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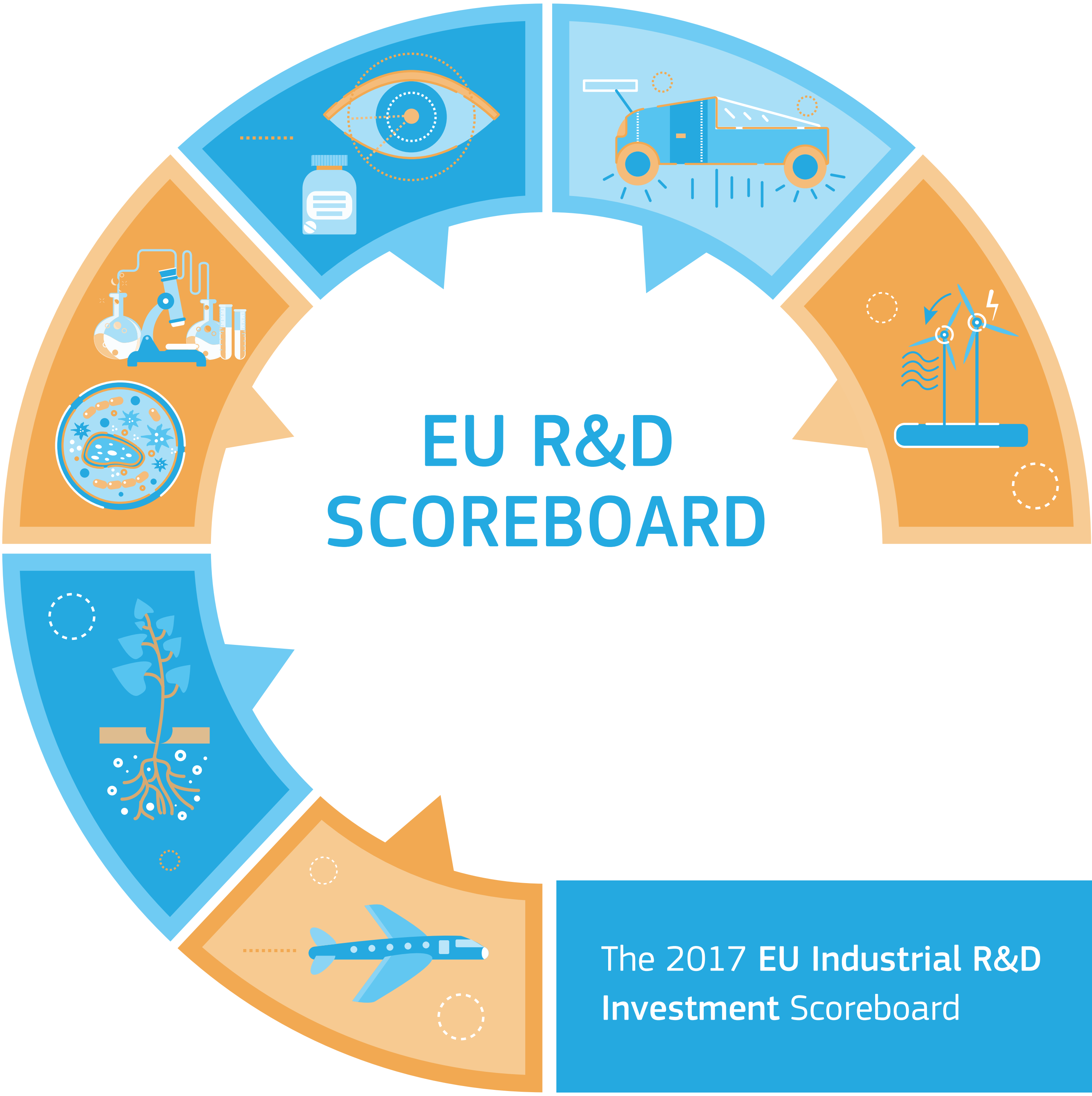

EU R&D SCOREBOARD

The 2017 **EU Industrial R&D Investment** Scoreboard

EUR 28870 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 2017 EU INDUSTRIAL R&D INVESTMENT SCOREBOARD

TABLE OF CONTENTS

0

SUMMARY / INTRODUCTION

Summary

The 2017 edition of the EU Industrial R&D Investment Scoreboard (the *Scoreboard*) comprises the 2500 companies investing the largest sums in R&D in the world in 2016/17. These companies, based in 43 countries, each invested over €24 million in R&D for a total of €741.6bn which is approximately 90% of the world's business-funded R&D. They include 567 EU companies accounting for 26% of the total, 822 US companies for 39%, 365 Japanese companies for 14%, 376 Chinese for 8% and 370 from the rest-of-the-world (RoW) for 13%.

This report analyses the main changes in companies' R&D and economic indicators over the past year and their performance over the past ten years. It also includes results from additional complementary studies on companies' productivity, their development of ICT-related technologies and scientific publication activity.

Highlights

1 The 2500 companies raised their total R&D by a substantial 5.8% over the previous year, the sixth consecutive year of significant increases. The increase was driven by the ICT services sector (up 11.7%). The EU group raised its R&D by 7.0% - more than the global average, just less than the US (7.2%) but much more than Japan (-3.0%). China increased its R&D by 18.8% but its total R&D is still small compared to the size of its economy.

2 Turning to other performance measures, the 2500 companies increased sales by only 0.1% over the previous year, operating profits by 8.7% and employee numbers by 1.7% but capex was down by 6.2%. Overall R&D intensity (R&D as % sales) was 4.1%, capex intensity 6.7% and profitability (profit as % sales) 9.5%.

3 Companies' R&D and financial performance varies greatly across industries and, since the sector mix of different world regions is very different, so is regional performance. All major regions have two-thirds to three-quarters of their R&D in three major industries but with very different mixes. The EU has 29.7% of its R&D in automotive, 19.5% in ICT and 23.2% in Health with Japan fairly similar (30% automotive, ICT 24.3% and health 12%). The US, on the other hand, has only 8.1% in automotive but 49.2% in ICT and 26.5% in Health. China has some similarities to the US with 12.5% in automotive and 44.1% in ICT but has only 3% in Health.

4 EU companies' R&D growth is led by automotive together with ICT and health whereas in non-EU companies it is led by the ICT and health industries.

5 Global R&D is concentrated in the largest companies with 40% of total R&D accounted for by the top 50 companies and 53% by the top 100. A substantial number of the world's top R&D investors are based in the EU with the top investor for the fourth consecutive year being Volkswagen. There are 16 EU companies in the world top 50 and 30 in the world top 100. The top 50 also contains 22 companies from the US, 10 from Asia and 2 from Switzerland.

6 An analysis of the ***Scoreboard***'s history database over the 10 year period 2007-16 shows that the EU's share of world R&D has remained constant at 26% with the US's rising a little to 40%, Japan's falling from 24% to 16% but both China and the rest of the world rising.

7 An analysis of the six largest R&D sectors over this 10-year period shows interesting sectoral and regional differences. The EU outperforms or performs comparably in size (of R&D and sales) and R&D intensity for Aerospace & Defence, Automobiles and Pharmaceuticals. But in Biotechnology, Software and IT hardware the EU shows persistent weakness in most indicators such as size and R&D/firm or sales/firm (in particular compared to the US). The EU/non-EU gap in these latter three sectors has widened over the last ten years.

8 The *Scoreboard* also contains extensive data on the 1000 top R&D investors in the EU drawn from 20 member states (the 567 in the global list plus another 433 with R&D between €7m and €24m). Nearly two-thirds of these companies are based in the three largest member states (Germany 224, UK 290 and France 108). The German companies show the largest sales growth with the UK showing the highest growth in R&D (and the highest profitability).

9 An analysis of firm performance shows that labour productivity (in terms of sales/employee) is 3 to 7 times higher for the most productive firms in a sector compared to the least productive. The EU has the most productive firms in Chemicals, Industrials and low tech sector groups with US firms most productive in health and ICT.

10 The *Scoreboard* also contains a study of patent data for the ICT sector and an analysis of scientific publications by company authors for a range of different sectors.

Key findings

In 2016/17, companies increased significantly their R&D investments and profits while showing an important decline in fixed capital investments, stagnation in revenue growth and a modest increase in number of employees

The top 2500 *Scoreboard* companies invested in R&D €741.6bn in 2016/17, an increase of 5.8% with respect to 2015/16, following an increase of 6.8% in the year before. Companies also raised significantly operating profits (8.7%) and more modestly the number of employees (1.7%). In contrast, net sales showed only 0.1% growth while capital expenditures fell substantially by 6.2% (*a Capex reduction of €77bn compared with the R&D increase of €64bn*). Profitability has remained close to 10% over the last five years. See evolution of key figures over the past 10 years in Figure S1.

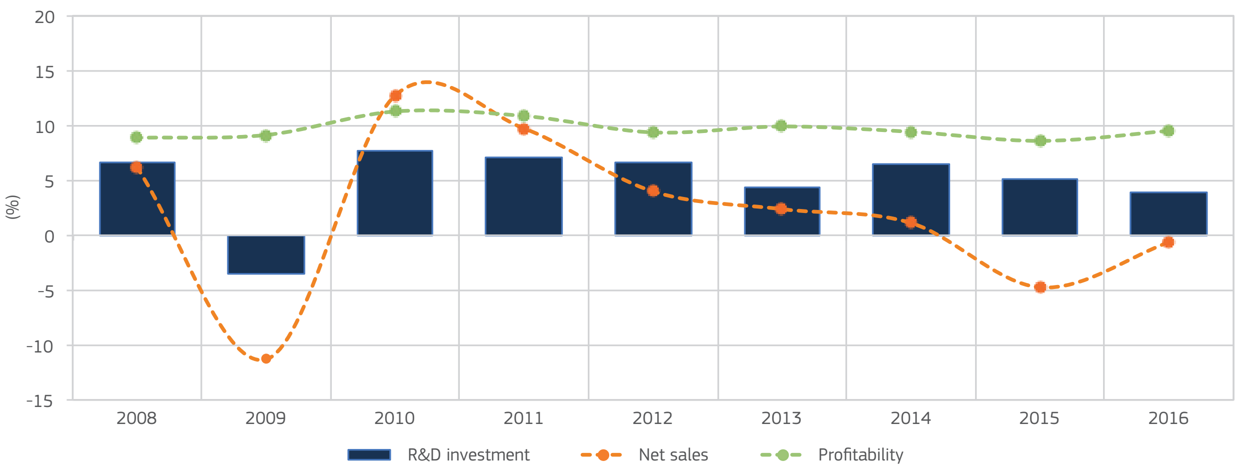

FIGURE S1: GLOBAL GROWTH RATE OF R&D AND NET SALES AND PROFITABILITY FOR THE PERIOD 2007-2016.
Note: growth rates for the three variables have been computed on 1697 out of the 2500 EU companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

Companies' R&D and economic results varied greatly across industries

The main contribution to the global R&D growth was made by the ICT and Health industries that also increased significantly their net sales. The overall fall in net sales was mostly due to low tech sectors, in particular due to oil-related companies, but was also caused by the Industrials and Chemicals sectors. The increase in operating profits was mostly due to high tech sectors (excepting ICT producers) whereas the decline in capital expenditures was mainly caused by the low tech and Automobiles sectors.

EU companies raised R&D above the world's average growth rate

The 567 companies based in the EU invested €192.5bn in R&D, a substantial increase in this period (7.0%) although at a lower pace than in the previous year (8.1%). The 822 companies based in the US and 376 in China showed a high R&D growth (7.2% and 18.8% respectively) while the 365 Japanese companies reduced their R&D investment by 3.0%. See comparison of EU and global companies' R&D growth in Figure S2.

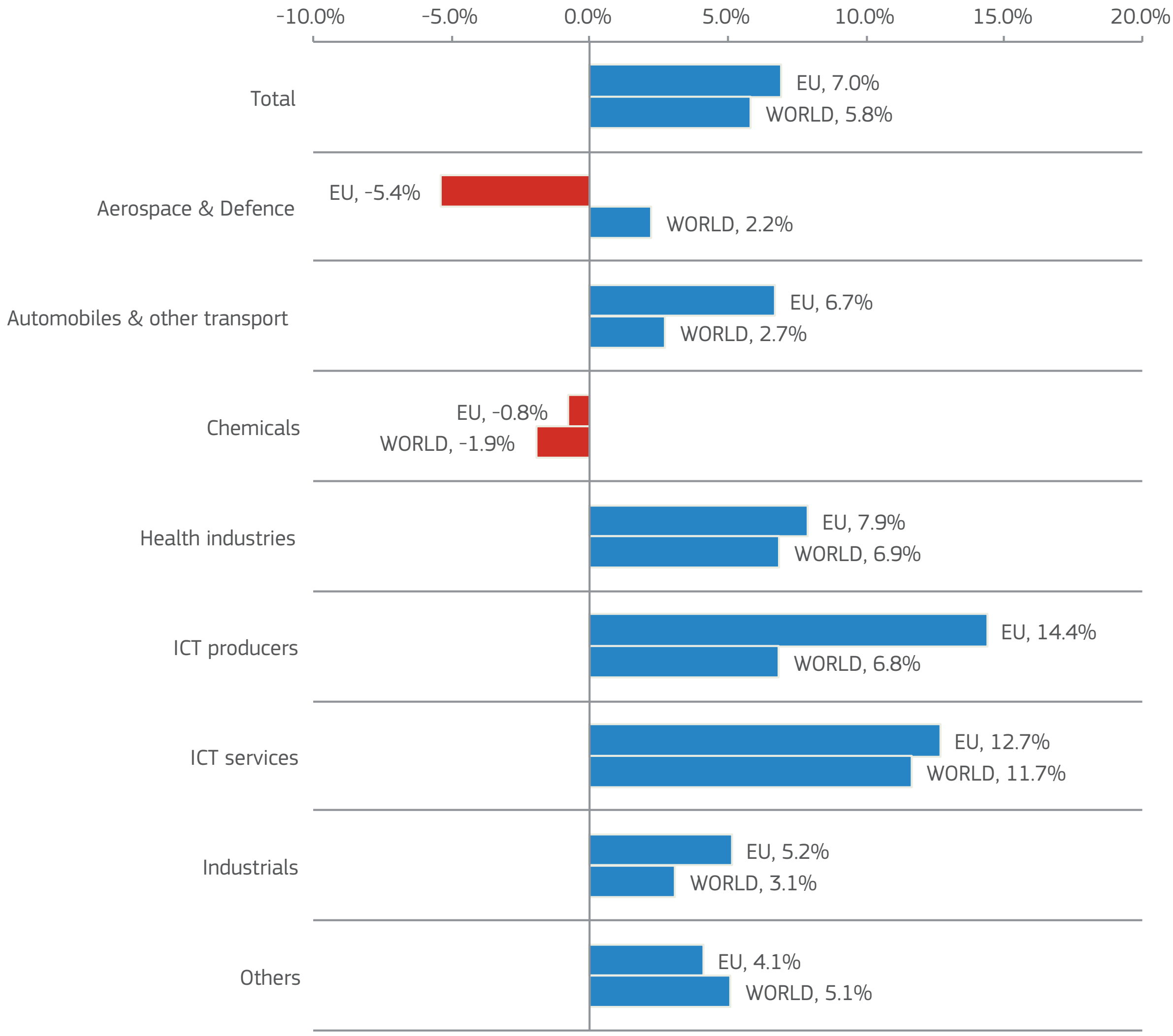

FIGURE S2: NOMINAL CHANGE OF R&D OVER THE PAST YEAR FOR THE EU AND WORLD SAMPLES OF COMPANIES.
Note: growth rates have been computed for 566 EU and 2493 World companies for which R&D data are available for both years 2015 and 2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Other indicators of EU companies showed mixed performance

