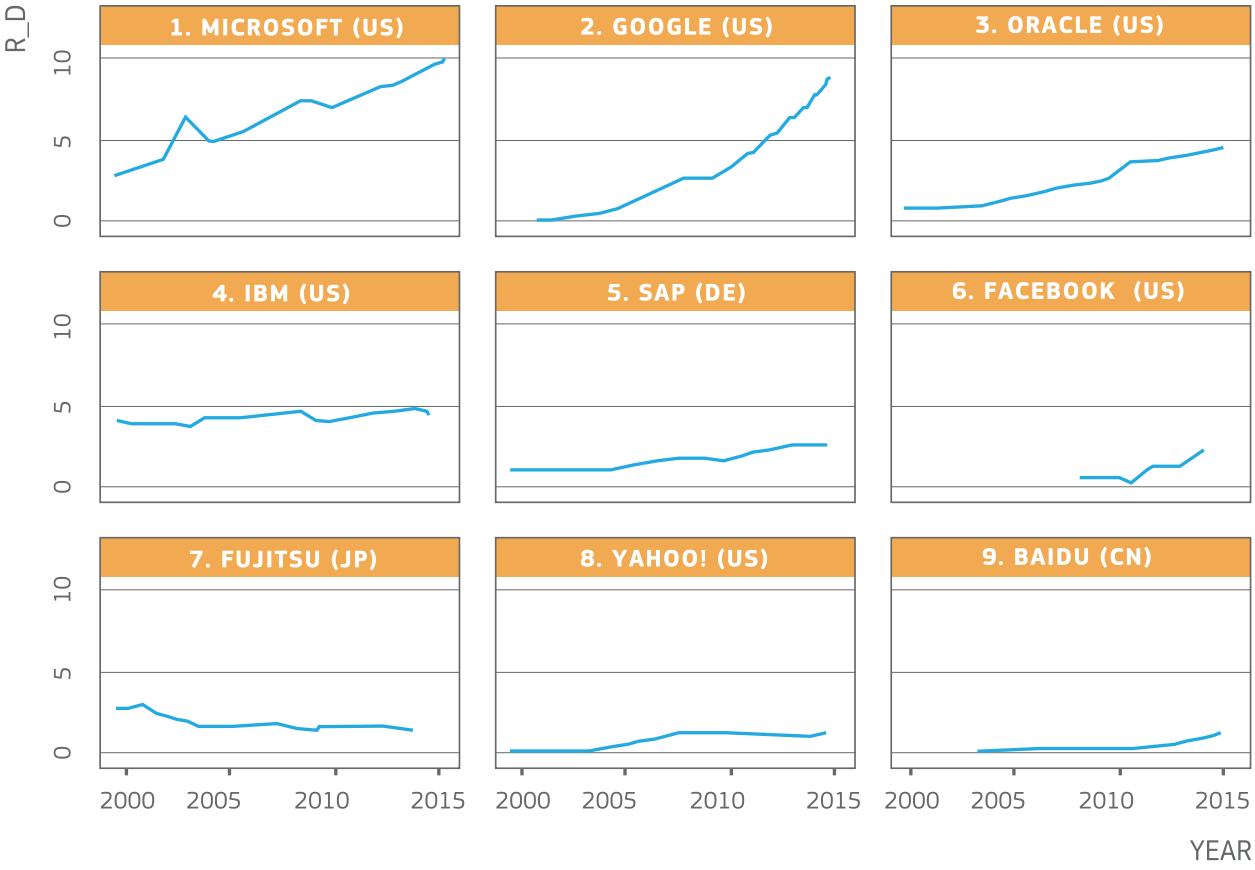

FIGURE 5.7 – R&D INVESTMENT OVER TIME, BY COMPANY, FOR THE LARGEST R&D INVESTING COMPANIES IN THE "ICT SERVICES" SECTOR.
Note : Firms sorted by R&D investment in 2014, in billions of Euros.

Pharmaceuticals and Biotechnology sector

Pharmaceutical companies also had mixed experiences regarding the evolution of their R&D investments (Figure 8). Novartis, Roche, and Johnson and Johnson had the most impressive growth of R&D. Meanwhile, Pfizer, Merck and Sanofi have struggled to maintain a stable level of R&D investment.

The avid reader will have noticed that the 9 largest R&D investors in the "Pharmaceuticals and Biotechnology" sector are all Pharmaceuticals (rather than Biotech) companies. In unreported analysis, we distinguish between pharmaceuticals and biotechnology by focusing only on the 9 largest biotech R&D investors.

Among biotech companies, R&D investment seems to be experiencing steady growth overall, although starting from a relatively low initial level.

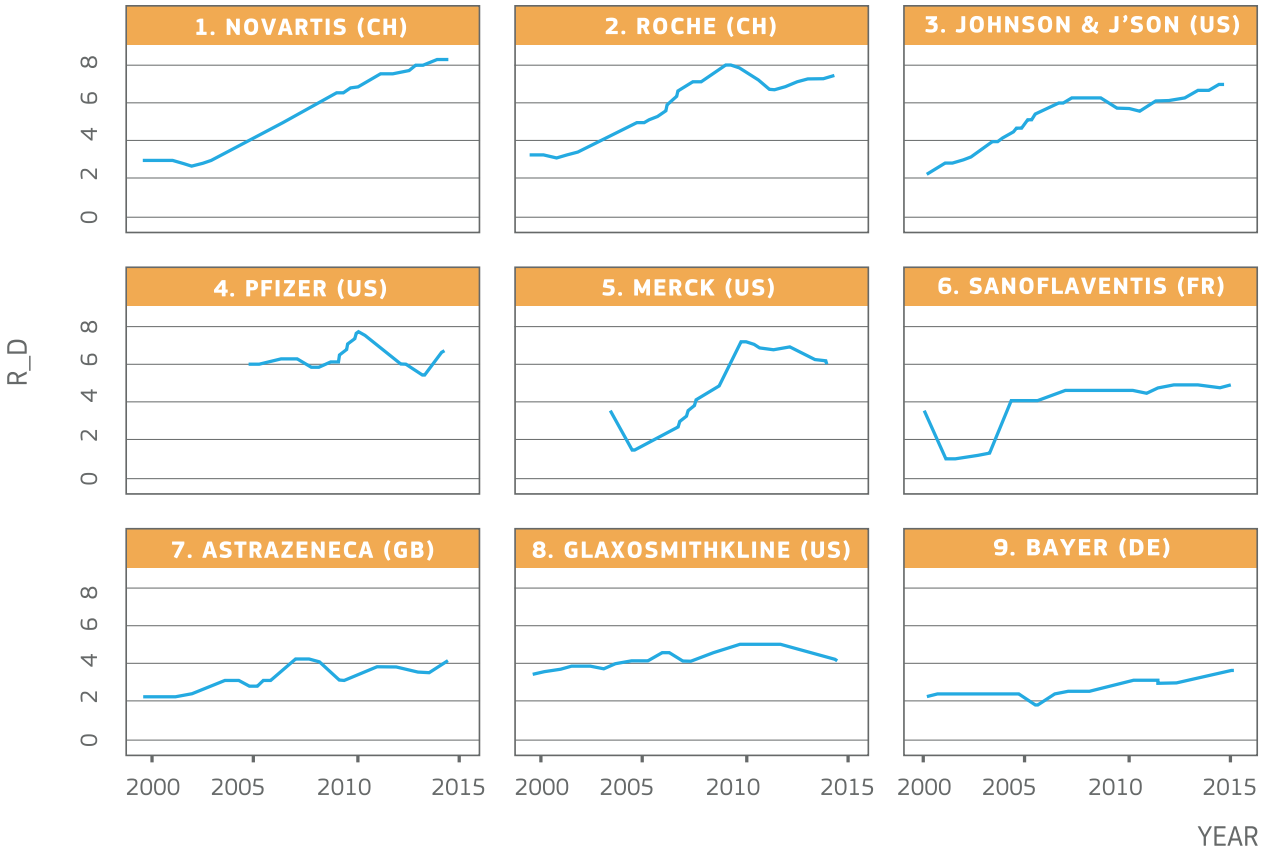

FIGURE 5.8 – R&D INVESTMENT OVER TIME, BY COMPANY, FOR THE LARGEST R&D INVESTING COMPANIES IN THE "PHARMACEUTICALS AND BIOTECHNOLOGY" SECTOR.

Note : Firms sorted by R&D investment in 2014, in billions of Euros.

The following points are observed:

- Firms in the same sector can have very different patterns of R&D investment. Some may have sustained growth while others may have sustained stagnation
- The financial crisis, per se, does not always seem to have strongly affected the R&D investment trends in all firms. Some firms appear conspicuously unaffected.
- Firms R&D trends appear to have reacted differently to the financial crisis.

6

DISTRIBUTION OF INDUSTRIAL **R&D ACROSS BORDERS**

6 Distribution of Industrial R&D Across Borders

Knowing the actual geographical distribution of companies' R&D activities across the globe is key to design effective R&I policies which can maximize their intended territorial impact. In the Scoreboard, normally companies are allocated to the countries where they have their headquarters (HQ).

However, companies make their decision on the location of R&D and production activities based on their market strategies, their need to optimize costs or for fiscal purposes. This has important policy implications and affects the analysis of economic and R&D trends of companies aggregated by country and region.

In this chapter, we present the results of an exercise which aims to improve our analysis of the location of companies' innovation activities. The location of innovation activities is estimated from the patent portfolio of the *Scoreboard* companies[15]. The actual location of innovation activities is proxied by the location of the inventors as reported in patent documents. R&D investments are then assigned to different countries/regions according to the share of patents from inventors residing in the specific area considered.

The analysis is carried out using the sample of top 2000 R&D investors worldwide as reported in the 2014 edition of the Scoreboard.

Key findings

- On average, companies located in the EU allocate 1/4 of their R&D investments outside the EU.
- The EU-US R&D flows are the largest R&D intraregional flows. UK is the EU member state with the highest outward R&D, while Switzerland is the second most important source of EU inward R&D.
- "Health Industries" show the highest volumes of inward and outward flows, while "Automobiles" are those with the lowest ones.
- Merck US, Novartis, Roche, General Motors and Intel are the non-EU based companies which invest more in the EU. For all these companies, the estimated R&D investment in EU is over 1 billion €.

[15] The patents filed by these companies at the European Patent Office (EPO) and the US Patent Office (USPTO) over the period 2011-2013 have been retrieved from the PATSTAT database. The matching has been carried out on a by-country basis using a series of string matching algorithms contained in the Imalinker system (Idener Multi Algorithm Linker) developed IDENER (Seville). The matching results have been improved using the PATSTAT standardized name as provided by ECOOM (K.U. LEUVEN).