The EU companies decreased significantly capital expenditures, by 5.1% (*a reduction of €18.5bn compared with the R&D increase of €12.6bn*). The best performance of EU companies was in terms of profits (+16.7%) which led to a significant increase of their profitability level (from 6.8% to 7.6%). The 567 companies employed 18.8million, 2.2% more than the year before.

R&D growth in the EU driven by Automobiles, ICT producers and Health industries

For the EU sample, the largest contribution[1] to R&D growth was made by Automobiles, ICT producers and Health industries but with negative contributions by Aerospace & Defence and Chemicals. Among the largest member

[1] The company or sector contribution to the R&D growth of the sample is the nominal growth rate of the company or sector weighed by the R&D share of the company or sector.

states, German and UK companies showed the highest R&D growth (7% and 9% respectively) while companies based in France and the Netherlands increased R&D at a lower than average rate (3.3%). In the EU sample, R&D growth was led by increases in R&D of companies such as NOKIA(96%), NXP(90%), SAP(13%), SHIRE(56%), ZF(40%), RENAULT(20%), DAIMLER(15%), CONTINENTAL(15%), GLAXOSMITHKLINE(12.9%) and ROBERT BOSCH(7.4%). R&D for some of these companies was increased by acquisitions, e.g. NOKIA's acquisition of Alcatel-Lucent.

▪ *Non-EU companies' R&D growth also led by ICT and Health industries*

The largest contribution to the R&D growth of non-EU companies was made by ICT services, ICT producers and Health industries but with negative contributions by the Chemicals and Automobiles sectors. In the non-EU group, top R&D companies showing high R&D growth were HUAWEI (29%), APPLE (25%), GILEAD (55%), BROADCOM (155%), ALPHABET (13%), DELL (116%), BOEING (42%), FACEBOOK (23%), MICROSOFT (9%), and WESTERN DIGITAL (50%). R&D for some of these companies was increased by acquisitions, e.g. DELL's $67bn acquisition of EMC.

▪ *An important number of top industrial R&D players are based in the EU*

For the 4th consecutive year the top R&D investor is the German company Volkswagen (€13.7bn). The 2nd and 3rd positions are taken by the US companies Alphabet (€12.9bn) and Microsoft (€12.4bn). The other companies in the top-ten are Samsung from South Korea, Intel, Apple and Johnson & Johnson from the US, Novartis and Roche from Switzerland and Huawei from China.

Among the top 50 R&D investors there are 16 EU companies, one more than last year, and 30 companies among the top 100, same number as in last ranking (see ranking of top 50 in Chapter 4).

The world top 50 companies ordered by R&D intensity are naturally almost all from the high tech sectors of ICT and biotech. This top 50 includes 12 from the EU, 26 from the US, 10 from Asia and 2 from Switzerland.

▪ *The share of global R&D for EU companies remained stable over 2007-2016 ...*

Over the past 10 years, EU companies' share of the total R&D remained practically unchanged, at about 26.0%. The main change in this indicator is observed for the Japanese companies whose R&D share fell by ca. 8 percentage points. The loss of R&D share by Japanese companies corresponds to increases in R&D shares for other Asian countries, especially for companies based in China (see Figure S3).

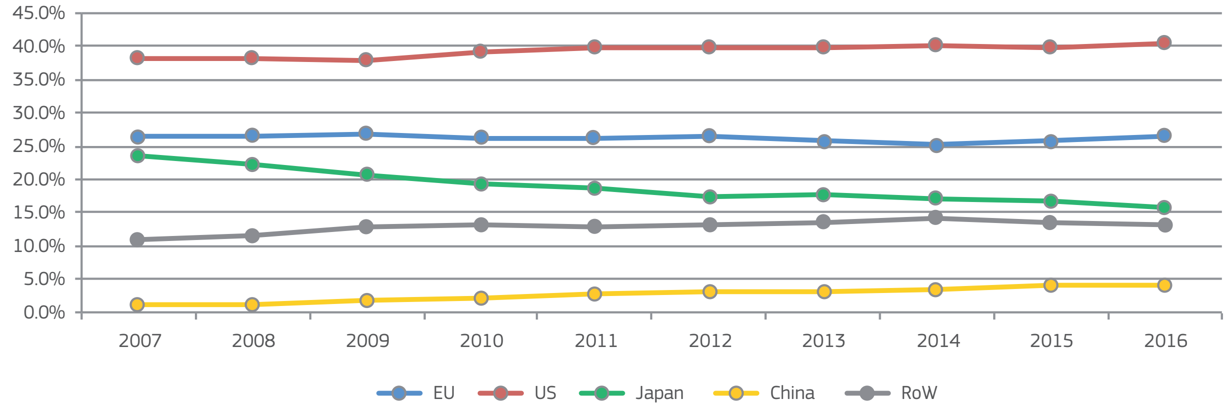

FIGURE S3: EVOLUTION OF R&D SHARES OF MAIN REGIONS OVER 2007-2016.
Note: Calculated for a sample of 1697 companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

... however, the sector composition of the EU sample underwent significant changes

EU companies increased significaltly their share of global R&D in the Automobiles & other transport sector (from 36% to 44%) and reduced their contribution to the total R&D of Aerospace & Defence (from 48% to 42%). In contrast, US companies strongly increased their global R&D share in ICT services (from 66% to 75%) while decreasing their contribution to the world R&D of Automobiles (from 25% to 19%). On the other hand, the R&D share of Chinese companies increased for all sectors whereas that of companies based in Japan fell across the bord. See evolution of global R&D shares for EU companies in Figure S4 and companies' R&D specialisation (sector's share within the region) for the EU and World samples in Figure S5.

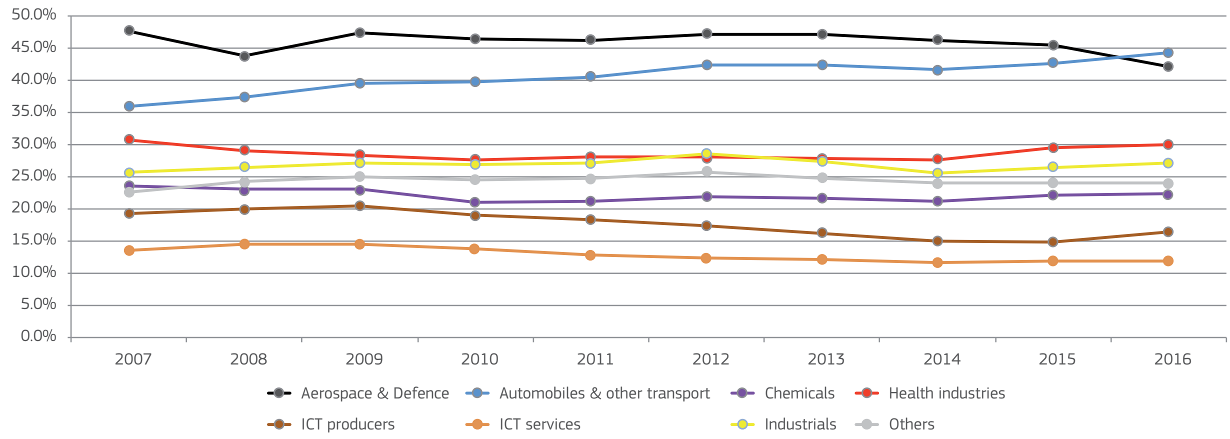

FIGURE S4: EVOLUTION OF GLOBAL R&D SHARES FOR THE EU COMPANIES BY INDUSTRIAL SECTOR.
Note: Calculated for a sample of 402 companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

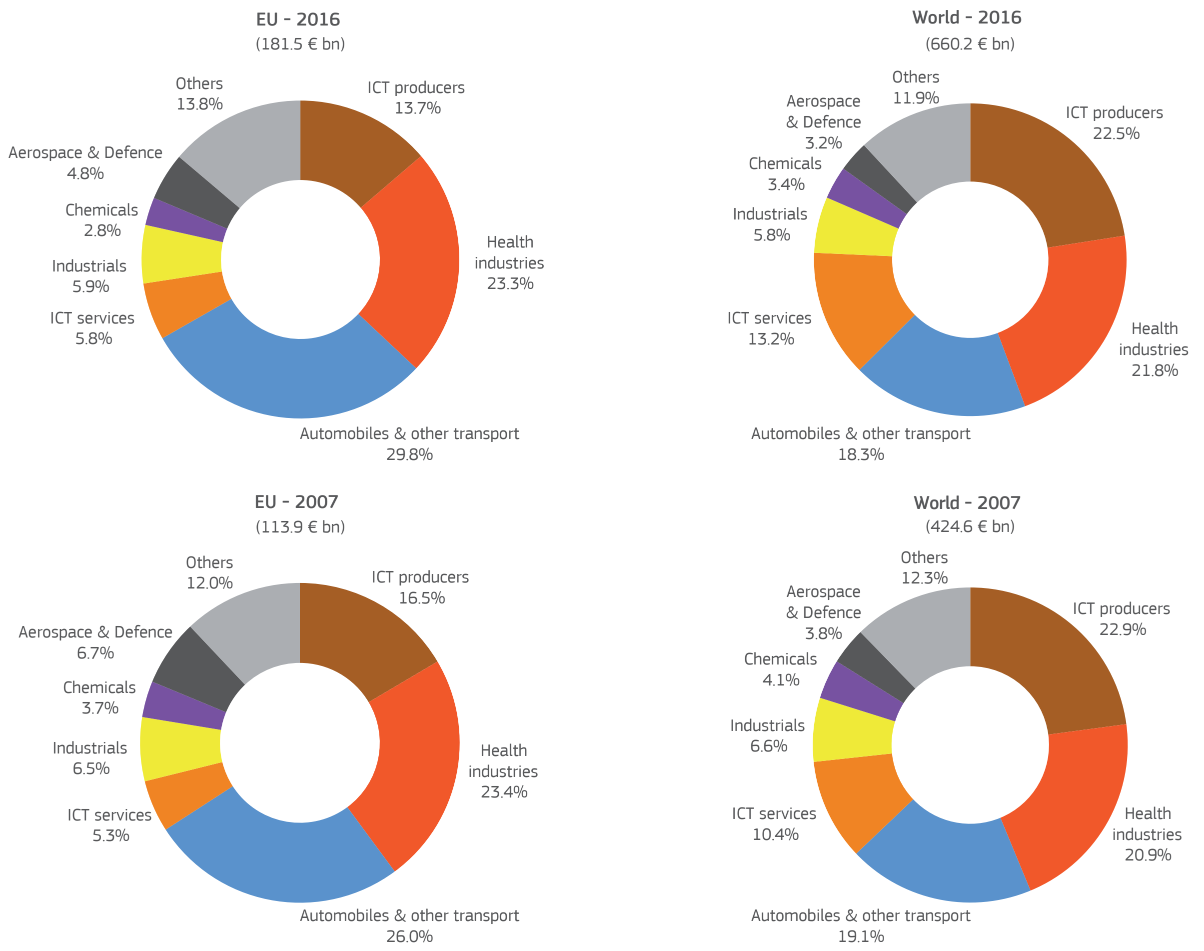

FIGURE S5: R&D SPECIALISATION (SECTORS' SHARES WITHIN EACH REGION) FOR EU AND WORLD COMPANIES IN 2007 AND 2016.
Note: shares computed for 456 EU and 1836 World companies for with R&D data are available for the all period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

An analysis of 10-year changes in R&D, net sales and employment across regions and sectors show characteristic structural differences[2]

In relative terms, Chinese companies showed the largest increases in all the three indicators, however, in absoute terms, the largest increase in R&D was made by the US companies and that of employment by companies based in the EU.

A closer look to the EU and US data show that their companies increased both net sales and employment at a similar rate (ca. 14%, i.e. labour poductivity unchanged). However, they show contrasting differences in the net sales/employees ratio at sector level (see Table S1 and Figure S6). For example:

- In Automobiles, EU 17.2% vs. US -14.6%;
- in ICT sectorss, EU -1.1% vs. US 31.1% and
- in Others (mainly low tech sectors), both with negative performance, EU -10.1% vs. US -33%.