Box 6.1 -
Key concept used in this chapter

→ The industrial classification used is an aggregate of ICB sectors focusing on the most innovative manufacturing and services industries:

ICT producers: Computer Hardware; Electronic Office Equipment; Semiconductors; Telecommunications Equipment; Electronic & Electrical Equipment.

Health industries: Pharmaceuticals; Health-biotechnology; Health care equipment & services.

ICT services: Computer Services; Internet; Software & Computer Services; Fixed Line Telecommunications; Mobile Telecommunications.

Automobiles: Automobiles; Auto Parts.

Industrials: General Industrials; Industrial Engineering, Industrial Metals & Mining, Industrial Transportation.

Aerospace & Defence: Aerospace; Defence.

Chemicals: Chemicals.

Other sectors: Leisure Goods; Oil & Gas Producers; Banks and Financial Services; Construction & Materials; Food producers; etc.

→ From a territorial viewpoint, R&D activity in a geographical area can be funded by local companies (home), which can also fund R&D in other geographical areas (outward), or by foreign affiliated companies (inward).

6.1 | Patent analysis to assess companies' major innovation location

This section shows the extent to which R&D investments of the *Scoreboard* companies flow between the EU and other economic areas. In the *Scoreboard* 2015 edition, a subchapter focused on the internationalization of the patenting activities of the *Scoreboard* companies[16]. Here we extend the methodology in order to estimate R&D flows across different economic areas by weighting patent data which have been fractionally counted based on inventors location information with R&D investments.

In other words, for each company R&D is allocated to different world regions based on the number of patents invented in that region, for this reason we invite the reader to interpret the results with caution.

The total amount of R&D invested in the EU from EU based Scoreboard companies is slightly over 112 billion €. These companies also invested almost 40 billion € in other geographical areas. The inflow of R&D investments from other geographical areas to the EU was approximately the same. R&D flows from the EU to the other economic areas and *viceversa* appears to be in balance

Figure 6.1 illustrates the R&D flows of EU companies toward external countries and EU R&D inflows from companies located in other countries. The R&D flows between EU and US are by far the largest ones. About 62% of EU outward R&D goes to the USA; at the same time the R&D inflows from the US represent 62% of the total EU inward R&D.

[16] See the " The 2015 EU Industrial R&D Investment Scoreboard"

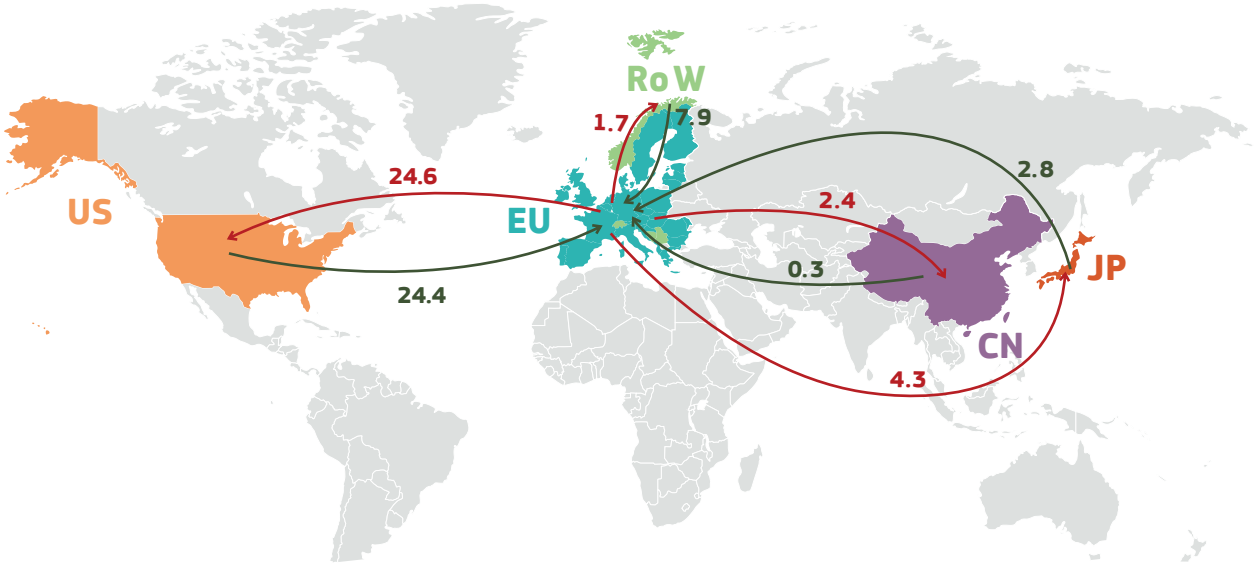

FIGURE 6.1 – R&D FLOWS FROM AND TOWARDS EU.

Other European countries (mainly Switzerland) contribute about 20% of the total EU inward R&D. Other economic areas (Rest of the World) contribute the remaining 18% of EU inward R&D. In particular, R&D outward flows from EU to China and Japan are greater than the corresponding inflows. In the following sections we explore these flows in more detail.

6.2 | How different sectors contribute to the R&D in-out-ward flows?

In the previous section, we saw that the estimated R&D flows from EU (outward) and to EU (inward) are balanced and that the highest R&D flows from and to the EU come from USA. Here we take a closer look to the extent to which different industrial sectors contribute to this overall picture.

Table 6.1, reports the inward and outward flows of R&D investment in and from EU. As explained in Box 6.1 "home" refers to the amount of R&D that has been invested from EU based companies within the EU while "outward" is the amount of R&D which was directed from EU companies to other countries/world regions. Finally "inward" R&D corresponds to investments in the EU coming from non EU based companies. The difference between inward and outward flows gives the R&D net balance for the EU. This figure can be disaggregated to show the "EU position" with respect to the rest of Europe and the rest of the world.

SECTOR	EU-28 R&D FLOWS			EU R&D NET BALANCE			
				By geographical areas			
	HOME	OUTWARD (O)	INWARD (I)	TOTAL (I-O)	REST OF EUROPE	USA	REST OF THE WORLD
Aerospace & Defence	7 616	1 514	1 661	146	-29	83	93
Automobiles	33 071	5 135	4 271	-918	-125	455	- 1 248
Chemical	3 630	1 136	1 541	405	305	61	39
Health Industries	19 614	10 036	13 507	3 471	4 436	-349	- 616
ICT Producers	16 587	7 127	7 439	312	149	1 082	-919
ICT Services	7 266	2 007	2 914	908	30	1 411	-534
Industrials	9 984	3 956	3 959	3	787	-98	-686
Other Sectors	14 272	8 744	4 194	-4 551	643	-2 911	-2 283
Total	**112 040**	**39 656**	**39 432**	**-224**	**6 196**	**- 268**	**-6 152**

TABLE 6.1 – ESTIMATED INWARD AND OUTWARD R&D FLOWS FOR EU BY SECTOR (€M).

EU based firms active in the "*Automobiles*" sector have invested more than thirty billion € within the Union followed by "*Health Industries*" (19,614 millions) and "*ICT producers*" (16,587 millions). Among these three industries the "*Health Industries*" show the highest volumes of inward and outward flows. Taken together, these are higher than the R&D invested at home by EU companies and give rise to a positive net balance. The positive balance is given by the high R&D inflows from other European countries (mainly Switzerland). In the "*Other sectors*" the EU shows a significant R&D deficit (which represent 32% of the home R&D investments). Overall, the slightly negative balance of the EU is mostly due to its position with respect to the "Rest of the world" and to a lesser extent to the US and it is almost compensated by the positive inward R&D from the rest of Europe.

The internationalisation of R&D activities can be defined as the sum of the inward and outward R&D investment over the R&D spending within the EU. Following this definition the "*Health Industries*", "*Other sectors*" and "*ICT Producers*" appears to be the most internationalised ones. In the "*Health Industries*" the sum of inward and outward flows outweigh the R&D invested within Europe, while in the "*Other sectors*" and "*ICT Producers*" it is around 90%. On the other side of the spectrum the "*Automobiles*" is the least internationalised sectors with a share of about 28%.

6.3 | Which EU companies are investing more abroad?

In this paragraph we explore the extent to which Scoreboard companies present heterogeneous profiles with respect to the recourse to external markets for their R&D investments. The focus in this section is at the firm level and we look at the 6 companies with the highest R&D investments outside the EU from each one of the main sectors presented previously. For these companies we report in table 6.2 the R&D investments performed in EU and the flows towards other European countries, towards US and towards the rest of the world. The share of outward R&D flows over the total R&D investment of each firm is also calculated. For each sector companies are ordered according to the total estimated R&D outflow.

GlaxoSmithKline, Astrazeneca and Robert Bosch are the companies with the highest R&D outflows from the EU; but while flows from the first two are mainly directed to the US, Bosch seems to be much more oriented towards the rest of the world. Companies in the ICT and financial services (e.g. Vivendi or HSBC) present very high outflows compared to their overall R&D investments[17].

[17] However, these results should be interpreted with caution because they are probably affected by the different policies of intellectual property offices with respect to software related patent. This type of patent cannot be filed at the EPO but are accepted at the USPTO. As a result, using patents for weighting R&D expenditure in that cases may lead to an overestimation of the R&D performed in the USA.

COMPANY	SECTOR	COUNTRY	R&D FLOWS				SHARE OF OUTFLOWS
			EU	REST OF EUROPE	USA	REST OF THE WORLD	
AIRBUS	Aerospace & Defence	NL	2 726	3	69	689	21.8
ROLLS-ROYCE		GB	528	12	143	16	24.4
ZODIAC AEROSPACE		FR	97	1	107	16	56.0
FINMECCANICA		IT	1 728		96	16	6.1
MEGGITT		GB	33	27	45	11	71.8
ROBERT BOSCH	Automobiles	DE	2 298	57	328	1 923	50.1
DELPHI		GB	309		416	170	65.5
FIAT		IT	2 402	7	461	74	18.4
DAIMLER		DE	5 042	14	166	327	9.1
CONTINENTAL		DE	1 585	2	173	53	12.6
BASF	Chemical	DE	1 333	60	256	97	23.7
DSM		NL	270	94	53	14	37.5
AKZO NOBEL		NL	203	9	109	26	41.3
SOLVAY		BE	175	1	44	22	27.5
EVONIK INDUSTRIES		DE	317	4	38	15	15.2
GLAXOSMITHKLINE	Health Industries	GB	2 056	24	1 819	383	52.0
ASTRAZENECA		GB	1 547	16	1 588	133	52.9
SANOFI-AVENTIS		FR	3 839	35	850	97	20.4
BAYER		DE	2 386	24	604	148	24.5
MERCK DE		DE	772	26	564	150	48.9
ALCATEL-LUCENT	ICT Producers	FR	1 202	5	797	437	50.8
NOKIA		FI	2 995	25	589	569	28.3
ERICSSON		SE	2 622	9	425	547	27.2
SIEMENS		DE	3 674	68	582	144	17.8
SEAGATE TECHNOLOGY TECHNOLOGY		IE	23	0	658	132	97.8
SAP	ICT Services	DE	1 342	13	378	425	37.8
SAGE		GB	16		171		91.3
DASSAULT SYSTEMS		FR	227		115	16	36.6
SQUARE ENIX		GB	12		3	119	90.9
YANDEX		NL	2		4	99	98.0
VOLVO	Industrials	SE	1 411	1	188	528	33.7
CNH INDUSTRIAL		NL	248	10	453	146	71.1
PHILIPS		NL	1 324	42	376	82	27.4
ALSTOM		FR	500	357	104	24	49.2
HEXAGON		SE	73	127	35	15	70.9
ROYAL BANK OF SCOTLAND	Other	GB	371	4	637	129	67.4
VIVENDI		FR	111		7	641	85.4
HSBC		GB	73	6	441	115	88.5
ROYAL DUTCH SHELL		GB	416	2	406	84	54.2
UNILEVER		NL	626	3	103	285	38.5

TABLE 6.2 – INTERNATIONAL R&D ACTIVITIES OF EU-28 COMPANIES.
(the 5 companies with the highest estimated R&D outflows are reported for each sector)
Source: Authors' own calculations on EPO-USPTO patent families.

In general there is high variance of outflows shares also within sectors. For example MEGGITT and ZODIAC Aerospace, which operate in the “Aerospace and Defence” sector, show very high shares of R&D outflows; close or over 50%. In the chemical sector, the five companies reported present the most similar R&D outflows shares.

In the “Automobiles” sector DELPHI (which started off as the parts arm of GM) shows a share or R&D outflows close to 66%; this high outflow share correspond to a volume of outward R&D spending close to Daimler.

Finally, among the 40 companies listed in the table, 10 are based in the UK, 9 in Germany, 7 in the Netherlands and 6 in France. With about 7 billion € of total outward R&D UK ranks first when considering investments abroad, followed by Germany (~6.6), France (~3.6) and the Netherlands (~2.7).

6.4 | Which non-EU companies are investing more in the EU?

Complementary to what was previously presented, it is interesting to look at the R&D invested in the EU by *Scoreboard* companies based elsewhere (in other European countries or in the rest of the world). To this aim we look at the 5 "foreign" companies with the highest estimated R&D investments in the EU. Also in this case, we report in table 6.3 the R&D investments performed in EU, in other European countries and in the rest of the world. However, now the focus is on the EU column, which in this case represents the flow or R&D investment towards EU and is used to order companies.

Also in this case the companies with the highest R&D flows are operating in the "*Health Industries*". Merck US, NOVARTIS and ROCHE, one based in the US and the other two in Switzerland, have each invested more than 2 billion € R&D in the EU.

In general, the share of R&D towards EU from companies in "*ICT Producers*" is higher than that of companies in the "*ICT Services*". With about 1 billion €, Intel is the company operating in the ICT related industries with the highest R&D investments in the EU, followed by CISCO System. Among the firms in the "*ICT Services*", Microsoft and IBM show the highest R&D investments in the EU.

In the “Aerospace and Defence” sector, the Canadian BOMBARDIER shows very high R&D investments in the EU, both in terms of volume and share (74%). This surprising result can be due to the activities of Bombardier in the transportation industry. A higher patent propensity in the transport sector than in the Aerospace could lead to biases in our analysis. In order to improve our methodology, we are currently looking into ways to estimate the cost related to the development of different technologies using *Scoreboard* companies.

COMPANY	SECTOR	COUNTRY	R&D FLOWS				SHARE OF OUTFLOWS
			EU	REST OF EUROPE	USA	REST OF THE WORLD	
BOMBARDIER	Aerospace & Defence	CA	878	52	46	216	73.8
UNITED TECHNOLOGIES		US	301	6	1 183	192	17.9
TEXTRON		US	97		310	18	22.8
BOEING		US	83	1	2 150	25	3.7
GENERAL DYNAMICS		US	61	1	182	11	23.8
GENERAL MOTORS	Automobiles	US	1 051	1	4 095	338	19.2
TATA MOTORS		IN	935	1	29	32	93.8
FORD MOTOR		US	579	64	3 375	138	13.9
NISSAN MOTOR		JP	197		36	2 977	6.1
AUTOLIV		US	181	1	72	81	53.9
SYNGENTA	Chemical	CH	193	376	258	82	21.2
DUPONT		US	157	25	1 133	177	10.5
DOW CHEMICAL		US	131	13	997	91	10.7
CLARIANT		CH	128	4	8	9	85.9
MONSANTO		US	119		884	70	11.1
MERCK US	Health Industries	US	2 346	82	2 596	514	42.4
NOVARTIS		CH	2 269	1 152	3 151	284	33.1
ROCHE		CH	2 215	1 259	2 790	581	32.4
JOHNSON & JOHNSON		US	949	382	3 827	497	16.8
PFIZER		US	885	5	4 290	217	16.4
INTEL	ICT Producers	US	1 008	16	4 835	1 176	14.3
CISCO SYSTEMS		US	711	207	2 753	613	16.6
BROADCOM		US	377	4	1 071	188	23.0
CANON		JP	257	46	745	1 042	12.3
HEWLETT-PACKARD		US	243	2	1 450	670	10.3
MICROSOFT	ICT Services	US	521	27	6 696	395	6.8
IMB		US	466	146	2 190	1 203	11.6
GOOGLE		US	302	131	3 927	392	6.4
ORACLE		US	195	78	2 841	397	5.6
MENTOR GRAPHICS		US	117		109	9	49.6
ABB	Industrials	CH	578	240	197	76	52.9
GENERAL ELECTRIC		US	562	28	2 311	447	16.8
LIEBHERR-INTERNATIONAL		CH	416	32		8	91.0
CATERPILLAR		US	239	5	1 281	121	14.5
DEERE		US	163		812	25	16.3
PROCTER & GAMBLE	Others	US	492	7	897	73	33.5
NESTLE		CH	301	589	353	74	22.9
SCHLUMBERGER		US	246	52	397	130	29.8
SONY		JP	241	2	199	2 711	7.6
DNB		NO	214				100.00

TABLE 6.3 – R&D ACTIVITIES OF EXTERNAL COMPANIES IN EU-28. (Note: the 5 companies with the highest estimated R&D inflows are reported for each sector)
Source: Authors' own calculations on EPO-USPTO patent families.

In the "Automobiles" sector GENERAL MOTORS (which own between others OPEL in Germany and Vauxhall in the UK) shows a high volume of R&D toward the EU (about 1 billion €). It is closely followed by TATA (which acquired Jaguar/ Land Rover) and FORD. As already discussed before, the main source of EU inward R&D are US based companies, followed by companies based in Switzerland (about 7.4 billion €) and in Japan (~2.8).

7

IMPACT OF CROSS-BORDER **MERGERS AND ACQUISITIONS**

7 Impact of cross-border mergers and acquisitions

This chapter analyses the geographical and sectoral trends of mergers and acquisitions (M&A) activities of the *Scoreboard* companies. The descriptive analysis is aimed to shed light on whether there is a transfer of ownership and control from non-European firms to European firms or viceversa. Using information on targets and acquirors' sector of activity, the descriptive analysis provides facts and figures on the volumes of M&A agreements by market and technological similarities between targets and acquirors.

The chapter concludes with the analysis on the relationship between the age of target firms and the performance of *Scoreboard* companies to determine what is the contribution of M&A to the growth of top R&D companies.

Key findings

- Companies based in the EU and the US are the main actors of both national and cross-border M&A. Considering the total value of the M&A deals, the US is a net target country, while the EU is a net acquiror.
- France, Germany and UK are the most targeted European countries and firms based in the US are the most active acquirors of European firms in general.
- 60% of M&A deals involve firms operating in different product markets. However, 59% of the total investments in M&A goes to technological related activities.
- The number of acquisitions seems to decline with the increase of the average age of the targeted companies.

7.1 | Introduction

Cross-border M&A are defined as M&A that involve an acquiror firm and a target firm whose headquarters are located in different countries. This type of investment constitutes one of the main forms of foreign direct investment and its effects on host economies are at the centre of the policy debate. On the one hand, they have become a major channel for reorganizing R&D activities both domestically and internationally, since they enable firms to quickly acquire technology from external sources and expand their knowledge base by accessing new technological assets. On the other hand, M&A activities may lead to important changes in the industry structure and concentration, and host countries' governments are concerned with their potential adverse effects and with the transfer of ownership to foreign hands. Examples of these vertical and horizontal industrial concentrations are given by M&A among *Scoreboard* companies: Rolls-Royce buying Germany-based Tognum (electrical components) for over €3bn, or Denali Intermediate (a company in computers and electrical components) buying Dell for € 24bn.

The data set on M&A deals is constructed using information from the Zephyr database of Bureau van Dijk. Specifically, the data include all the acquisitions of majority stakes (at least 50% of ownership) on both acquiror and target country and sector.

The data collected consists of all the acquisitions made by the companies included in the 2013 *Scoreboard* over the period 2003-2012[18]. A total of 8,370 deals for a total value €2624bn were reported. Figure 7.1 reports the total number and total value of these deals over time[19], showing the cyclical nature of M&A. Economic expansion, regulatory changes and the emergence of new technologies influence the volumes of M&A deals, which follow a succession of high (2006) and low points (2009, end of financial crisis).

In addition, the value of M&A deals is highly skewed: the median value of a deal is €75m, the mean value is €600m and the standard deviation is €2.7bn.

[18] The sample of M&As includes 1,566 different Scoreboard acquirors. Therefore, most of the Scoreboard acquirors engage in multiple acquisitions.

[19] Data on deal value is available for around half of the M&A deals.