[2] For a set of 1476 companies that reported R&D, net sales and number of employees over the whole period 2007-2016, EU-400, US-503, Japan-343, China-96 and RoW group-134 (see sectors definition in Chapter 1).

Region	Sector	R&D (€ bn.)		Net Sales (€ bn.)		Employment (million)	
		2007	2016	2007	2016	2007	2016
EU	Aerospace & Defence	7.7	8.8	117.0	173.8	0.5	0.5
	Automobiles & other transport	28.9	53.0	628.0	967.6	2.2	2.9
	Chemicals	4.0	5.0	169.0	194.0	0.4	0.5
	Health industries	25.8	41.0	212.7	358.6	0.9	1.3
	ICT sectors	24.6	34.3	476.8	516.5	2.2	2.4
	Industrials	7.0	10.1	492.6	496.1	2.4	2.5
	Others	10.9	16.4	2062.2	2015.1	5.1	5.5
US	Aerospace & Defence	7.6	9.7	224.9	271.4	0.8	0.7
	Automobiles & other transport	5.9	7.8	227.0	223.4	0.7	0.8
	Chemicals	4.9	6.6	171.8	178.5	0.3	0.3
	Health industries	35.3	62.9	370.6	610.8	0.8	1.0
	ICT sectors	69.2	119.9	850.1	1266.1	2.8	3.2
	Industrials	7.7	11.0	388.8	356.5	1.2	1.2
	Others	12.4	15.5	1233.9	1025.2	1.8	2.2

TABLE S1: R&D, NET SALES AND EMPLOYEES FOR THE EU AND US COMPANIES BY SECTOR IN 2007 AND 2016.
Note: For a set of companies that reported R&D, net sales and number of employees over the whole period 2007-2016, EU-400, US-503 (see sectors definition in Chapter 1).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

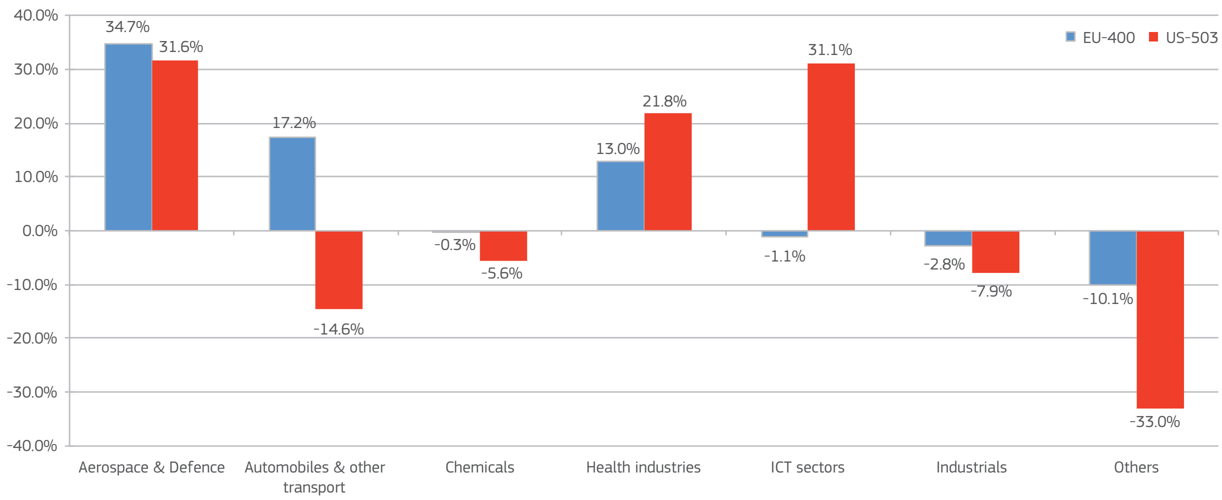

FIGURE S6: CHANGE OF THE NET SALES/EMPLOYEES RATIO OVER 2007-2016 FOR THE EU AND US COMPANIES BY SECTOR.
Note: For a set of 400 EU and 503 US companies for which all variables are available over the 2007-2016 period.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

- ***An analiysis of company dynamics for the six largest R&D sectors over the past 10 years show strenghts, weaknesses and challenges for EU companies***

The 10-year trajectory of EU companies is compared against their non-EU counterparts for six sectors where R&D is a critical competitiveness factor.

For the first three sectors (Aerospace & Defence, Automobiles and Pharmaceuticals), EU companies outperform or show comparable performance to their global counterparts in terms of the main performance ratios (R&D/firm, net sales/firm, R&D/net sales) and show a very large size of both R&D and sales compared to the weight of the EU economy in the world (see Table S2).

But in three other high tech sectors (Biotechnology, Software and IT-hardware), EU companies show persistent weaknesses compared to their non-EU counterparts in most of the indicators (in particular due to the strong performance of US companies). In general the EU companies show much lower ratios[3] of R&D/firm and Sales/firm and only in terms of R&D intensity do they have a similar ratio (Biotechnology) or higher ratio (Software and IT-hardware). The EU sample also has a much smaller size in terms of both R&D and net sales for all these three sectors, well below the weight of the EU economy in the world. It is also observed that the EU/non-EU gap in these three sectors has widened over the past 10 years.

Sector	Region	N. of firms	R&D/firm in 2016/17 (€million)	Net sales/firm in 2016/17 (€million)	R&D intensity (%)	ratio EU/non-EU for R&D	ratio EU/non-EU for Net sales
Aerospace & Defence	EU	16	554.7	11029.5	5.0	0.70	0.55
	non-EU	33	383.4	9725.3	3.9		
Automobiles	EU	36	1495.5	26975.1	5.5	0.89	0.60
	non-EU	126	479.3	12834.3	3.7		
Pharmaceuticals	EU	53	699.9	5095.6	13.7	0.49	0.47
	non-EU	145	519.8	3929.4	13.2		
Biotechnology	EU	30	78.9	328.5	24.0	0.09	0.10
	non-EU	127	214.0	816.3	26.2		
Software	EU	45	185.9	1647.8	11.3	0.10	0.10
	non-EU	223	358.2	3318.5	10.8		
IT hardware	EU	29	551.9	3506.1	15.7	0.15	0.08
	non-EU	246	423.2	5183.7	8.2		

TABLE S2: MAIN INDICATORS ON SELECTED INDUSTRIES FOR THE EU AND NON-EU SAMPLES OF COMPANIES.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

- ***An analysis of the performance of firms in terms of labour productivity (net sales per employee) shows a significant gap between the most productive firms and the lagging firms for both the main industries and the major world regions***

Depending on the sector, the labour productivity is between 3 and 7 times higher for the most productive firms and this gap is rather stable over the 10-yer period.

The top and bottom performers present distinctive features such as the ratio R&D per employee that is consistently higher for top performers or the capital expenditures that mostly differ across sectors.

The geographic distribution of top performers is very sector specific with the EU hosting the largest shares of the most productive firms from the Chemicals, Industrials and low tech sector groups, whereas most of the top performers from the Health and ICT sectors are located in the US. Chinese firms have not managed to gain a significant share amongst the top performers.

- ***A study based on patent data shows the development of ICT-related technologies by the Scoreboard companies, the positioning of the EU and the actual location of the innovation activity***

As shown by the *Scoreboard* R&D figures, EU companies lag behind in the development of ICT technologies. Only one fourth of the total patent families by EU companies relate to digital technologies whereas 81% of those by the Chinese companies are ICT-related, 37% by US ones and 33% by companies based in Japan.

[3] Except for IT hardware where the R&D/firm is higher for the EU companies.

Top target ICT subfields are High-speed network, Mobile communication, Security, and Large capacity information analysis. EU companies also specialise in Electronic measurement and Sensor and device network.

Sectoral specificities arise in the development of digital technologies. Large capacity information analysis is particularly relevant in the Software and Pharmaceuticals & Biotech industries. The Aerospace & Defence industry is very active in the development of a diversified portfolio of digital technologies.

EU and US companies rely to a great extent on inventors located abroad. This is particularly true for ICT-related technologies where respectively about one fourth and one third of patents by EU and US companies depend on international inventors.

▪ *A bibliometric study shows that the* Scoreboard *companies are actively engaged in scientific publications in a wide range of fields, very often in collaboration with academia*

Article publication in peer reviewed journals is a widespread phenomenon among top R&D investors. Engaging in scientific publications does not seem to be a choice of a few firms, but is quite common among firms actively engaged in R&D. There is a positive correlation between a firm's R&D expenditure and the number of publications to which the firm has contributed just as there is with patents.

Introduction

The 2017 edition of the "EU Industrial R&D Investment Scoreboard" (the *Scoreboard*)[4] comprises the **2500 companies investing the largest sums in R&D in the world** and an additional 433 companies to provide data on the **top 1000 R&D investing companies based in the EU**[5]. In total, there are 2933 companies incorporated in the 2017 *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 their subsidiary companies.

Companies' R&D rankings are based on information taken from the companies' latest published accounts. For most companies these correspond to calendar year 2016, but significant proportions have financial years ending on 31 March 2017 (Japanese companies in particular). There are few companies included with financial years ending as late as end June 2017 and a few for which only accounts to end 2015 were available.

It should be noted that the *Scoreboard* relies on the 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 example, it is a legal requirement in some countries that R&D investment is disclosed in company annual reports. For these reasons, companies from some countries such as Southern or Eastern European countries might be under-represented while others such as the 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* (€741.6 billion) is equivalent to more than 90% of the total expenditure on R&D financed by the business sector worldwide[6].

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 enhanced by information gathered about the ownership structure of the *Scoreboard* parent companies and the main indicators for their subsidiaries. In 2017, we have collected available indicators reported by the more than 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 their actual economic or innovation activity.

In this edition we have continued to use the patent data of parent companies and their subsidiaries to characterise the location of companies' innovation activity and technological profile.

Report structure

In this edition, we are using a different structure of the EU R&D *Scoreboard* report, organising differently the description of data and the analytical parts and giving more emphasis to long-term issues supported by our extensive history database.

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

[5] 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).

[6] According to the latest figures reported by Eurostat, i.e. R&D financed by the business enterprise sector in 2015 compared with R&D figures in the 2016 Scoreboard.

In chapter 1 we provide an overview of the main characteristics of the industrial R&D, including the main economic factors and technological drivers that have shaped R&D investments over the past year. The dataset of this *Scoreboard* edition is described in detail and, in particular, the geographic and sector distribution of R&D and its concentration at company, industry and country levels.

Chapter 2 presents an overview of global trends for industrial R&D. It outlines the main indicators for the top 2500 companies and the main changes that took place over the past year. Companies are aggregated by industry and world region to analyse their performance in terms of R&D, net sales, profitability and employment over the past 10 years.

Chapter 3 presents an analysis of the main R&D and economic indicators of companies aggregated by industrial sector, with comparisons of EU companies and their main worldwide counterparts. This chapter also includes an analysis of company R&D dynamics over the past 10 years for selected high R&D investing industries.

The performance of individual companies among the top R&D investors is analysed in chapter 4. 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 13 years. It also includes an analysis of the ranking of the top 50 large companies by R&D intensity.

Chapter 5 discusses trends in the R&D and economic performance of companies included in the extended sample comprising the top 1000 R&D investors based in the EU and focused on the ten largest countries of the EU accounting for more than 98% of the total R&D of the sample of all 1000 companies based in the EU.

Chapter 6 analyses the performance and dynamics of firms in terms of labour productivity (net sales per employee), comparing the most productive firms with the lagging firms for main industries and world regions.

In chapter 7, patent data are applied to investigate the development of ICT-related technologies by the *Scoreboard* companies. The chapter aims to identify the companies leading the development of relevant ICT technologies, to assess the positioning of EU companies and to analyse the actual location of companies' innovation activity.

Finally, chapter 8 presents the results of an exercise aiming to assess the scientific publication activity of the *Scoreboard* companies. It is based on information collected and analysed regarding articles by authors affiliated to *Scoreboard* parent companies and their subsidiaries, published in peer reviewed journals over the period 2011-2015.

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

The methodological approach of the *Scoreboard*, its scope and limitations are described in Annex 2, including a summary of main caveats in Box A2.1.

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/scoreboard17.html

1

THE INDUSTRIAL
R&D LANDSCAPE

1 The industrial R&D landscape

This chapter provides an overview of global industrial R&D and main economic factors and technological drivers that have shaped corporate R&D investments over the past year. It outlines the main characteristics of the 2017 Scoreboard *dataset, including the distribution of companies and their R&D investments by country, world region and industrial sectors.*

1.1 | Economic context and technological drivers

This section summarises the main economic factors and technological trends that affected companies' R&D investment in the period 2016/17 covered by this report.

1.1.1 Economic environment for the *Scoreboard* companies in 2016/17

Three of the major external economic and governmental issues affecting the business environment for R&D were interest rates, the oil price and growth rates of the major world economies. On the political front, there were no major surprises in 2017's elections in France, Germany and The Netherlands compared with those seen in 2016 (Brexit and the US presidency). The three economic issues are each discussed below.

Interest rates are important for companies since they determine the cost of borrowing for investment. Interest rates have been extraordinarily low since the financial crisis and observers were watching the US Federal Reserve (the Fed) throughout 2015 to see when the first rate rise would occur. The Fed eventually raised rates from zero to 0.25% in December 2015 with another rise in December 2016 (from 0.25% to 0.5%). The Fed predicted three more rises in 2017. The first of these occurred in March and the second in June – both by another 0.25% – while the third is likely to happen in December with further increases expected in 2018. The Bank of England raised its interest rate from the 0.25% to 0.5% in early November and indicated that two more rises were likely in 2018. In addition, the Fed has already announced that it is to put its multi-trillion-dollar QE programme into gradual reverse from October 2017 although its asset-trimming programme would be suspended should economic conditions deteriorate substantially. Then in late October the ECB announced it was reducing its QE programme starting in January 2018. Monthly asset purchases are being halved from €60bn to €30bn although the programme of purchases is being extended to September 2018 (or beyond if necessary). It therefore looks as if the Fed, the ECB and the BoE all want to return to normality although they remain concerned about raising rates/reducing QE too fast and thereby slowing economic growth while inflation remains low. The Fed's series of interest rate increases and the recent one by the BoE are likely to be followed later on by other central banks. The reason is that central banks all need to raise interest rates and wind down QE so that they regain the firepower needed to deal with future financial instabilities.