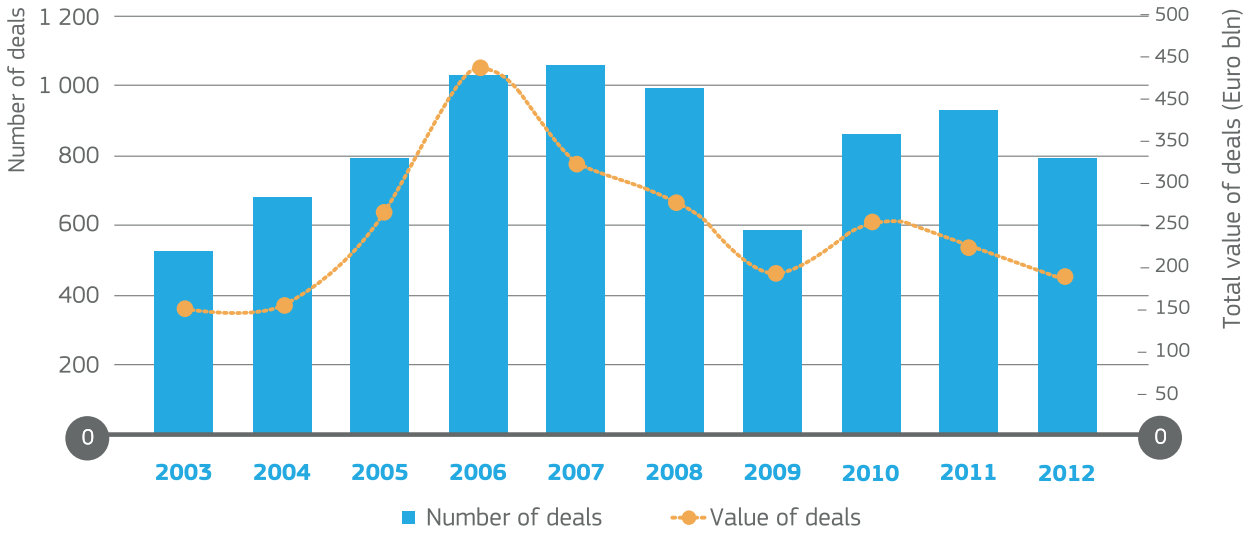

FIGURE 7.1 - NUMBER AND VALUE OF M&A DEALS.

7.2 | Trends in geographical distribution of M&A

Figure 7.2 shows that the majority of the M&A deals involve companies based in the EU and the US both as acquirors and targets. US appear to be a net acquiring country, while Europe is both an active acquiring and targeted region. However, about 62% of total M&A involves firms located in the same geographical area (national M&A). In particular, 30.5% of the deals in the sample are within US firms, while 21% are within EU firms. Cross-border M&A represent 38% of all deals in the sample.

Looking at the total value of M&A deals in these two economic regions, the total value of the deals that targeted US companies was larger than the total US M&A investment. This situation is reversed for the EU.

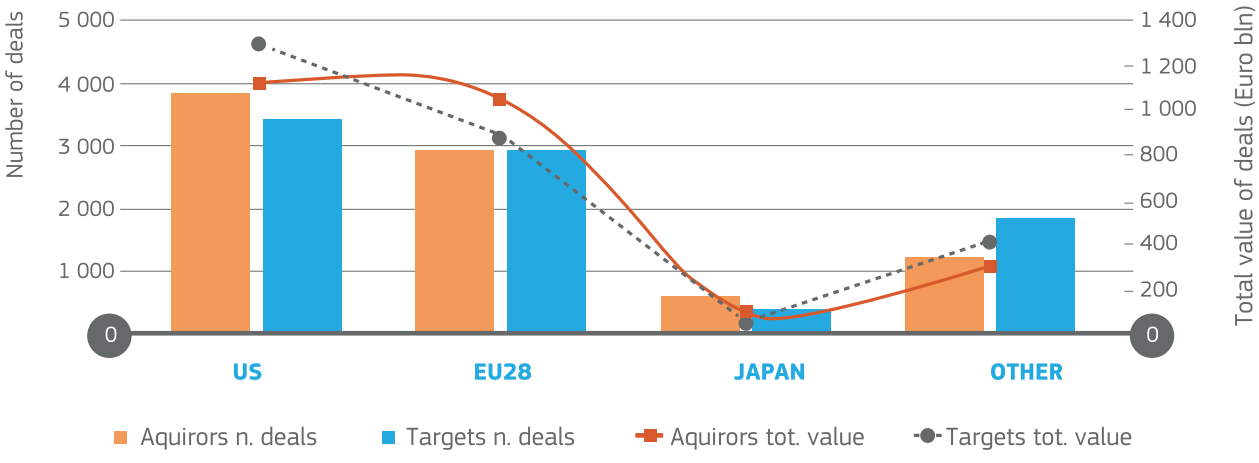

FIGURE 7.2 - NUMBER AND VALUE OF M&A BY GEOGRAPHICAL AREAS.

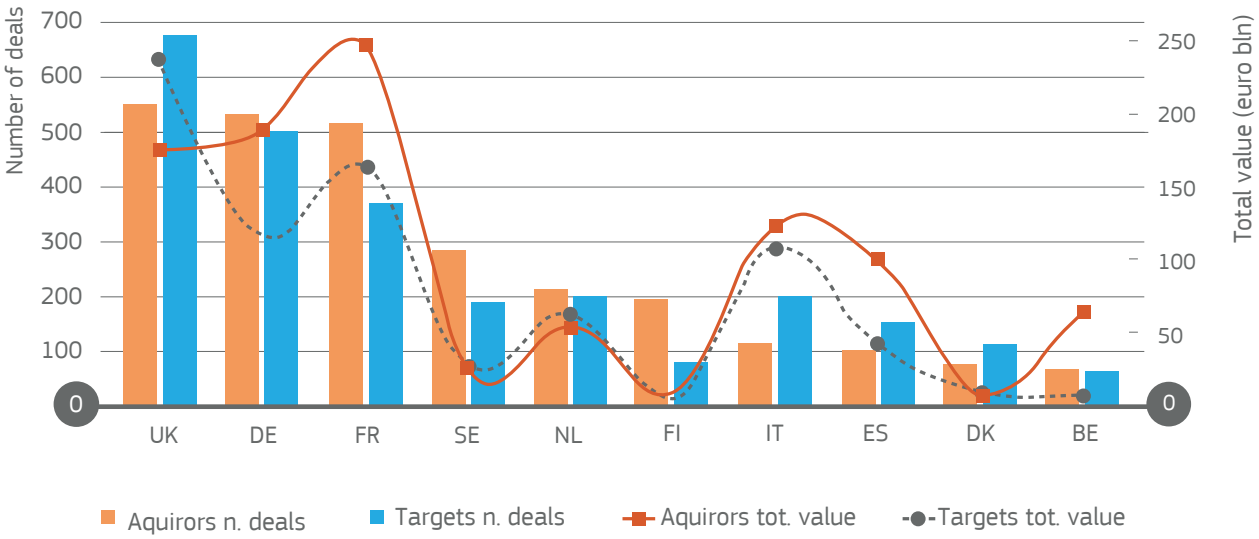

FIGURE 7.3 - TOP EU COUNTRIES IN M&A ACTIVITIES.

Figure 7.3 reports the total number and values of M&A deals in the top European countries. UK, Germany and France are the most active acquiror countries in M&A. Differently from Germany and France, UK is a net target country.

About 50% of M&A deals (and 43% in terms of their value) involve firms located in different countries (i.e., cross-border M&A). Figure 7.4 reports the number and value of cross-border M&A investment undertaken by *Scoreboard* companies based in the EU. While the number of deals follow a similar trend to the total number of deals in Figure 7.1, the total value exhibit a peak in 2009, at the end of the financial crisis, to then drop dramatically in 2010 due to recession.

Non-EU cross-border M&As with a EU target represent around 26% of the total number of cross-border M&As, but their share in total value is significantly smaller (around 16.5% of the total value of cross-border M&As).

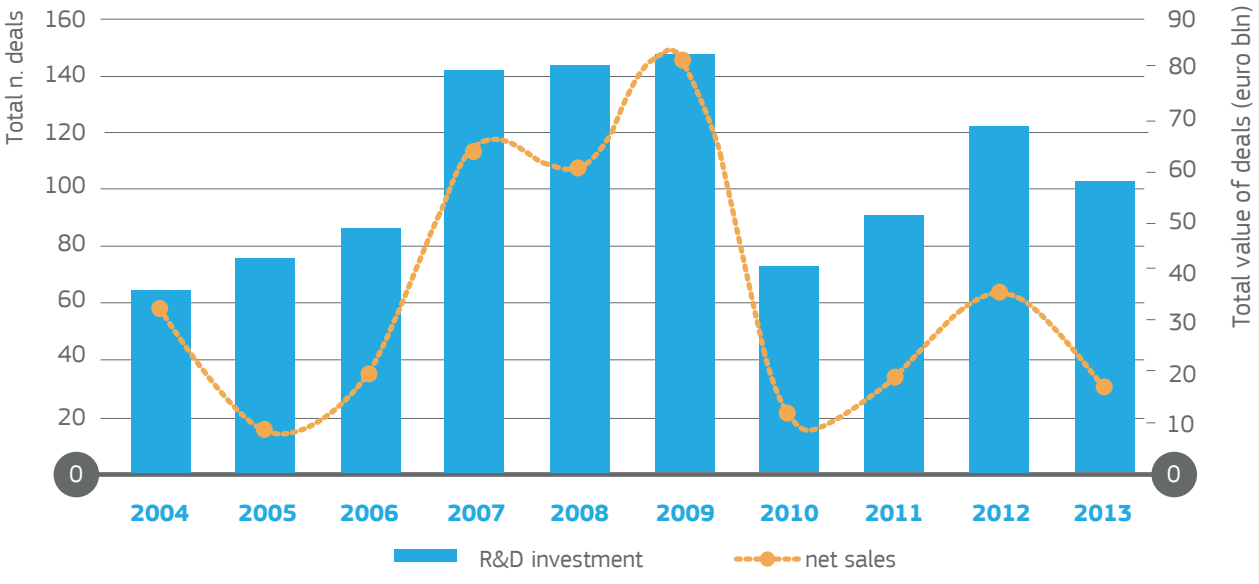

FIGURE 7.4 - EU CROSS-BORDER M&A (EU SCOREBOARD COMPANIES).

Figure 7.5 shows that the value of non-EU acquisitions made by European firms exceeds the value of acquisitions made by non-European firms within the EU. France, Germany and United Kingdom are the most targeted European countries by non-European *Scoreboard* firms. While, US *Scoreboard* firms are the most active acquirers of European firms (see Figure 7.6).

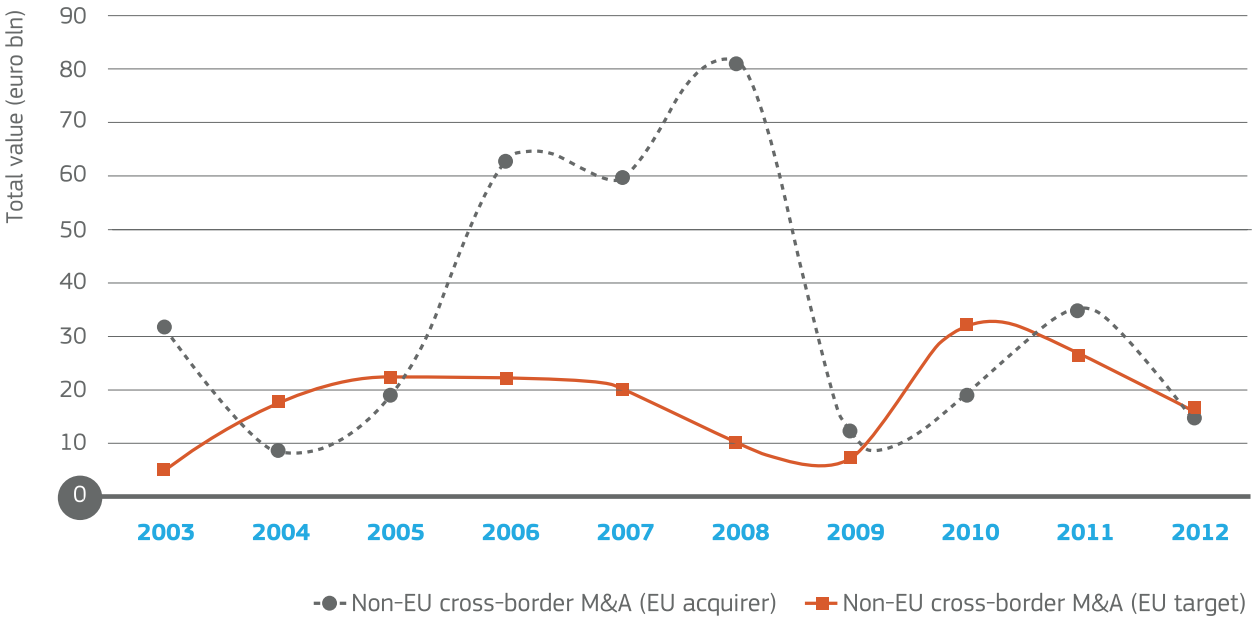

FIGURE 7.5 – CROSS-BORDER M&A (EU TARGETS AND ACQUIRORS).

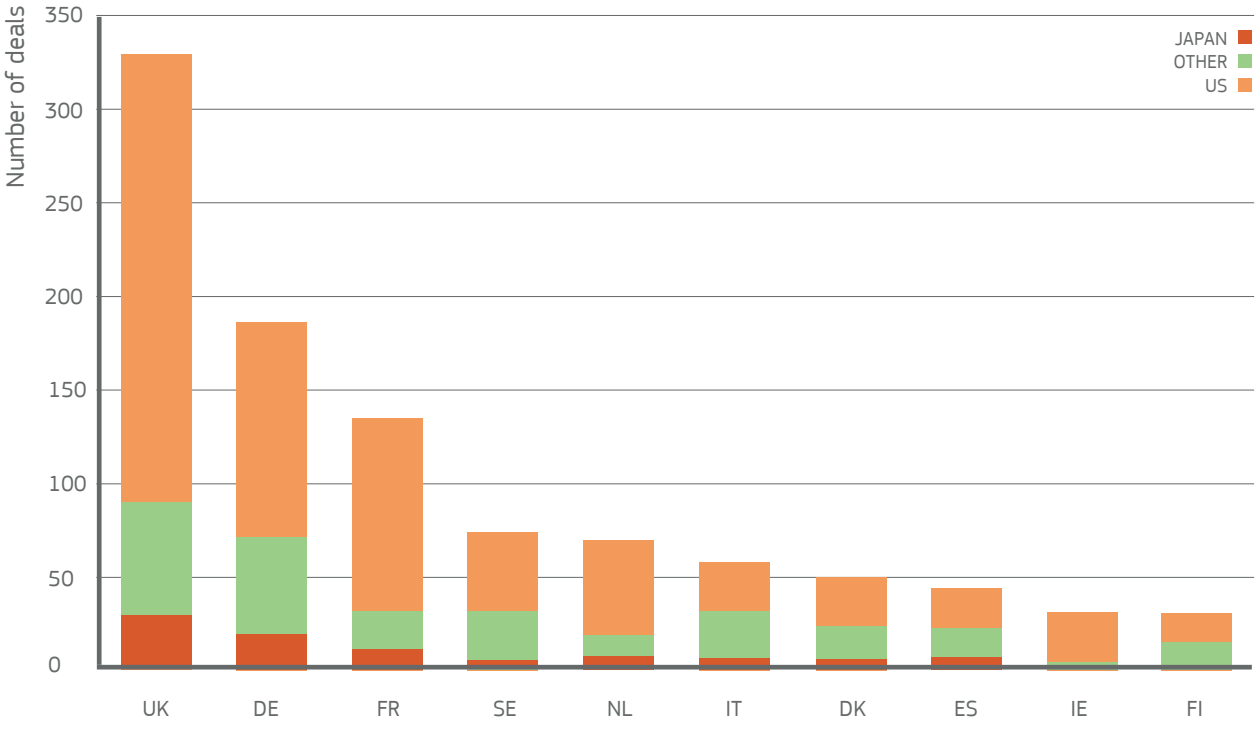

FIGURE 7.6 – TOP 10 EU TARGET COUNTRIES BY ACQUIRORS' GEOGRAPHICAL AREAS.

7.3 | Trends in sectoral distribution of M&A

Figure 7.7 shows that M&A is concentrated in knowledge intensive service (KIS) sectors, and high tech and medium-high tech manufacturing. *Scoreboard* companies mainly acquire targets in these sectors, and most of the *Scoreboard* acquirors belong to these sectors.

A significant number of M&A occur within the same sector, and in particular, within medium-high tech manufacturing sectors, and high tech manufacturing sectors.

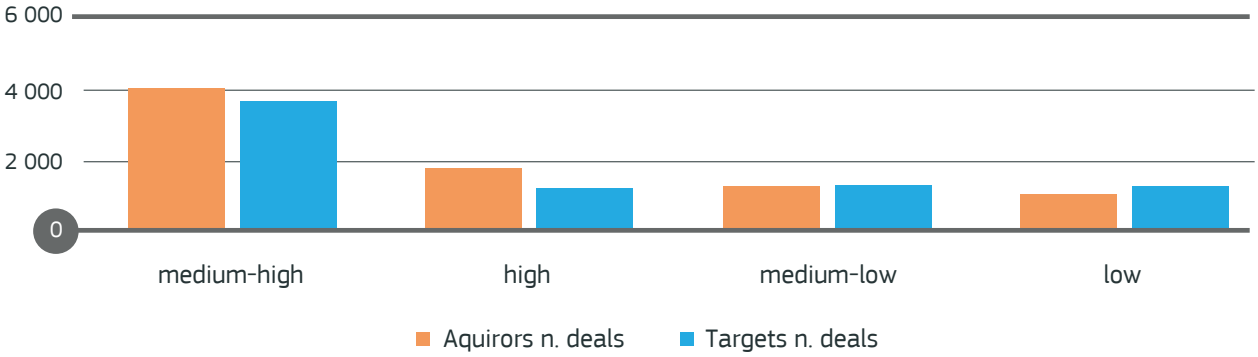

FIGURE 7.7 – M&A DEALS BY SECTOR GROUP.

Firms can enter new technology markets by targeting firms that are operating in different technologies. In this regard, technological related M&A activities are those deals between firms within the same sector[20].

The majority (53% in number of deals and 66% in value) of deals are between technologically related sectors and occur within medium-high R&D intensity sectors.

Scoreboard companies mainly acquire targets in sectors with high and medium-high R&D intensity (around 67% of the deals). More in detail, Table 7.1 shows that Computer, electronic and optical products and other manufacturing (manufacturing of jewellery, music instruments, medical supplies, etc.) are the most targeted high and medium-high R&D intensity sectors, representing around 66% of the deals from high-tech *Scoreboard* companies.

Target high and medium-high R&D intensity sectors	(NACE r.2) SECTOR	R&D INTENSITY OF ACQUIROR SECTOR		
		HIGH	MEDIUM-HIGH	MEDIUM-LOW
	Computer, electronic and optical products	245	116	45
	Other manufacturing	154	60	11
	Wholesale trade	49	44	7
	Computer programming, consultancy and related activities	39	53	18
	Manufacture of other transport equipment	30	10	3
	Telecommunications	28	30	54
	Manufacture of machinery and equipment	18	3	3
	Human health activities	14	15	6
	Others	26	81	11
	Total	**603**	**412**	**158**

TABLE 7.1 – CROSS-TABULATION OF M&A IN HIGH R&D INTENSIVE SECTORS.

[20] This variable places firms in a certain technology space rather than measures direct technological linkages between them. As pointed out in the literature review, technological relatedness is mainly constructed using patent information from the target and the acquirer. Unfortunately, we do not have data on patent applications.

Finally, Figure 7.8 reports the time trend of both technological- and non-technological-related M&A, to understand the extent to which *Scoreboard* firms invest in other product markets that are more or less complementary with theirs. Deals are grouped according to whether acquirors and targets compete in the same product market or not. In practice, (product) market related M&A are deals between firms within the same 4-digit NACE sectors.

Around 60% of M&A deals involve firms operating in different product markets (non-market related deals). In this respect, M&A may be seen as an instrument for product market diversification. However, 59% of the total investments in M&A goes to technological related activities.

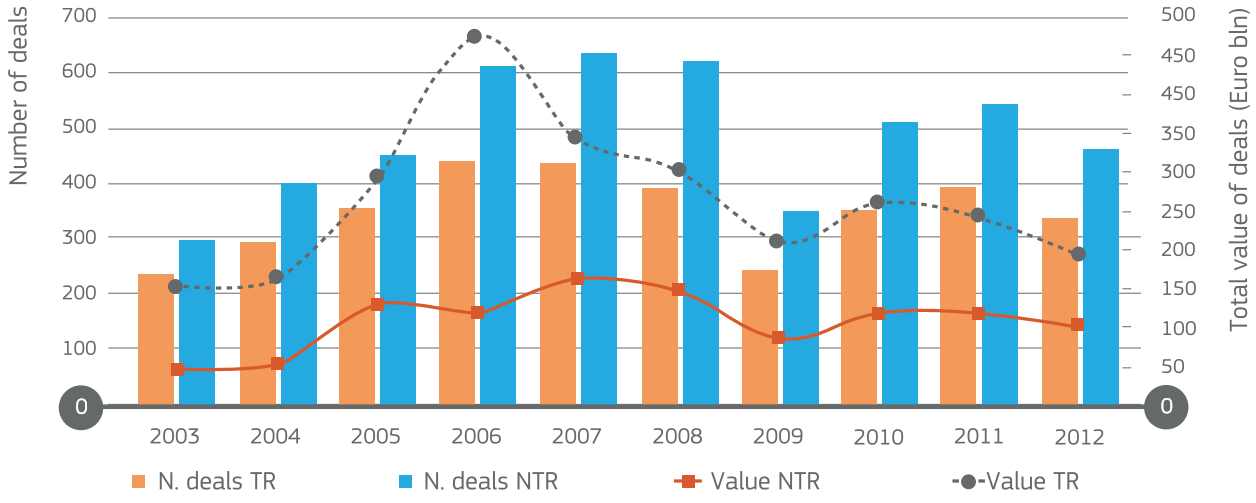

FIGURE 7.8 – NUMBER AND VALUE OF TECHNOLOGICAL RELATED M&A.