Average **crude oil prices** had been a little above $100/barrel for the year up to mid-2014 but then began a steady decline to under $30/barrel in January 2016. There was a limited recovery to $54/barrel in January/February 2016 but since mid-August 2016 the price has remained in the range of approximately $44-$54 per barrel and was around $50/barrel in mid-October 2017. The prices of other commodities such as metals have recovered in 2017 from lows in the period Q3 2015 to Q3 2016. What seems to be happening for oil is that US shale producers have lowered their costs so that they can sell profitably in the $44-$54 range and this limits OPEC's ability to raise prices even when its members can agree to limit output. A relatively low and stable oil price as we have had for over a year is helpful for economic stability (the 1970s showed the harmful effects on economies of sudden and large oil price rises).

Economic growth has been modest but positive in the major economies and there have been no major political surprises. The surprises of 2016 have had less effect than predicted – Brexit did not have much effect on UK growth in 2016 and Donald Trump's election did not spur growth as some expected mainly because the anticipated tax changes and substantial infrastructure investment have not happened yet. In June 2017 the OECD described the economic outlook as "Better but not good enough". Real world GDP growth is expected by the OECD to be 3.5% in 2017, up from 3% in 2016. A small further increase to 3.6% is expected for 2018. In the developed world, 2017 growth is expected to be led by the US with 2.1% followed by the Eurozone (1.8%) and Japan (1.4%).

Central banks' progress in normalising interest rates and the OECD growth projections suggest that companies are likely to view 2017-18 fairly optimistically. Combined with a wealth of technological opportunities in the main R&D-intensive sectors, that means R&D directors should be able to argue for higher R&D budgets in 2018 provided they can present their CEO's with innovative project and new product proposals.

1.1.2 Key technological trends affecting the top R&D investing companies

In the next section, Figure 1.5 shows that three broad sectors - ICT, Health and automotive – account for three-quarters of the R&D of the top 2,500 companies. Fig 1.6 shows that the largest of these three sectors by R&D in the EU and Japan is automotive while ICT is the largest in the US and China. This section therefore highlights areas of active development in these three major sectors – transport (particularly electric & self-driving technologies), ICT (robotics & artificial intelligence (AI) and their applications including to transport) and health (cancer immunotherapy, gene editing and stem cells).

Any major technological change in a sector creates winners and losers – this was graphically illustrated by the demise of Kodak as photography transitioned from chemical to digital image recording. Another example is smartphones where leaders in mobile telephony such as Nokia and Motorola failed to make the transition to smartphones which are now dominated by new entrants such as **Apple** and **Samsung**. In the same way some current automotive manufacturers are likely to suffer like Kodak while others will succeed in adapting. At the same time new entrants such as **Tesla**, **Waymo** (Google) and **Dyson** have opportunities to grow their market shares with innovative new electric/self-driving car products. The following sections describe recent developments in the transport, ICT and health sectors:

Transport

Electric vehicles

Automotive is the third largest sector by amount of R&D in the 2017 *Scoreboard* and the largest single sector in both the EU and Japan. During 2016/17 there have been important political, technological and commercial announcements about electric vehicles. The UK and French governments have both said that all new vehicles sold in their countries from 2040 must have electric propulsion. And **Volvo** announced in July 2017 that all their new cars introduced from 2019 will be either electric or hybrid. The cost of lithium batteries is being reduced – as, for example, in the batteries produced by **Tesla's** large new battery factory. This has enabled Tesla to introduce its new model 3 at a starting US price of $35,000.

Several mainstream vehicle manufacturers have also announced plans for ranges of new electric models. These include **Volkswagen** (pledged 50 pure electric and 30 hybrids by 2025), **Daimler** (entire portfolio to be electrified by 2022), **Renault** (50% electric or hybrid by 2022) and **Honda** (two-thirds of European sales to be offered with a hybrid option by 2025). But there are also new entrants in addition to Tesla. For example, Sir

James Dyson announced in September 2017 that his company (**Dyson**) is investing £2.5bn to produce "a unique electric car" with robotic partially driverless abilities which would be on the market by 2020. Other new entrants are **Faraday Future** of the US (which has just acquired its first factory in California) and **Rimac** of Croatia which makes electric supercars. European autocatalyst makers such as **Johnson Matthey** and **Umicore** are investing in novel battery technology and substantial investment is now going into the charging infrastructure needed for electric vehicles – for example, **Shell** is planning to install fast chargers in its worldwide petrol stations starting in the UK and Netherlands. Improved infrastructure together with lower prices and improved performance from better batteries will help grow the electric vehicle market.

And it is not just road vehicles; in September 2017 **EasyJet**, the budget airline, announced a partnership with **Wright Electric** of the US to develop, within a decade, a battery-propelled aircraft for short haul flights of up to 535km.

Batteries

The battery is the most expensive component in an electric car and determines key parameters such as the range and recharge time (and too many rapid recharges can degrade current batteries). Recent developments include **Panasonic** and **Tesla's** new, lower cost lithium battery pack used in Tesla's latest model. But the future is likely to be in solid state batteries to give increased range with longer life and reduced charging time. **Toyota**, for example, is working on an improved lithium battery with a solid electrolyte and other solid state batteries are likely to follow. **Dyson** is very likely to use a solid state battery in its new electric car based on technology from the **Sakti3** company it acquired in 2015 for $90m.

Self-driving vehicles

Tesla's new model 3 comes with autopilot, a step towards full self- driving. But although the Tesla and certain other current models offer partial autonomy, full autonomy or self-driving in mass production cars is some years away – probably in the period after 2025. However, non-automotive companies such as **Alphabet** (Google) are well advanced in testing self-driving cars. The Google self-driving project – now an Alphabet subsidiary called **Waymo** – demonstrated its first fully self-driving vehicle without a steering wheel on public roads in 2015. Waymo is about to launch a driverless taxi service in Phoenix, Arizona. Regulatory authorities are encouraging testing with 27 companies now having permits in California to test self-driving cars on public roads (but with a human in the car 'just in case'). And the UK government is to allow wirelessly-connected truck convoys on British motorways by the end of 2018. Road transport is the most visible application for autonomous vehicles but sea and air transport will follow.

ICT, Robotics and AI

The increase in computer processing power and the reduction in memory costs are enabling the use of big data, AI (artificial intelligence) and of more connected devices. AI is the key to the new smart robotics which is finding a wide range of applications from self-driving cars to medical diagnostics, surgery and farming. These new applications use AI and big data and are the next step on from the earlier generation of industrial robots programmed to carry out relatively simple repetitive tasks on a production line.

Smart robots are finding applications not just in replacing manual jobs but increasingly in skilled manual and white collar jobs too. Self-driving cars are one of the most visible smart robotic applications but currently have humans on board just-in-case of malfunction and also to satisfy regulators. However, technology will progress to enable higher degrees of autonomy until the passenger simply programmes in his destination and the car drives there autonomously. Machine learning will enable analogous advances in medical diagnostics, autonomous drones and speech recognition. Military robots are inevitable – military drones are already being used for anti-terrorist missions in the Middle East – and will receive substantial development funding. Military robots are likely to evolve to intelligent fighting systems that can make decisions without human control. Other sectors that will be transformed by intelligent robots are logistics and warehousing, farming, law, education, elderly care (an important area of R&D in Japan) and many others – but each on a different timescale. Improved cybersecurity will become ever more important as these applications are developed further. The major companies in AI include **Alphabet** (which acquired **DeepMind** of the UK – the company whose AI system defeated the world champion at Go), **Amazon**, **Facebook**, **IBM** and **Microsoft**.

Medicine and health

Medical technology is advancing rapidly with systems such as intuitive Surgical's *da Vinci* robotic surgery system in widespread use for a variety of different operations (each system currently controlled by a surgeon). **Elekta** and **Philips** are in the final stages of developing a MRI-guided radiotherapy system which allows both a tumour and the surrounding soft tissue to be viewed during radiotherapy. And **Medtronic** has MRI-safe small-size pacemakers, small drug-eluting stents and a system for replacing aortic heart valves without open-heart surgery all approved and on the market. Jarvik artificial hearts are in use to extend the life of patients awaiting transplants. AI is likely to be increasingly used in medical diagnoses and diagnoses without the use of AI are likely to become rare after 2025.

Advances in cancer and other drugs

Biotech is advancing rapidly and August 2017 saw the first ever approval of a Car-T therapy by the FDA – **Novartis's** *Kymriah*. Car-T stands for Chimeric antigen receptor Therapy in which a patient's blood cells are extracted in a hospital, then the immune system T-cells are modified in a laboratory by inserting a gene so they are armed to recognise and attack cancer cells. *Kymriah* has shown very promising results in clinical trials on young blood cancer patients. *Kymriah* is one example of an immunotherapy in which the body's own immune system is used to fight cancer. Other immunotherapy drugs approved during 2016/17 include **Bristol-Myers Squibb's** nivolumab *(Opdivo*) and **Merck's** pembrolizumab (*Keytruda*) for several different cancers and **AstraZeneca's** durvalumab (*Imfinzi*) for bladder and other cancers. **Roche's** atezolizumab *(Tecentriq*) was approved for non-small cell lung cancer in late 2016. This first wave of immunotherapy drugs is providing hope for patients with advanced cancers and the next few years are likely to see further progress in this exciting new approach to cancer treatment.

All the drugs mentioned above with generic names ending in 'mab' are monoclonal antibodies, the basis of many modern drugs. **MorphoSys** has one of the world's largest libraries of fully human antibodies and has partnerships with most of the major pharmaceutical companies to develop effective new drugs using its antibodies.

Gene therapy

The cost of genetic sequencing has fallen massively over the last decade. The cost of the first sequencing of the whole human genome in 2003 was $2.7bn but this had fallen to $300,000 by 2006 when **Illumina**, the world leader in genomic sequencing announced its first machine. By 2014 Illumina could do the same thing for $1,000 and the company is now predicting a future cost of $100. **Oxford Nanopore**, a biotech unicorn, has developed low cost genomic and DNA sequencing devices. These advances in gene and DNA sequencing together with the CRISPR/Cas9 gene editing tool are enabling a new range of personalised treatments tailored to a patient's genetic make-up. Treatment of inherited genetic diseases by gene therapy is just one example where the faulty or missing DNA that is causing the disease is replaced. Genomic medicine has the potential to accelerate diagnoses and provide routes to treat rare diseases linked to genetic faults. Gene editing and gene synthesis are also behind major developments to improve plants and farm animals.

Stem cells and drugs for neurological diseases

Stem cell therapy is an example of another promising area with bone marrow transplants for blood cancers being a long established and effective treatment. However, research suggests that stem cell therapy could also be effective for neurological conditions such as Parkinson's, for brain and spinal cord injuries and for heart conditions. Recent research at the Wellcome Trust has demonstrated expanded potential stem cells. There are also a number of new drugs in clinical trials for serious neurological diseases such as Alzheimer's, Parkinson's and MS.

1.2 | Portrayal of the R&D investment

This section outlines the main characteristics of the 2017 *Scoreboard* dataset and highlights, in particular, the industrial R&D concentration at company, industry and country levels.

The 2500 companies each invested more than €24 million in 2016/17, accounting together for €741.6 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.

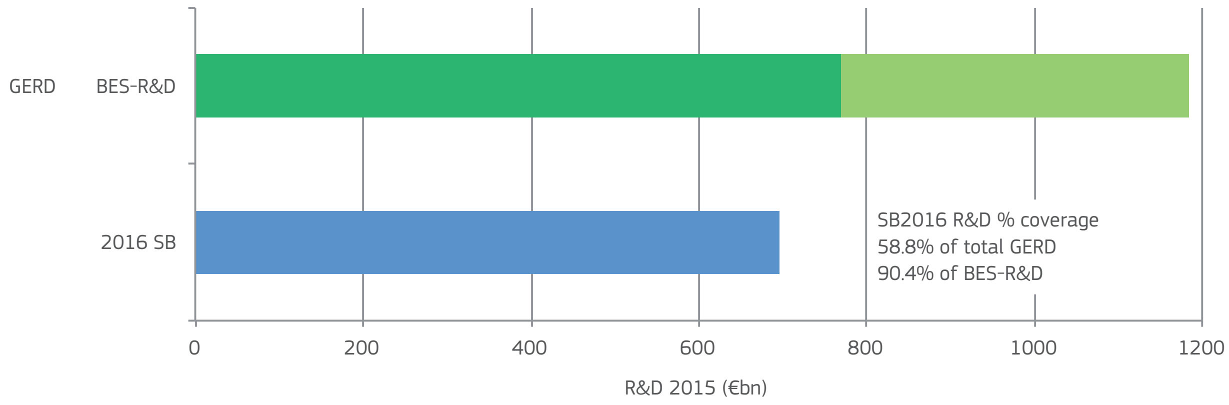

FIGURE 1.1: COMPARISON OF R&D FIGURES OF THE SCOREBOARD AND TERRITORIAL STATISTICS.
Note: Total R&D expenditure (GERD) and R&D financed by the business sector (BES-R&D) in 2015 (green dark overlapping bar represent the BES-R&D).
Sources: Latest figures reported by *Eurostat* (14 November 2017) including most countries reporting R&D.
The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

This is illustrated in figure 1.1 where the latest 2015 territorial statistics are compared with the corresponding figures from the previous 2016 *Scoreboard* (GERD €1183.2bn, R&D financed by the business enterprise sector "BES-R&D" €769.6bn and the 2016 *Scoreboard* €696.0bn).