7.4 | Age and performance of acquiring firms

This section provides a descriptive analysis of the relationship between the age of target firms and the performance of *Scoreboard* companies.

The sample on M&A deals is therefore completed with quantitative information of the targets collected from the Orbis database of Bureau van Dijk. In particular, we retain information on R&D investments, turnover and number of employees. As performance measures, we use labour productivity (turnover per employee), R&D intensity (R&D investment/turnover) and respective growth rates. In addition, the target's age is approximated by the number of years from the date of incorporation to 2013. After dropping all observations for which some of this data is missing, the remaining sample contains 2674 M&A deals involving *Scoreboard* acquirors for the period 2003-2012.

The average age of target firms is 20.5 years. Figure 9 shows the average age of target firms by NACE rev. 2 sectors and the numbers of observations (deals). Targets in ICT, R&D and computer and electronics are the youngest, while firms in metal products, machinery and equipment are the oldest. The trend of the number of acquisitions seems to decline with the average age of the targets.

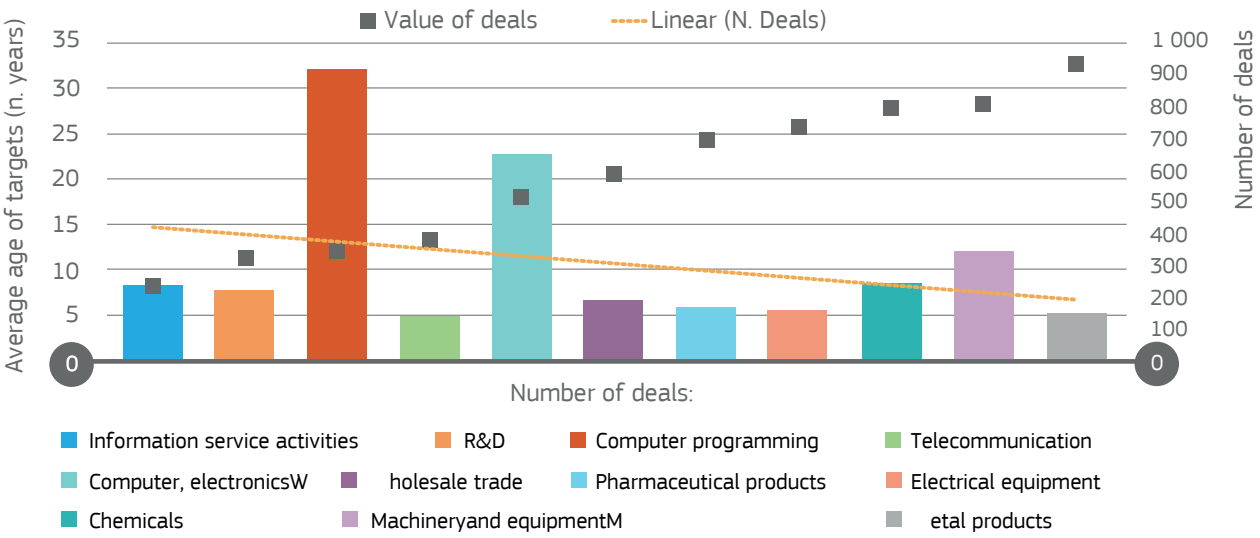

FIGURE 7.9 - AGE AND NUMBER OF TARGETS BY SECTOR GROUP.

To observe the relationship between acquirors performance and age of the targets, we divide the age into three age groups, using the 25th and 75th percentiles cut-off values (13 and 30 years, respectively).

Table 2 reports the average R&D intensity, labour productivity levels and growth rates, together with the growth rates of employment and net sales of the Scoreboard companies by categories of targets' age.

TARGET AGE GROUP	R&D INTENSITY	R&D GROWTH	LABOUR PRODUCTIVITY	LP GROWTH	EMPLOYMENT GROWTH	NET SALES GROWTH
Young	33.5%	10.4%	320.3	4.1%	6.4%	10.9%
Medium	30.5%	13.6%	310.8	0.5%	9.7%	11.4%
Old	19.2%	8.5%	292.5	2.8%	3.6%	7.0%

TABLE 7.2 - SCOREBOARD COMPANIES PERFORMANCE BY AGE GROUP.

Except for R&D intensity and R&D growth, companies acquiring younger targets are more productive and grow faster than those companies that acquire medium and mature targets, with employment and net sales growth rates circa twice as large.

Firms acquiring medium old firms (with an age between 14 and 30 years) have the highest R&D growth, but the lowest (negative) productivity, turnover employment growth rates.

Figure 7.10 shows the percentage of acquisitions and related deals by age group of the targets and by acquirors' region. US and EU28 have the largest shares of deals (the total number of deals per age group is reported in parentheses next to the legend). However, the situations for EU28 and US appear to be reversed. US Scoreboard firms acquire a considerable larger share of young and medium-old firms (41%), and fewer mature firms (28%). EU28 Scoreboard acquirers, on the other hand, have a different M&A strategy, acquiring a similar share of young, medium-aged and old companies.

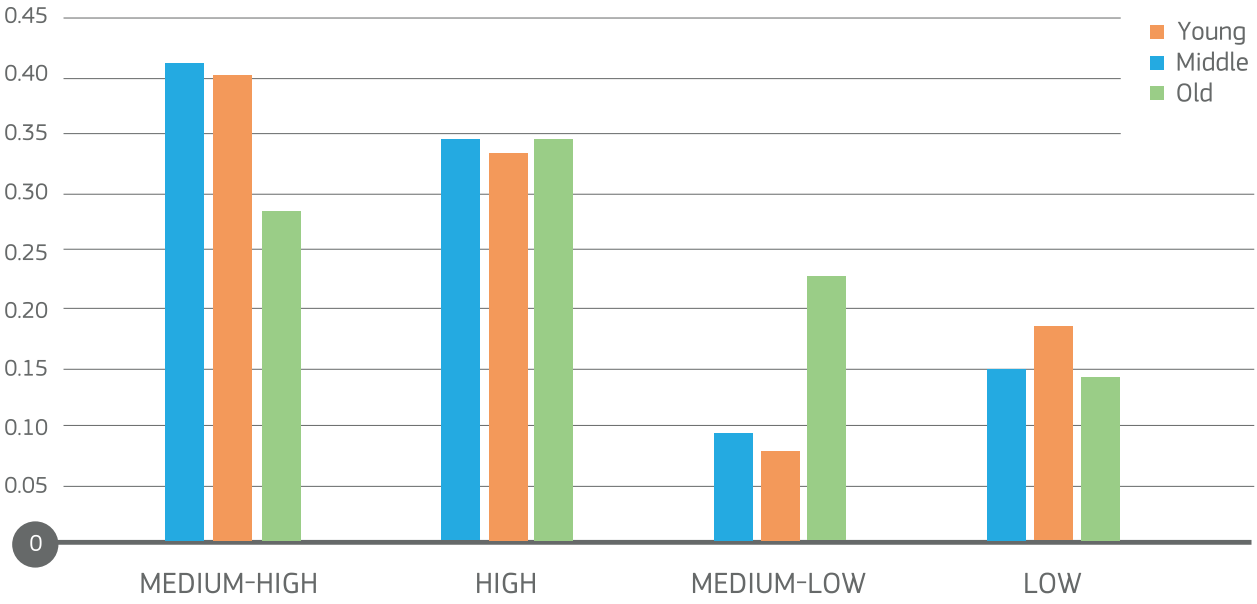

FIGURE 7.10 – PERCENTAGE OF M&A DEALS BY TARGET AGE GROUP AND ACQUIRER REGION.

We conclude this analysis by investigating the cross-border M&A activities targeting young firms in the EU and the US. Figure 7.11 reports the number of deals concerning young US and EU target with high, medium and low levels of R&D intensity. In general, the shares of cross-border M&A are smaller than the national M&A ones, except for young companies with a medium-low level of R&D intensity. As for the "cherry-picking" of young and high R&D intensive firms, the figure shows that in relative terms, the EU is picking roughly the same amount of cherries in the US than the US in the EU (22% versus 19% respectively).

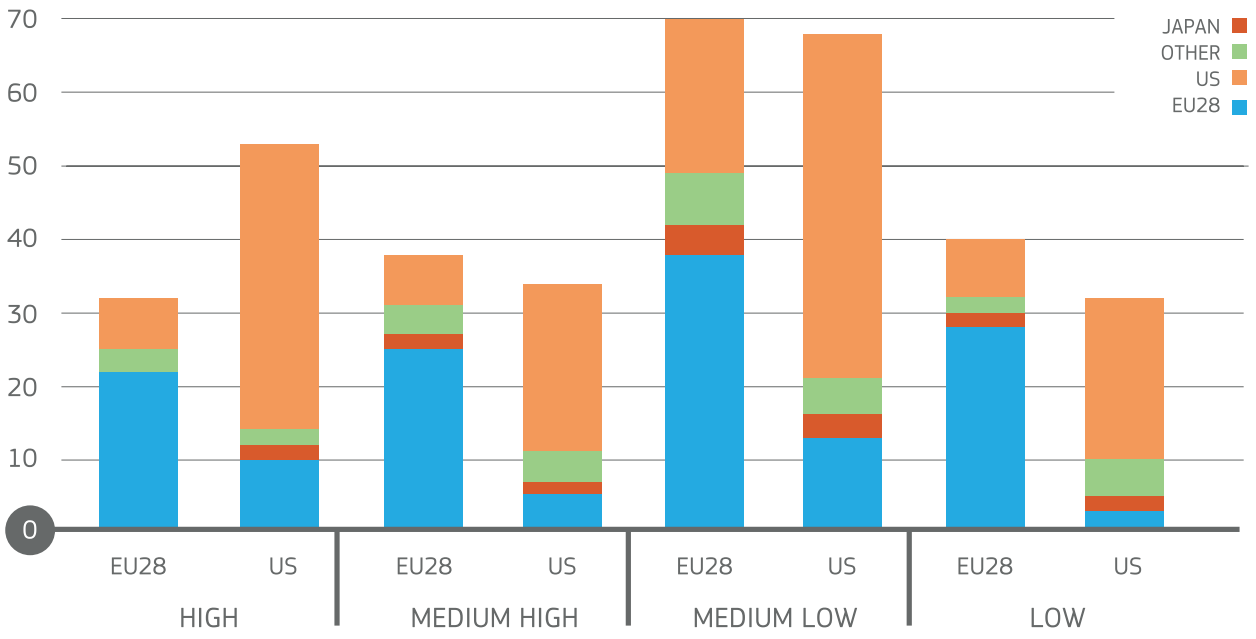

FIGURE 7.11 – M&A IN US AND EU BY TARGET R&D INTENSITY AND ACQUIRING COUNTRY.