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 €7 million R&D in 2016/17. Of these 1000, 567 appear in the world top 2,500 and another 433 are added with R&D between €7m and €24m.

This additional sample of 1000 is analysed separately in chapter 5.

Companies' distribution by country

The 2017 *Scoreboard* comprises companies with headquarters in 43 countries of which 18 are member states of the EU. The sample includes companies based in the EU (567), the US (821), China (377), Japan (365), Taiwan (105), South Korea (70), Switzerland (52), Canada (27), India (25) and a further 17 countries. See Table 1.1 and Figure 1.2.

Number of companies by country			
EU		non-EU	
Germany	134	US	822
UK	134	China	376
France	71	Japan	365
Netherlands	39	Taiwan	105
Sweden	36	South Korea	70
Denmark	26	Switzerland	52
Italy	24	Canada	27
Ireland	23	India	25
Finland	19	Israel	22
Austria	16	Australia	15
Spain	16	Norway	12
Belgium	15	Brazil	9
Luxembourg	6	Turkey	7
Greece	3	Singapore	6
Portugal	2	Malaysia	3
Hungary	1	New Zealand	3
Malta	1	Mexico	2
Slovenia	1	Further 8 countries	12
Total	**567**	**Total**	**1933**

TABLE 1.1: DISTRIBUTION OF COMPANIES BY COUNTRY.
Note: the 2500 companies all have R&D investment above €24 million.
Source: The 2017 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

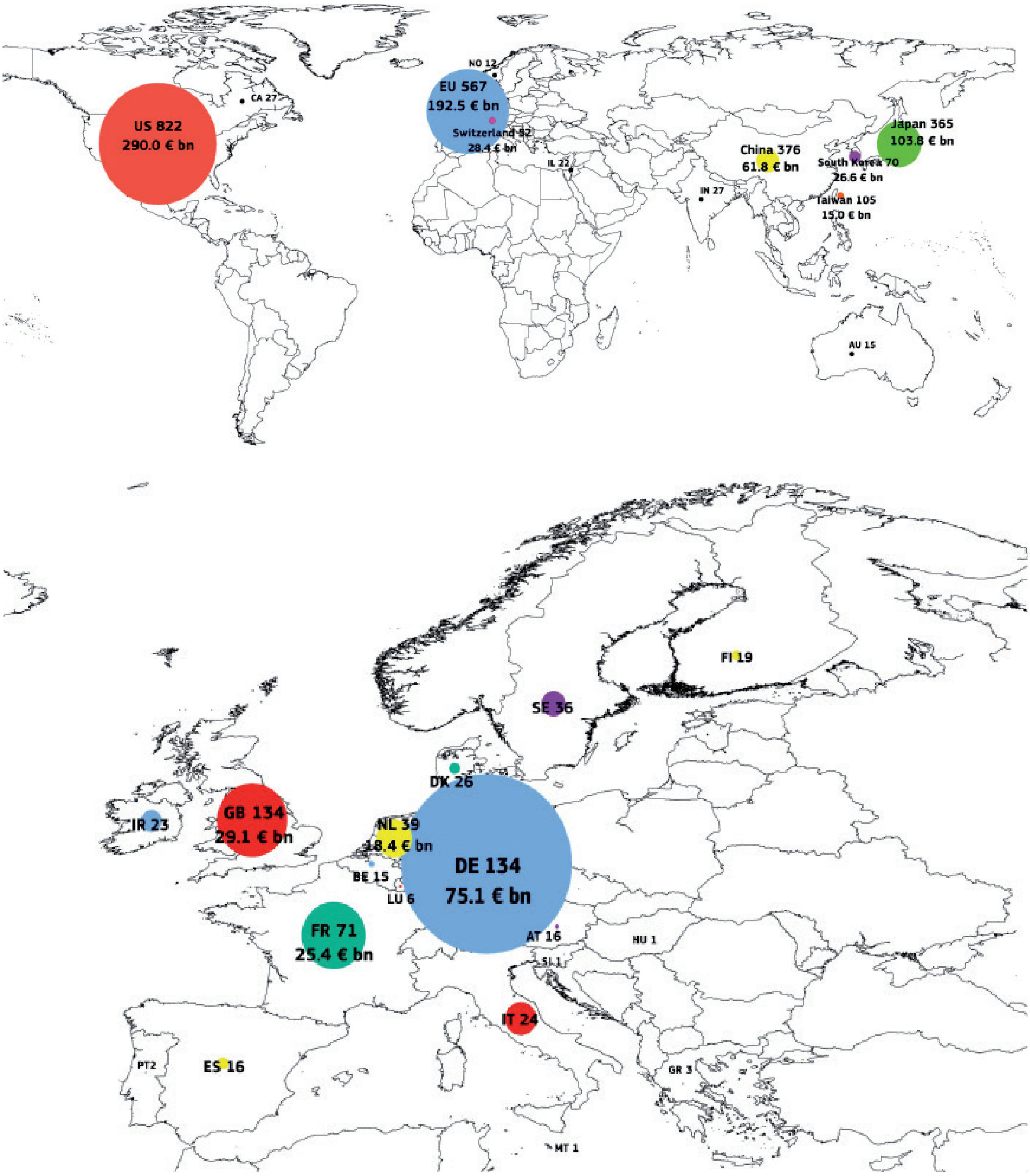

FIGURE 1.2: DISTRIBUTION OF THE 2500 COMPANIES IN THE 2017 *SCOREBOARD* BY HEADQUARTERS COUNTRY.
Note: Number of companies indicated besides the country code (the world map includes only countries with at least 10 companies). R&D is represented with a bubble which size is proportional to R&D in 2016 in the country.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Companies' aggregation by industrial sector

Assigning companies to industrial sectors according to existing classification systems is not a straightforward task. In fact, often sector definitions do not fit unambiguously with actual company activities that may also change over time, and in addition, many companies operate in two or more very different industrial sectors. However companies usually indicate their main sector of activity in their annual reports, for example, public companies use a taxonomy such as the International Classification Benchmark (ICB)[7].

According to the ICB, the *Scoreboard* comprises companies operating in a wide range of manufacturing and services sectors, including more than 50 industries with a special concentration on the most innovative ones such as ICT, health, transport and the engineering related industries. In the *Scoreboard* we use different levels of sector aggregation, following the distribution of companies' R&D. Tables 1.2 and 1.3 describe two typical levels of the industrial classification applied in the *Scoreboard*.

The number of companies by industry for the EU and non-EU regions is shown in Table 1.4. The top 3 companies by level of R&D investment for each type of industry are presented in Table 1.5.

Industrial Sector	Sector classification ICB4 digits	N. of firms	% of total R&D
Aerospace & Defence	Aerospace; Defence	49	2.9%
Automobiles & other transport	Auto Parts; Automobiles; Commercial Vehicles & Trucks; Tires	197	17.1%
Chemicals	Commodity Chemicals; Specialty Chemicals	123	3.2%
Health industries	Biotechnology; Health Care Providers; Medical Equipment; Pharmaceuticals	491	21.5%
ICT producers	Computer Hardware; Electrical Components & Equipment; Electronic Equipment; Electronic Office Equipment; Semiconductors; Telecommunications Equipment	514	23.4%
ICT services	Computer Services; Fixed Line Telecommunications; Internet; Mobile Telecommunications; Software	299	13.1%
Industrials	Aluminium; Containers & Packaging; Diversified Industrials; Industrial Machinery; Iron & Steel; Nonferrous Metals; Transportation Services	303	5.8%
Others*	Alternative Energy; Banks; Beverages; Construction & Materials; Electricity; Financial Services; Food & Drug Retailers; Food Producers; Forestry & Paper; Gas, Water & Multiutilities; General Retailers; Household Goods & Home Construction; Leisure Goods; Life Insurance; Media; Mining; Nonlife Insurance; Oil & Gas Producers; Oil Equipment, Services & Distribution; Personal Goods; Real Estate Investment & Services; Support Services; Tobacco; Travel & Leisure	524	13.1%
Total		**2500**	**100.0%**

TABLE 1.2: INDUSTRIAL CLASSIFICATIONS APPLIED IN THE *SCOREBOARD* -8 INDUSTRIAL GROUPS-.
* Sectors in the "Others" group are presented at ICB-3 digits level.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Sector R&D intensity*	Sector classification ICB4 digits**	N. of firms	% of total R&D
high	Aerospace; Biotechnology; Computer Hardware; Computer Services; Defence; Electronic Office Equipment; Health Care Providers; Internet; Leisure Goods; Medical Equipment; Pharmaceuticals; Semiconductors; Software; Technology Hardware & Equipment; Telecommunications Equipment	1128	54.6%
medium-high	Auto Parts; Automobiles; Commercial Vehicles & Trucks; Commodity Chemicals; Containers & Packaging; Diversified Industrials; Electrical Components & Equipment; Electronic Equipment; Financial Services; Household Goods & Home Construction; Industrial Machinery; Personal Goods; Specialty Chemicals; Support Services; Tires; Travel & Leisure	970	35.4%
medium-low	Alternative Energy; Beverages; Fixed Line Telecommunications; Food Producers; General Retailers; Media; Oil Equipment, Services & Distribution; Tobacco	138	3.9%
low	Aluminium; Banks; Construction & Materials; Electricity; Food & Drug Retailers; Forestry & Paper; Gas, Water & Multiutilities; Iron & Steel; Life Insurance; Mining; Mobile Telecommunications; Nonferrous Metals; Nonlife Insurance; Oil & Gas Producers; Real Estate Investment & Services; Transportation Services	264	6.1%
Total		**2500**	**100.0%**

TABLE 1.3: INDUSTRIAL CLASSIFICATIONS APPLIED IN THE *SCOREBOARD* -4 SECTORS BY R&D INTENSITY-.
Note: 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.
* For simplification, in this report these 4 groups are also referred to as high tech, medium-high tech, medium-low tech and low tech.
**Sectors included in the "Others" group in table 1.2 are presented at ICB3 level
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[7] http://www.ftse.com/products/downloads/ICBStructure-Eng.pdf.

Industry	EU	non-EU	Total
ICT producers	67 (13%)	447 (87%)	514
Health industries	109 (22%)	382 (78%)	491
Industrials	91 (30%)	212 (70%)	303
ICT services	53 (18%)	246 (82%)	299
Automobiles & other transport	45 (23%)	152 (77%)	197
Chemicals	22 (18%)	101 (82%)	123
Aerospace & Defence	16 (33%)	33 (67%)	49
Others	164 (31%)	360 (69%)	524
Total	**567 (22.7%)**	**1933 (77.3%)**	**2500**

TABLE 1.4: DISTRIBUTION OF COMPANIES BY INDUSTRIAL SECTOR AND REGION.
Note: The figures in brackets show each sector's EU & non-EU percentages of the total number of companies in each sector.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Health industries		Automobiles & other transport	
ROCHE	Switzerland	VOLKSWAGEN	Germany
JOHNSON & JOHNSON	US	GENERAL MOTORS	US
NOVARTIS	Switzerland	DAIMLER	Germany
ICT Services		**ICT producers**	
ALPHABET	US	SAMSUNG	South Korea
MICROSOFT	US	INTEL	US
ORACLE	US	HUAWEI	China
Aerospace & Defence		**General Industrials**	
BOEING	US	GENERAL ELECTRIC	US
AIRBUS	Netherlands	TOSHIBA	Japan
UNITED TECHNOLOGIES	US	HONEYWELL	US
Chemicals		**Others**	
BASF	Germany	PANASONIC	Japan
DUPONT*	US	SONY	Japan
DOW CHEMICAL*	US	LG ELECTRONICS	South Korea

TABLE 1.5: TOP 3 COMPANIES BY R&D FOR THE MAIN INDUSTRIES COMPRISED IN THE 2017 *SCOREBOARD*.
*Dow Chemical and Dupont agreed a merger in 2017.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Distribution of the R&D investment by company, sector and country

Industrial R&D is highly concentrated. A small subset of companies, industries and countries account for a large share of the total R&D investment of the 2500 sample. As observed in the *Scoreboard* since 2004, this characteristic R&D concentration remains practically unchanged from year to year.

Figure 1.3 presents the distribution of the 2500 companies ranked by their level of R&D investment.

The R&D concentration (% of total R&D) for the top 10, top 50, top 100 and top 500 companies is respectively 15%, 40%, 53% and 81%.

There are 7 companies having an R&D investment of more than €10bn, 68 more than €2bn and 143 more than €1bn. The latter group of companies comprises 39 from the EU, 51 from the US, 22 Japanese, 14 Chinese and 5 each from South Korea & Switzerland.

The group of top 100 companies mostly operate in three sectors: 25 in Health industries (EU 9), 19 in Automobiles & other transport (EU 10) and 34 in ICT industries (EU 6).

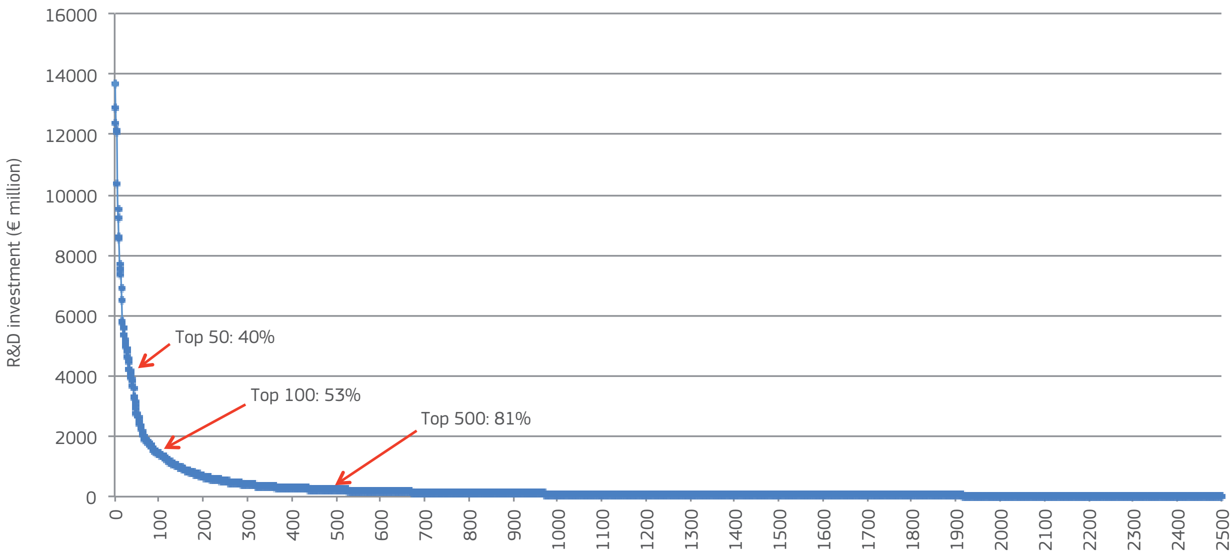

FIGURE 1.3: COMPANIES OF THE 2017 *SCOREBOARD* RANKED BY R&D.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

R&D is also very much concentrated by country and world region. This is observed in figure 1.4 which shows the R&D share of main countries and regions.