Examples of US *Scoreboard* companies acquiring EU targets are the acquisition of Torex, a UK-based European market leader for till systems by Micro Systems (a subsidiary of Oracle), as well as the acquisition of the Dutch hemodynamic monitoring solutions company BMEYE by Edwards Lifesciences Corporation for €32.5bn. On the other hand, the French company Nexans (optical fibre cable products) completed a strategic acquisition of the Valley Group (the world leader in the cable industry, in the field of real-time thermal rating technology for overhead power lines).

Another example is the recent acquisition of Dutch NXP Semiconductors by Qualcomm for €35.2bn, when in March 2015, NXP made its own deal, buying a US smaller peer, Freescale Semiconductor, for €10.8bn.

ANNEXES

- BACKGROUND INFORMATION
- METHODOLOGICAL NOTES
- COMPOSITION OF THE EU 1000 SAMPLES
- ACCESS TO THE FULL DATASET

A.1 Background information

Investment in research and innovation is at the core of the EU policy agenda. The Europe 2020 growth strategy includes the Innovation Union flagship initiative[21] with a 3 % headline target for intensity of research and development (R&D)[22].

R&D investment from the private sector plays also a key role for other relevant Europe 2020 initiatives such as the Industrial Policy[23], Digital Agenda and New Skills for New Jobs flagship initiatives.

The Industrial Research and Innovation Monitoring and Analysis (IRIMA) project[24] supports policymakers in these initiatives and monitors progress towards the 3 % headline target. The *Scoreboard*, as part of the IRIMA project, aims to improve the understanding of trends in R&D investment by the private sector and the factors affecting it.

The annual publication of the *Scoreboard* is intended to raise awareness of the importance of R&D for businesses and to encourage firms to disclose information about their R&D investments and other intangible assets.

The data for the *Scoreboard* are taken from companies' publicly available audited accounts. As in more than 99% of cases these accounts do not include information on the place where R&D is actually performed, the company's whole R&D investment in the Scoreboard is attributed to the country in which it has its registered office[25]. This should be borne in mind when interpreting the *Scoreboard*'s country classifications and analyses.

The *Scoreboard*'s approach is, therefore, fundamentally different from that of statistical offices or the OECD when preparing Business Enterprise Expenditure on R&D (BERD) data, which are specific to a given territory[26]. The *Scoreboard* data are primarily of interest to those concerned with benchmarking company commitments and performance (e.g. companies, investors and policymakers), while BERD data are primarily used by economists, governments and international organisations interested in the R&D performance of territorial units defined by political boundaries. The two approaches are therefore complementary. The methodological approach of the *Scoreboard*, its scope and limitations are further detailed in Annex 2 below.

Scope and target audience

The *Scoreboard* is a benchmarking tool which provides reliable up-to-date information on R&D investment and other economic and financial data, with a unique EU-focus. The 2500 companies listed in this year's *Scoreboard* account for more than 90%[27] of worldwide business enterprise expenditure on R&D (BERD).

Furthermore, the dataset is extended to cover the top 1000 R&D investing companies in the EU.

The data in the *Scoreboard*, published since 2004, allow long-term trend analyses, for instance, to examine links between R&D and business performance. The *Scoreboard* is aimed at three main audiences.

- Companies can use the *Scoreboard* to benchmark their R&D investments and so find where they stand in the EU and in the global industrial R&D landscape. This information could be of value in shaping business or R&D strategy.

[21] The Innovation Union flagship initiative aims to strengthen knowledge and innovation as drivers of future growth by refocusing R&D and innovation policies for the main challenges society faces.

[22] This target refers to the EU's overall (public and private) R&D investment approaching 3 % of gross domestic product (see: http://ec.europa.eu/europe2020/pdf/targets_en.pdf).

[23] The Industrial Policy for the Globalisation Era flagship initiative aims to improve the business environment, notably for small and medium-sized enterprises, and support the development of a strong and sustainable industrial foundation for global competition.

[24] See: http://iri.jrc.ec.europa.eu/home /. The activity is undertaken jointly by the Directorate General for Research (DG RTD A; see: http://ec.europa.eu/research/index.cfm?lg=en) and the Joint Research Centre, Institute for Prospective Technological Studies (JRC-IPTS; see: https://ec.europa.eu/jrc/en/science-area/innovation-and-growth).

[25] The registered office is the company address notified to the official company registry. It is normally the place where a company's books are kept.

[26] The Scoreboard refers to all R&D financed by a company from its own funds, regardless of where the R&D is performed. BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of finance. The sources of data also differ: the Scoreboard collects data from audited financial accounts and reports whereas BERD typically takes a stratified sample, covering all large companies and a representative sample of smaller companies. Additional differences concern the definition of R&D intensity (BERD uses the percentage of R&D in value added, while the Scoreboard considers the R&D/Sales ratio) and the sectoral classification (BERD uses NACE (the European statistical classification of economic sectors), while the Scoreboard uses the ICB (the International Classification Benchmark).

[27] According to latest Eurostat statistics.

- Investors and financial analysts can use the *Scoreboard* to assess sectoral trends and investment opportunities and risks.

- Policy-makers, government and business organisations can use R&D investment information as an input to policy formulation or other R&D-related actions.

Furthermore, the *Scoreboard* dataset has been made freely accessible so as to encourage further economic and financial analyses and research by any interested parties.

A.2 Methodological notes

The data for the 2016 EU Industrial R&D Scoreboard (the *Scoreboard*) have been collected from companies' annual reports and accounts by Bureau van Dijk Electronic Publishing GmbH (BvD). The source documents, annual reports & accounts, are public domain documents and so the *Scoreboard* is capable of independent replication. In order to ensure consistency with our previous *Scoreboards*, BvD data for the years prior to 2012 have been checked with the corresponding data of the previous *Scoreboards* adjusted for the corresponding exchange rates of the annual reports.

Main characteristics of the data

The data correspond to companies' latest published accounts, intended to be their 2015 fiscal year accounts, although due to different accounting practices throughout the world, they also include accounts ending on a range of dates between late 2014 and mid-2016. Furthermore, the accounts of some companies are publicly available more promptly than others. Therefore, the current set represents a heterogeneous set of timed data.

In order to maximise completeness and avoid double counting, the consolidated group accounts of the ultimate parent company are used. Companies which are subsidiaries of any other company are not listed separately. Where consolidated group accounts of the ultimate parent company are not available, subsidiaries are included.

In case of a demerger, the full history of the continuing entity is included. The history of the demerged company can only go back as far as the date of the demerger to avoid double counting of figures.

In case of an acquisition or merger, pro forma figures for the year of acquisition are used along with pro-forma comparative figures if available.

The R&D investment included in the *Scoreboard* is the cash investment which is funded by the companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes the companies' share of any associated company or joint venture R&D investment when disclosed. Where part or all of R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash investment and any amortisation eliminated.

Companies are allocated to the country of their registered office. In some cases this is different from the operational or R&D headquarters. This means that the results are independent of the actual location of the R&D activity.

Companies are in industry sectors according to the NACE Rev. 2[28] and the ICB (Industry Classification Benchmark).

Limitations

The *Scoreboard* relies on disclosure of R&D investment in published annual reports and accounts. Therefore, companies which do not disclose figures for R&D investment or which disclose only figures which are not material enough are not included in the *Scoreboard*. Due to different national accounting standards and disclosure practice, companies of some countries are less likely than others to disclose R&D investment consistently.

In some countries, R&D costs are very often integrated with other operational costs and can therefore not be identified separately. For example, companies from many Southern European countries or the new Member States are under-represented in the *Scoreboard*. On the other side, UK companies are over-represented in the *Scoreboard*.

For listed companies, country representation will improve with IFRS adoption.

[28] NACE is the acronyme for "Nomenclature statistique des activités économiques dans la Communauté européenne".

The R&D investment disclosed in some companies' accounts follows the US practice of including engineering costs relating to product improvement. Where these engineering costs have been disclosed separately, they have been excluded from the *Scoreboard*. However, the incidence of non-disclosure is uncertain and the impact of this practice is a possible overstatement of some overseas R&D investment figures in comparison with the EU.

Where R&D income can be clearly identified as a result of customer contracts it is deducted from the R&D expense stated in the annual report, so that the R&D investment included in the *Scoreboard* excludes R&D undertaken under contract for customers such as governments or other companies. However, the disclosure practise differs and R&D income from customer contracts cannot always be clearly identified. This means a possible overstatement of some R&D investment figures in the *Scoreboard* for companies with directly R&D related income where this is not disclosed in the annual report.

In implementing the definition of R&D, companies exhibit variability arising from a number of sources: i) different interpretations of the R&D definition. Some companies view a process as an R&D process while other companies may view the same process as an engineering or other process; ii) different companies' information systems for measuring the costs associated with R&D processes; iii) different countries' fiscal treatment of costs.

Interpretation

There are some fundamental aspects of the *Scoreboard* which affect their interpretation.

The focus of the *Scoreboard* on R&D investment as reported in group accounts means that the results can be independent of the location of the R&D activity. The *Scoreboard* indicates the level of R&D funded by companies, not all of which is carried out in the country in which the company is registered. This enables inputs such as R&D and Capex investment to be related to outputs such as Sales, Profits, productivity ratios and market capitalisation.

The data used for the *Scoreboard* are different from data provided by statistical offices, e.g. BERD data. The *Scoreboard* refers to all R&D financed by a particular company from its own funds, regardless of where that R&D activity is performed. BERD refers to all R&D activities performed by businesses within a particular sector and territory, regardless of the location of the business's headquarters, and regardless of the sources of finance.

Further, the *Scoreboard* collects data from audited financial accounts and reports. BERD typically takes a stratified sample, covering all large companies and a representative sample of smaller companies. Additional differences concern the definition of R&D intensity (BERD uses the percentage of value added, while the *Scoreboard* measures it as the R&D/Sales ratio) and the sectoral classification they use (BERD follows NACE, the European statistical classification of economic sectors, while the *Scoreboard* classifies companies' economic activities according to the ICB classification).

Sudden changes in R&D figures may arise because of acquisitions, divestments or a change in company accounting standards. For example, the first time adoption of IFRS[29], may lead to information discontinuities due to the different treatment of R&D, i.e. R&D capitalisation criteria are stricter and, where the criteria are met, the amounts must be capitalised.

For many highly diversified companies, the R&D investment disclosed in their accounts relates only to part of their activities, whereas sales and profits are in respect of all their activities. Unless such groups disclose their R&D investment additional to the other information in segmental analyses, it is not possible to relate the R&D more closely to the results of the individual activities which give rise to it. The impact of this is that some statistics for these groups, e.g. R&D as a percentage of sales, are possibly underestimated and so comparisons with non-diversified groups are limited.

[29] Since 2005, the European Union requires all listed companies in the EU to prepare their consolidated financial statements according to IFRS (International Financial Reporting Standards, see: http://www.iasb.org/).

At the aggregate level, the growth statistics reflect the growth of the set of companies in the current year set. Companies which may have existed in the base year but which are not represented in the current year set are not part of the *Scoreboard* (a company may continue to be represented in the current year set if it has been acquired by or merged with another).

For companies outside the Euro area, all currency amounts have been translated at the Euro exchange rates ruling at 31 December 2015 as shown in Table A3.1. The exchange rate conversion also applies to the historical data. The result is that over time the *Scoreboard* reflects the domestic currency results of the companies rather than economic estimates of current purchasing parity results. The original domestic currency data can be derived simply by reversing the translations at the rates above. Users can then apply their own preferred current purchasing parity transformation models.

COUNTRY	AS OF 31 DEC 2014	AS OF 31 DEC 2015
Australia	$ 1.48	$ 1.49
Brazil	3.22 Brazilian real	4.25 Brazilian real
Canada	$ 1.41	$ 1.51
China	7.43 Renminbi	7.07 Renminbi
Czech Republic	27.72 Koruna	27.03 Koruna
Denmark	7.43 Danish Kronor	7.44 Danish Kronor
Hungary	314.46 Forint	312.50 Forint
India	76.86 Indian Rupee	72.20 Indian Rupee
Israel	4.72 Shekel	4.25 Shekel
Japan	146.41 Yen	131.23 Yen
Mexico	17.87 Mexican Peso	18.73 Mexican Peso
Norway	9.02 Norwegian Kronor	9.59 Norwegian Kronor
Poland	4.06 Zloty	4.25 Zloty
Russia	68.31 Rouble	79.37 Rouble
South Korea	1 333.33 Won	1 282.05 Won
Sweden	9.39 Swedish Kronor	9.19 Swedish Kronor
Switzerland	1.20 Swiss Franc	1.08 Swiss Franc
Turkey	2.82 Turkish Lira	3.17 Turkish Lira
UK	£ 0.78	£ 0.73
USA	$ 1.21	$ 1.09
Taiwan	$ 40.02	$ 35.88

TABLE A3.1. EURO EXCHANGE RATES APPLIED TO *SCOREBOARD* DATA OF COMPANIES BASED IN DIFFERENT CURRENCY AREAS (AS OF 31 DEC 2015).

Glossary of definitions

1 **Research and Development (R&D) investment** in the *Scoreboard* is the cash investment funded by the companies themselves. It excludes R&D undertaken under contract for customers such as governments or other companies. It also excludes the companies' share of any associated company or joint venture R&D investment. Being that disclosed in the annual report and accounts, it is subject to the accounting definitions of R&D. For example, a definition is set out in International Accounting Standard (IAS) 38 "Intangible assets" and is based on the OECD "Frascati" manual. **Research** is defined as original and planned investigation undertaken with the prospect of gaining new scientific or technical knowledge and understanding. Expenditure on research is recognised as an expense when it is incurred. **Development** is the application of research findings or other knowledge to a plan or design for the production of new or substantially improved materials, devices, products, processes, systems or services before the start of commercial production or use. Development costs are capitalised when they meet certain criteria and when it can be demonstrated that the asset will generate probable future economic benefits. Where part or all of R&D costs have been capitalised, the additions to the appropriate intangible assets are included to calculate the cash investment and any amortisation eliminated.

2 **Net sales** follow the usual accounting definition of sales, excluding sales taxes and shares of sales of joint ventures & associates. For banks, sales are defined as the "Total (operating) income" plus any insurance income. For insurance companies, sales are defined as "Gross premiums written" plus any banking income.

3 **R&D intensity** is the ratio between R&D investment and net sales of a given company or group of companies. At the aggregate level, R&D intensity is calculated only by those companies for which data exist for both R&D and net sales in the specified year. The calculation of R&D intensity in the *Scoreboard* is different from than in official statistics, e.g. BERD, where R&D intensity is based on value added instead of net sales.

4 **Operating profit** is calculated as profit (or loss) before taxation, plus net interest cost (or minus net interest income) minus government grants, less gains (or plus losses) arising from the sale/disposal of businesses or fixed assets.

5 **One-year growth** is simple growth over the previous year, expressed as a percentage: 1 yr growth = 100*((C/B)-1); where C = current year amount, and B = previous year amount. 1yr growth is calculated only if data exist for both the current and previous year. At the aggregate level, 1yr growth is calculated only by aggregating those companies for which data exist for both the current and previous year.

6 **Three-year growth** is the compound annual growth over the previous three years, expressed as a percentage: 3 yr growth = 100*(((C/B)^(1/t))-1); where C = current year amount, B = base year amount (where base year = current year - 3), and t = number of time periods (= 3). 3yr growth is calculated only if data exist for the current and base years. At the aggregate level, 3yr growth is calculated only by aggregating those companies for which data exist for the current and base years.

7 **Capital expenditure (Capex)** is expenditure used by a company to acquire or upgrade physical assets such as equipment, property, industrial buildings. In accounts capital expenditure is added to an asset account (i.e. capitalised), thus increasing the asset's base. It is disclosed in accounts as additions to tangible fixed assets.

8 **Number of employees** is the total consolidated average employees or year-end employees if average not stated.

A.3 Composition of the EU 1000 sample

The analysis of chapter 4 applies an extended sample of 1000 companies based in the EU. It consists of 590 companies included in the world R&D ranking of top 2500 companies and additional 410 companies also ranked by level of R&D investment. The composition by country and industry of the EU 1000 sample is presented in the table A3.1 below.

INDUSTRY	EU COUNTRY CODES																					
ICB 3-D	AT	BE	CW	CZ	DE	DK	ES	FI	FR	GR	HU	IE	IT	LU	MT	NL	PL	PT	RO	SE	SI	UK	TOTAL
Aerospace & Defence				1	2		1		7				2			1				1		9	24
Alternative Energy					4	1								1								0	6
Automobiles & Parts	4				18			1	6				5			2				2		9	47
Banks		2			7	2	2		2	1		2	2			2		2		2		7	33
Beverages		1																				1	2
Chemicals	2	3			14	1		3	3							3				3		10	42
Construction & Materials	2	5	1		7	1	4	2	4			2	2							2	1	3	36
Electricity		1		1	1	1	2	2	2				2					1		1		4	18
Electr. & Electrical equipment	3	3			14	2		4	9			1	4	1		5				4		19	69
Financial Services					6				1					1		1				4		4	17
Fixed Line Telecommunications	1				1	1	1		1				1					1		1		2	10
Food & Drug Retailers																1						2	3
Food Producers	1				2	1		2	3	2		2				5						8	26
Forestry & Paper								3	1			1								3		2	10
Gas, Water & Multi-utilities	1				2				3				1									2	9
General Industrials		1			10	1	1	1	2			1	2	2		2				7		5	35
General Retailers					3																	5	8
Health Care Equipment & Services		2	1		13	3			3			2				2				5		13	44
Household Goods & Home Const.					5			1	2				2	1						3	1	4	19

TABLE A3.1 - DISTRIBUTION OF THE SAMPLE OF 1000 COMPANIES BASED IN THE EU BY COUNTRY AND INDUSTRY.

TABLE CONTINUES ON NEXT PAGE →

INDUSTRY	EU COUNTRY CODES																					
ICB 3-D	AT	BE	CW	CZ	DE	DK	ES	FI	FR	GR	HU	IE	IT	LU	MT	NL	PL	PT	RO	SE	SI	UK	TOTAL
Industrial Engineering	5	2			37	3	3	7	7			2	7	2		4				11		14	104
Industrial Metals & Mining	2	3			5		1	1	1					2		1				2		0	18
Industrial Transportation				1	1	1			3				2							1		1	10
Leisure Goods						2		1								1						1	5
Media									4				1							2		6	13
Mining														1						2		3	6
Mobile Telecommunications		1			1			1														1	4
Oil & Gas Producers	1						1	1	1				1						1			2	8
Oil Equipment, Services & Distrib.									2			1		1		1						1	6
Personal Goods	1				6				3				4	1								0	15
Pharmaceuticals & Biotechnology	1	5			14	11	4	1	20	1	1	8	4	1		8		1		9	1	43	133
Real Estate Investment & Services					3								1									1	5
Software & Computer Services	2				20	2	2	5	17			1		1		3	1			5		53	112
Support Services					12				3			1				1				6		26	49
Technology Hardware & Equip.	2	1			6	1		2	6	1		1				6				5		10	41
Tobacco																				1		1	2
Travel & Leisure	1				3			1	1						1					1		3	11
TOTAL	29	30	2	3	217	34	22	39	117	5	1	25	43	15	1	49	1	5	1	83	3	275	1000

TABLE A3.1 - DISTRIBUTION OF THE SAMPLE OF 1000 COMPANIES BASED IN THE EU BY COUNTRY AND INDUSTRY.

A.4 Access to the full dataset

The 2016 *Scoreboard* comprises two data samples:

- The world's top 2500 companies that invested more than €21 million in R&D in 2015.
- The top 1000 R&D investing companies based in the EU with R&D investment exceeding €6 million.

For each company the following information is available:

- Company identification (name, country of registration and sector of declared activity according to ICB classifications).
- R&D investment
- Net Sales
- Capital expenditure
- Operating profit or loss
- Total number of employees
- Main company indicators (R&D intensity, Capex intensity, Profitability)
- Growth rates of main indicators over one year and three years.

The following links provide access to the two *Scoreboard* data samples containing the main economic and financial indicators and main statistics over the past four years.

R&D ranking of world top 2500 companies

R&D ranking of EU top 1000 companies

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