The top 3, top 5 and top 10 countries account respectively for 63%, 75% and 90% of the total R&D investment.

Within the EU, the R&D is even more concentrated, the top 3, top 5 and top 10 countries account respectively for 67%, 82% and 98% of the total R&D invested by the companies based in the EU.

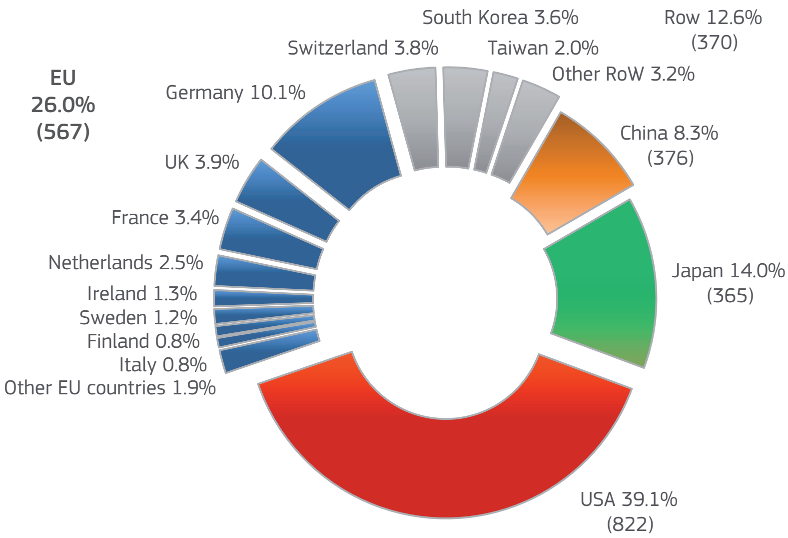

FIGURE 1.4: R&D INVESTMENT BY THE 2500 COMPANIES BY MAIN COUNTRY/REGION (% OF TOTAL €741.6 bn).
Source: The 2017EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

The R&D is also largely concentrated by industrial sector, as illustrated in figure 1.5 presenting the distribution of R&D by industry for the main countries/regions. The four largest R&D investing sectors (ICT producers, Health industries, Automobiles & other transport and ICT services) account for 75% of the total R&D of the 2500 companies. The main contribution to the total *Scoreboard* R&D:

- By EU companies is 45% to Automobiles & other transport, 41% to Aerospace & Defence and 28% to Health industries;
- By US companies is 72% to ICT services, 48% to health industries and 45% to Aerospace & Defence;

- By Japanese companies is 31% to Chemicals, 24% to Automobiles & other transport and 23% to Industrials;
- By Chinese companies is 12% to ICT producers, 12% to Industrials and 20% to other sectors.

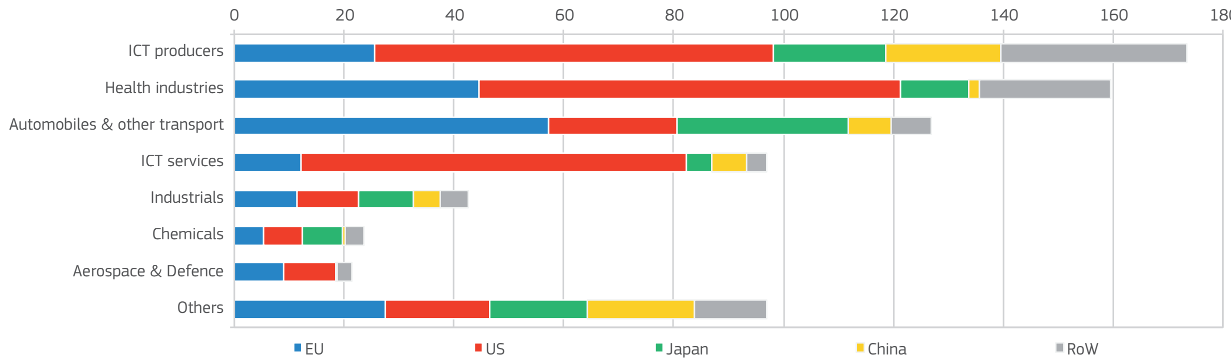

FIGURE 1.5: R&D INVESTMENT BY THE 2500 COMPANIES BY INDUSTRY AND MAIN COUNTRY/REGION (€ bn).
Source: The 2017EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Finally, the R&D shares of industrial sectors for each main country/region are presented in figure 1.6. This figure shows that each country/region has a characteristic R&D specialisation. The top three sectors by level of R&D investment for each region account for:

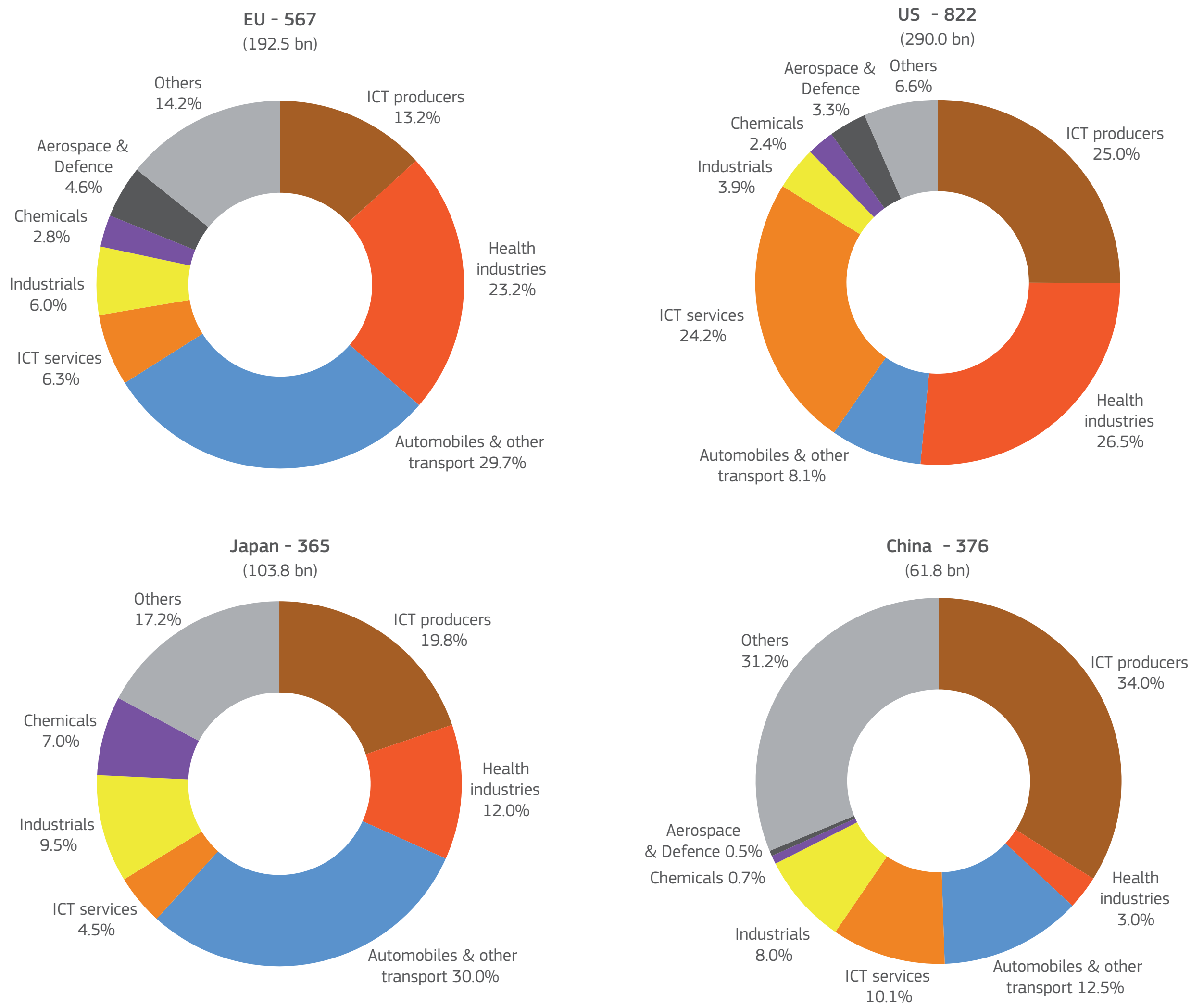

FIGURE 1.6: R&D SHARES OF INDUSTRIAL SECTORS WITHIN MAIN COUNTRIES/REGIONS.
Source: The 2017EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

- 66% within the EU (Automobiles & other transport 29%; Health industries 23% and ICT producers 13%).

- 76% within the US (Health industries 27%; ICT producers 25% and ICT services 24%).

- 62% within Japan (Automobiles & other transport 30%; ICT producers 20% and Health industries 12%).

- 57% within China (ICT producers 34%; Automobiles & other transport 13%; and ICT services 10%).

Whereas the top five companies in the EU and the US account for 19.2% of the total R&D of those regions, the top five in China account for 28.6% and the top five for 23.4% in Japan. Huawei alone accounts for 16.8% of China's *Scoreboard* R&D.

2

GLOBAL INDUSTRIAL R&D TRENDS

2 Global industrial R&D trends

This chapter provides an overview of the main trends in R&D and economic indicators for the world's top 2500 companies that each invested more than €24 million in R&D in 2016/17. The first part concentrates on the evolution of companies' indicators over the previous year and the second section analyses the long-term performance of companies aggregated by main world regions. The 2500 companies are grouped into five main sets: the top 567 companies from the EU, 822 companies from the US, 365 from Japan, 376 Chinese companies and 370 companies from the Rest of the World group (RoW). The RoW group includes companies from Taiwan (105), South Korea (70), Switzerland (52), Canada (27), India (25), Israel (22) and companies based in a further 16 countries.

2.1 | Changes in companies' indicators in 2016/17

In 2016/17, companies in aggregate increased significantly their R&D investments and profits while showing an important decline in fixed capital investments and stagnation in revenues growth. These companies' results, varying greatly across world regions and industries, are presented below. Tables 2.1 and 2.2 at the end of the section present the one-year change of main indicators for the whole set of companies and also by main region and country.

Key points

R&D trends

- Overall R&D investment continued to increase significantly in 2016/17 for the sixth consecutive year. The 2500 *Scoreboard* companies invested €741.6 billion in R&D, 5.8% more than in 2015/16, following the increase of 6.8 % in the year before.
- The 567 companies based in the EU invested €192.5bn in R&D, a substantial increase in this period (+7.0%) although at a lower pace than in the previous year (+8.1%). The 822 companies based in the US and 376 in China showed a high R&D growth (7.2% and 18.8% respectively) while the 365 Japanese companies reduced their R&D investment (-3.0%). See figure 2.1.
- Worldwide R&D growth was driven by ICT services sectors (+11.7%), followed by the Health and ICT producers sectors (7%). Automobiles and Aerospace & Defence grew R&D at a lower pace (respectively 2.7% and 2.2%) and Chemicals reduced R&D (-1.9%).
- For the EU sample, the largest contribution[8] to R&D growth was made by Automobiles, ICT producers and Health industries but with negative contributions by Aerospace & Defence and Chemicals. Among the largest member states, German and UK companies showed the highest R&D growth (7% and 9% respectively) while companies based in France and the Netherlands increased R&D at a lower than average rate (3.3%). In the EU sample, R&D growth was led by increases in R&D of companies such as NOKIA(96%), NXP(90%), SAP(13%), SHIRE(56%), ZF(40%), RENAULT(20%), DAIMLER(15%),

[8] The company or sector contribution to the R&D growth of the sample is the nominal growth rate of the company or sector weighed by the R&D share of the company or sector.

CONTINENTAL(15%), GLAXOSMITHKLINE(12.9%) and ROBERT BOSCH(7.4%). See figure 2.2. R&D growth for some of these companies (and for some of the non-EU ones) was increased by acquisitions.

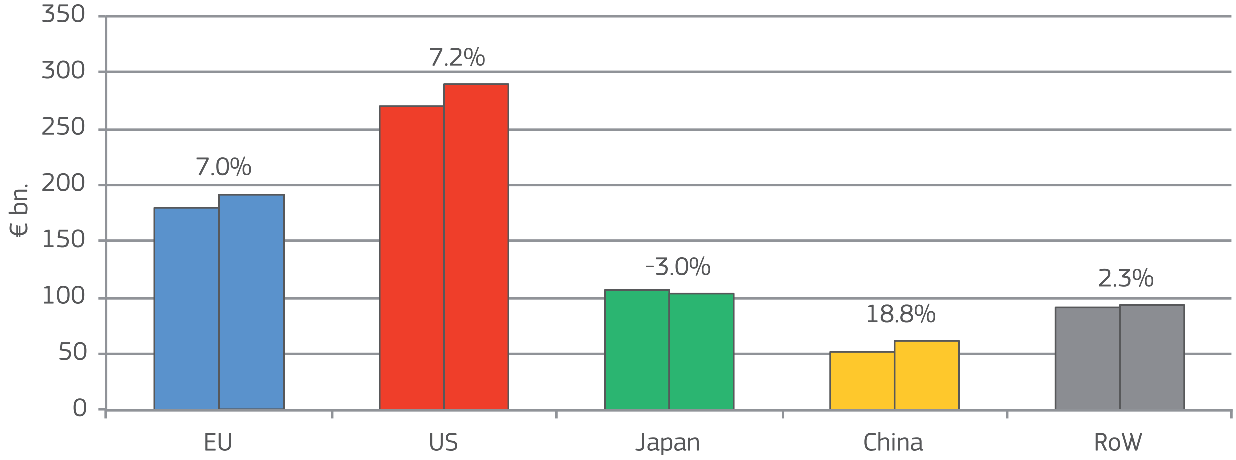

FIGURE 2.1: R&D INVESTMENT BY MAIN WORLD REGION IN THE LATEST TWO YEARS.
Note: growth rates have been computed for 566 EU, 818 US, 364 Japanese, 375 Chinese and 370 RoW companies for which data are available for both years 2015 and 2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

- The largest contribution to the R&D growth of non-EU companies was made by ICT services, ICT producers and Health industries and negative contribution by Chemicals and Automobiles sectors. In the non-EU group, top R&D companies showing high R&D growth were HUAWEI (29%), APPLE (25%), GILEAD (55%), BROADCOM (155%), ALPHABET (13%), DELL (116%), BOEING (42%), FACEBOOK (23%), MICROSOFT (9%), WESTERN DIGITAL (50%).

Other indicators

- For the fifth consecutive year the net sales of the 2500 companies underperformed with respect to R&D with only 0.1% growth although this was an improvement on the previous year's negative growth rate (-3.8%). *This was mostly due to negative growth of net sales in low tech sectors while high R&D investing industries grew net sales well above the world's average*. Capital expenditures fell substantially worldwide by 6.2% (*a reduction of €77.2bn compared with the R&D increase of €64bn*). Operating profits increased significantly (+8.7%). The number of employees by the 2500 companies increased modestly (+1.7%).

- The net sales of the 567 companies based in the EU reached €5.4trillion, 1.0% less than in the previous year. Sectors showing the best sales performance were ICT services, Health industries and ICT producers (+7.7%, 7.2% and 6.3% respectively) and the biggest sales declined was shown by Chemicals (-6.0%).

- The EU companies decreased significantly capital expenditures, by 5.1% (*a reduction of €18.5bn compared with the R&D increase of €12.6bn*). The best performance of EU companies was in terms of profits (+16.7%) which led to a significant increase of their profitability level (from 6.8% to 7.6%). The 567 companies employed 18.8million, 2.2% more than the year before.

- The 822 companies based in the US increased modestly net sales (+1.9%) and profits (+1.7%) and reduced significantly capital expenditures by 4.3% (*a reduction of €12.8bn compared with the R&D increase of €19.5bn*). US companies showed a modest increase on profits (1.7%), below their growth rate of sales therefore their profitability slightly decreased (from 12.9% to 12.7%). Finally, the US companies slightly decreased employee numbers by 1.1% to 11.1million.

- The 365 companies based in Japan dropped net sales by 4.5% and capital expenditures by 4.8%. They increased modestly profits (2.2%) and profitability increased to 7.6%. Number of employees of Japanese companies grew by 2.1%.

- The 376 Chinese companies showed a robust growth in net sales (+7.4%) and net profits (+13.4%), reaching a profitability level of 6.9%. Chinese companies increased employees' number by 4.4%. In terms of capital expenditure, in line with worldwide companies, Chinese ones dropped it by 4.7% (*a reduction of €7.3bn compared with the R&D increase of €9.8bn*).

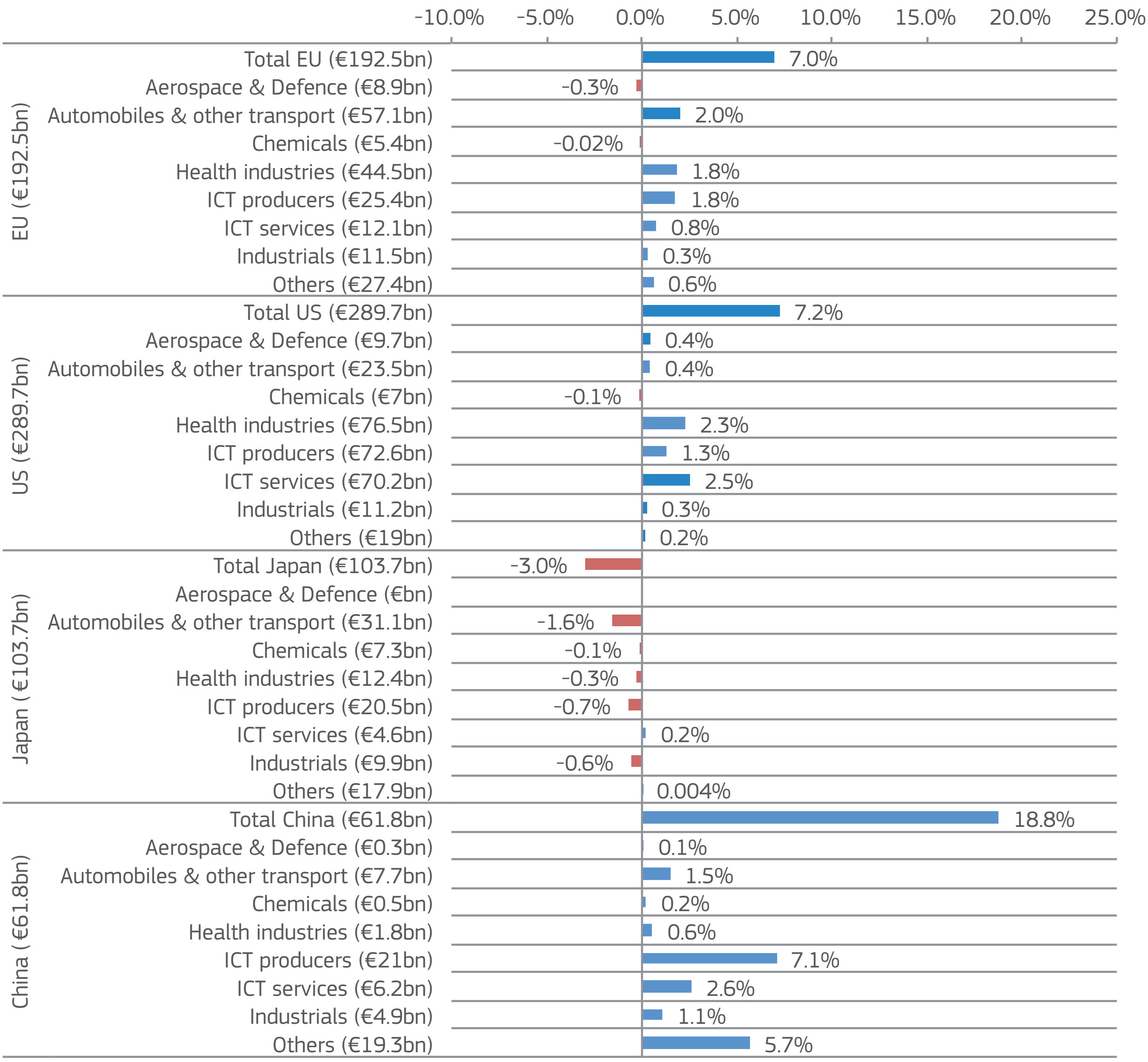

FIGURE 2.2: INDUSTRIES' NET CONTRIBUTION TO THE ONE-YEAR R&D GROWTH RATE OF MAIN REGIONS*.

* R&D growth rate of the industry weighed by its R&D (the sum of industry contributions is the Region's R&D growth).

Note: growth rates have been computed for 566 EU, 818 US, 364 Japanese, 375 Chinese and 370 RoW companies for which data are available for both years 2015 and 2016.

Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	World 2500
R&D in 2016/17, € bn	741.6
One-year change, %	*5.8*
Net Sales, € bn	17910.3
One-year change, %	*0.1*
R&D intensity, %	4.1
Operating profits, € bn	1671.2
One-year change , %	*8.7*
Profitability, %	9.3
Capex, € bn	1167.9
One-year change , %	*-6.2*
Capex / net sales, %	6.5
Employees, million	53.0
One-year change, %	*1.7*

TABLE 2.1: OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2017 *SCOREBOARD*.

Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	EU	USA	Japan	China	RoW
No. of companies	567	822	365	376	370
R&D in 2016/17, € bn	192.5	290.0	103.8	61.8	93.6
World R&D share, %	26.0	39.1	14.0	8.3	12.6
One year change, %	7.0	7.2	-3.0	18.8	2.3
Net Sales, € bn	5427.2	4665.1	2976.4	2174.1	2667.6
One year change, %	-1.0	1.9	-4.5	7.4	-0.5
R&D intensity, %	3.5	6.2	3.5	2.8	3.5
Operating Profit, € bn	414.8	592.9	225.2	150.8	287.4
One year change, %	16.7	1.7	2.2	13.4	17.0
Profitability (1)	7.6	12.7	7.6	6.9	10.8
Capex, € bn	344.3	285.0	178.7	148.7	211.3
One year change, %	-5.1	-4.3	-4.8	-4.7	-12.4
Capex intensity, %	6.3	6.1	6.6	6.8	8.0
Employees, million	18.8	11.1	8.8	8.8	5.5
One year change, %	2.2	-1.1	2.1	4.4	0.5

TABLE 2.2A: OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2017 *SCOREBOARD*.
Note: The RoW group comprises companies based in Taiwan, South Korea, Switzerland, Canada and a further 18 countries.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	Germany	UK	France	Netherlands
No. of companies	134	134	71	39
R&D in 2016/17, €bn	75.1	29.1	25.4	18.4
World R&D share, %	10.1	3.9	3.4	2.5
One year change, %	6.8	8.9	3.3	3.3
Net Sales, €bn	1744.1	1016.4	975.2	429.0
One year change, %	1.4	-2.4	-3.8	3.0
R&D intensity, %	4.3	2.9	2.6	4.3

TABLE 2.2B: PERFORMANCE OF COMPANIES BASED IN THE LARGEST R&D COUNTRIES OF THE EU.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	Switzerland	South Korea	Taiwan	Canada
No. of companies	52	70	105	27
R&D in 2016/17, € bn	28.4	26.6	15.0	4.8
World R&D share, %	3.8	3.6	2.0	0.6
One year change, %	0.1	1.9	3.1	1.6
Net Sales, € bn	382.1	850.2	517.2	101.2
One year change, %	1.5	1.1	-2.4	-0.5
R&D intensity, %	7.4	3.1	2.9	4.8

TABLE 2.2C: PERFORMANCE OF COMPANIES BASED IN THE LARGEST COUNTRIES OF THE ROW GROUP.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.2 | Long-term performance of companies

This section presents the evolution of the majority of company indicators over the past 10 years for the main world regions.

2.2.1 Long-term R&D trends

The figures below illustrate 10 years evolution of R&D and main indicators for companies based in the EU, US, Japan and China. Figure 2.3 shows the world R&D share of each region and Figures 2.4 to 2.7 present the annual growth rates of R&D and net sales and profitability. These figures are based on our history database comprising the R&D and economic indicators over the whole 207-2016 period for 1699 companies (EU 404, US 599, Japan 345, China 114 and RoW 287).

Key points

- Over the past 10 years, the R&D share of EU companies over the total R&D remained practically unchanged, about 26.0%. The main change in this indicator is observed for the Japanese companies whose R&D share fell by ca. 8 percentage points. The loss of R&D share by Japanese companies corresponds to increases in R&D shares for the other countries/regions, especially for companies based in China.

- Companies based in the EU continued the R&D positive trend observed over the past years. Since 2012 the growth rate of R&D has been significantly higher than that of net sales, however over the same period the growth rate of capital expenditures showed a negative trend. The same negative trend has been observed for net sales although for the last period they remained practically unchanged. On the other hand, the profitability the EU companies showed a stable behaviour (with a significant increase over the last year), but the level of profitability remains significantly lower than that of US companies.

- Companies based in the US continued to show significant R&D investment growth, similar to the level prior to the crisis. However over the past two years the level of capital expenditures has fallen significantly for the US companies. On terms of net sales, US companies seem to recover the negative figures of 2015; however, net sales growth remains well below the level of R&D growth. The US-based companies continued to show a high level of profitability since 2010, although it shows a slight decreasing trend over the past three years. 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 in 2011, showed a two years positive trend for both R&D investment and net sales. However since 2015 growth rates of R&D and especially that of net sales decelerated again. The profitability of Japanese companies continued a slightly upward trend observed since 2013, but remained at low levels, especially compared with that of the US companies.

- The Chinese companies show a strong R&D trend over the whole 10 years period. However over the past two years the level of capital expenditures decreased significantly for the Chinese companies. In terms of net

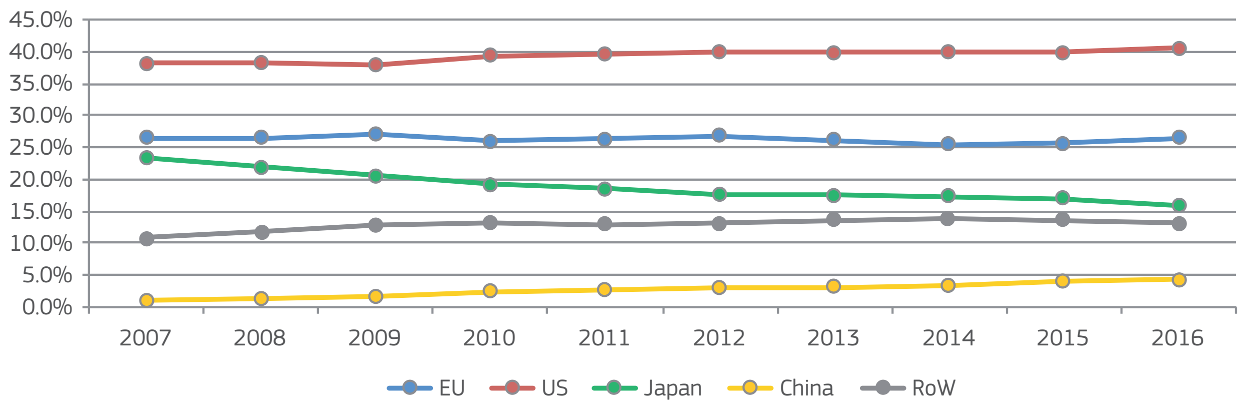

FIGURE 2.3: EVOLUTION OF R&D SHARES OF MAIN REGIONS.
Note: figures displayed refer only to the 1697 companies (402 EU; 549 US; 345 Japan; 114 China; 287 RoW) with R&D data available for the all period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

sales, they have had high positive growth rates, except over 2015/16 where net sales significantly fell. The China-based companies have decreased profitability slightly over the past four years and remain lower as compared with their worldwide counterparts, especially lower than US ones.

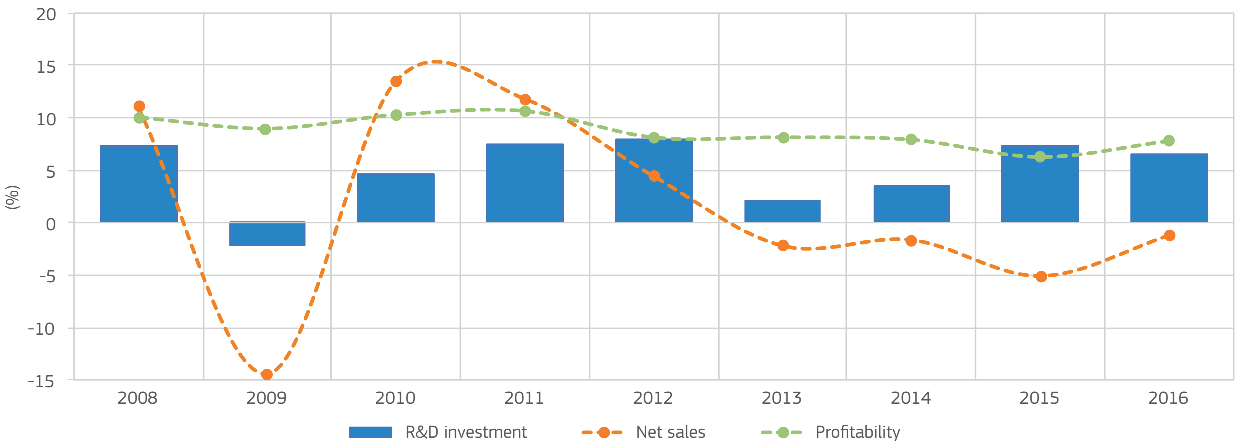

FIGURE 2.4: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY FOR THE EU COMPANIES.
Note: growth rates for the three variables have been computed on 402 out of the 567 EU companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

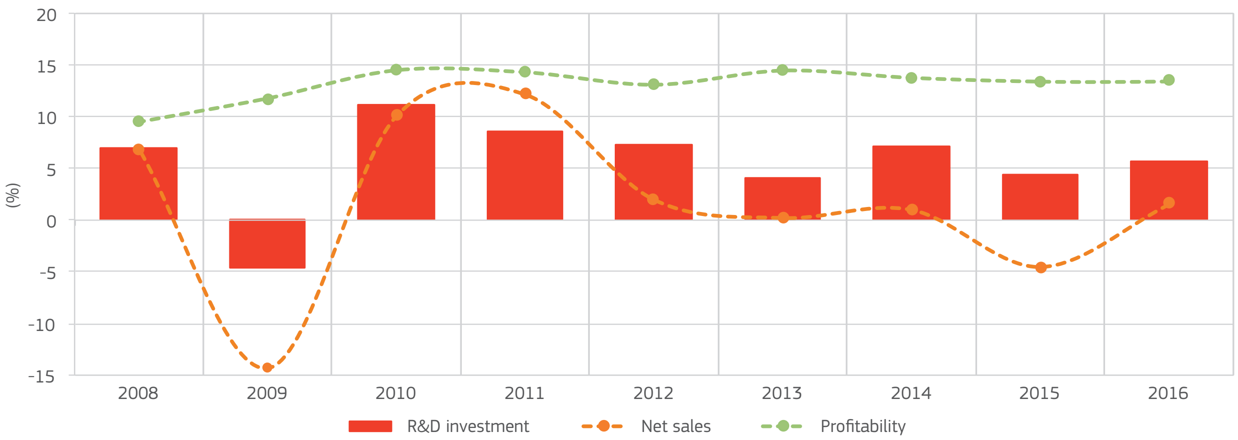

FIGURE 2.5: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY FOR THE US COMPANIES.
Note: growth rates for the three variables have been computed on 549 out of the 822 US companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

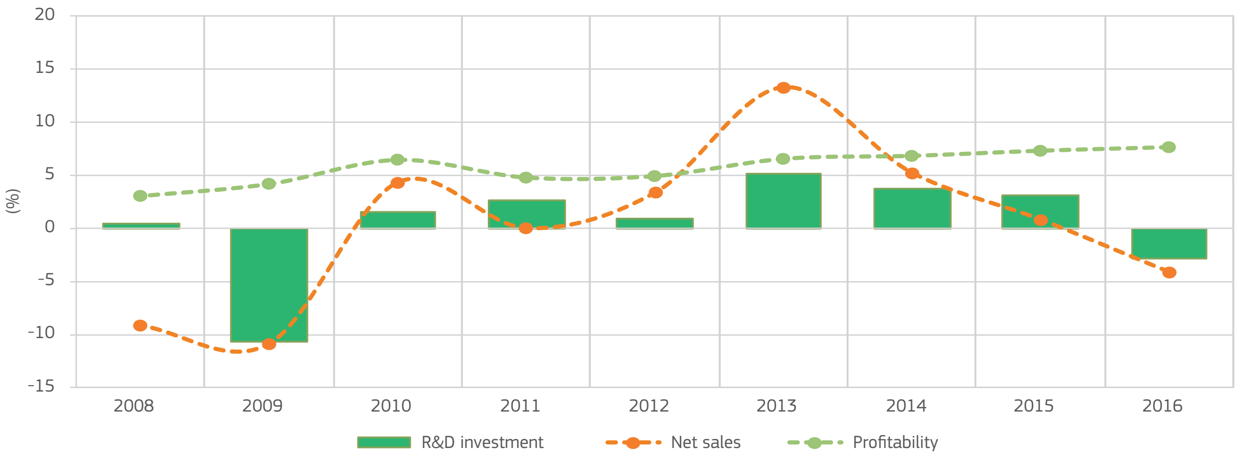

FIGURE 2.6: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY FOR THE JAPANESE COMPANIES.
Note: growth rates for the three variables have been computed on 345 out of the 365 Japanese companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

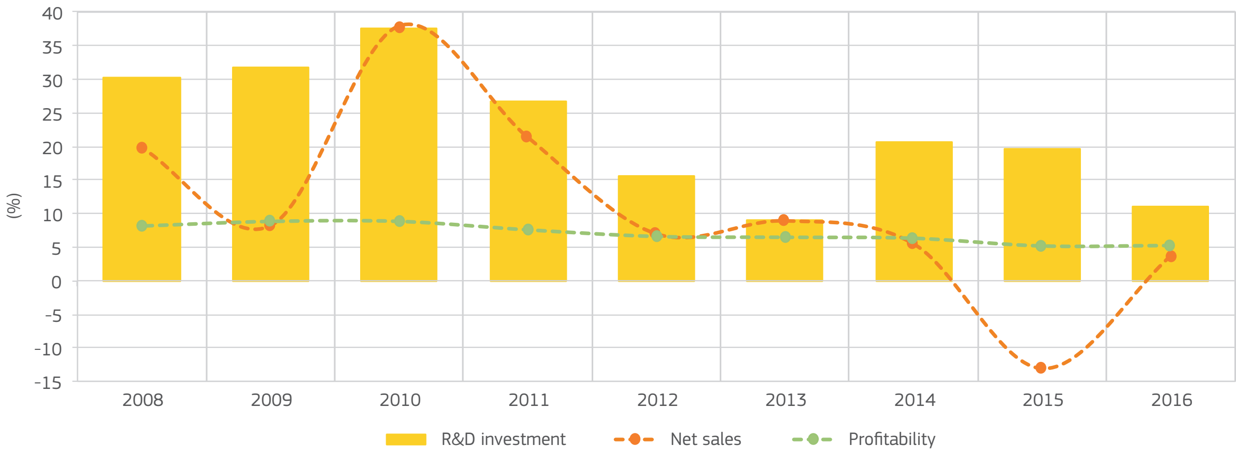

FIGURE 2.7: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE CHINESE COMPANIES.
Note: growth rates for the three variables have been computed on 114 out of the 376 Chinese companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.2.2 Change in R&D over 2007-2016 for groups of sectors and main regions

The changes in R&D over the past 10 years are presented in figure 2.8 for groups of industrial sectors with characteristic R&D intensities[9] (see definition in Chapter 1 – Table 1.3). The figures refer to a set of 1476 companies that reported R&D over the whole period 2007-2016 (EU-400, US-503, Japan-343, China-96 and RoW group-134).

Key points

- The world 1476 companies increased R&D by 50%:
  – By sector, high tech 56%, medium-high tech 42%, medium-low tech 34% and low tech 48%.
  – By region, EU 55%, US 63%, Japan 3% and China 478%.

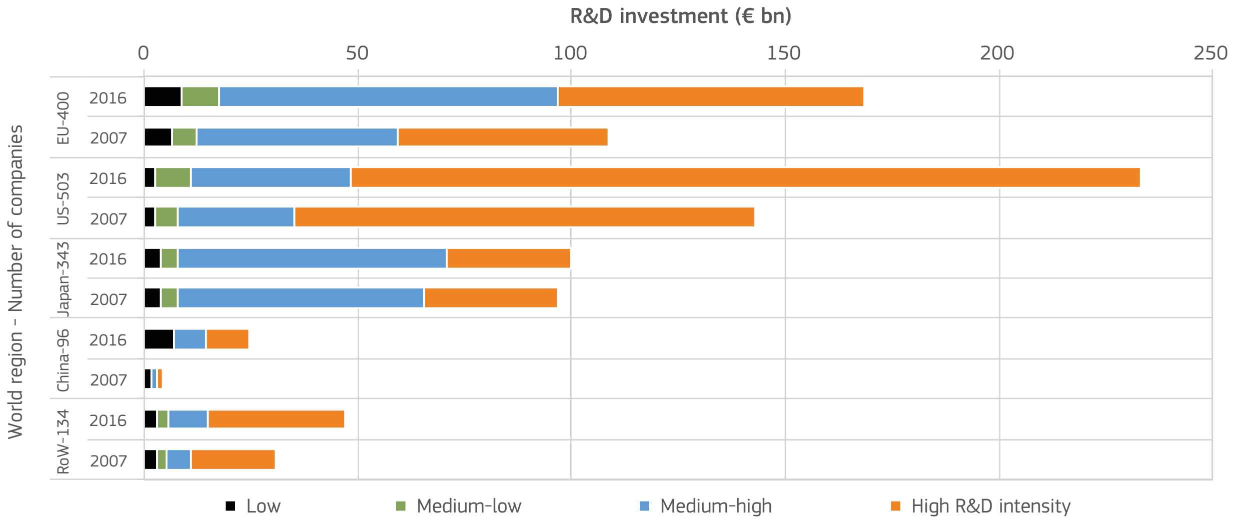

FIGURE 2.8: R&D INVESTMENT IN 2007 AND 2016 BY MAIN REGION AND SECTOR GROUPS.
Note: figures displayed refer only to the 1476 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2007 and 2016).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[9] For simplification, in this section these groups may be also referred to as high tech, medium-high tech, medium-low tech and low-tech.

- For the 400 EU companies, the main R&D increases were in medium-high tech sectors (70%) and high tech (44%)
- For the 503 US companies, the main R&D increases were in high tech (72%) and medium-low tech (53%).
- For the 343 Japanese companies, the only R&D increase was in medium-high tech (9%) and main R&D decreases in the high tech (-7%).
- For the 96 companies based in China, the main R&D increases were in high R&D-intensive (632%) and medium-high (446%).

2.2.3 Change in net sales over 2007-2016 for groups of sectors and main regions

The net sales in 2007 and 2016 are presented in figure 2.9 for groups of industrial sectors with characteristic R&D intensities (see definition in Chapter 1 – Table 1.3). The figures refer to a set of 1476 companies that reported R&D over the whole period 2007-2016 (EU-400, US-503, Japan-343, China-96 and RoW group-134).

Key points

- The world 1476 companies increased net sales by 17%:
  - By sector, high tech 43%, medium-high tech 20%, medium-low tech 26% and low tech -6%.
  - By region, EU 14%, US 13%, Japan 1% and China 137%.
- For the 400 EU companies, the main net sales increases were in high R&D-intensive sectors (44%) and medium-high sectors (40%) and main net sales decrease in low sectors (-12%).
- For the 503 US companies, the main net sales increases were in high sectors (52%) and medium-low R&D-intensive sectors (64%) and main net sales decrease in low sectors (-52%).
- For the 343 Japanese companies, the only net sales increase was in medium-high R&D-intensive sectors (4%) and main net sales decreases in low sectors (-5%).
- For the 96 companies based in China, all sectors showed 3-digits rise in net sales. Net sales went up in medium-high R&D-intensive (274%) and high sectors (159%).

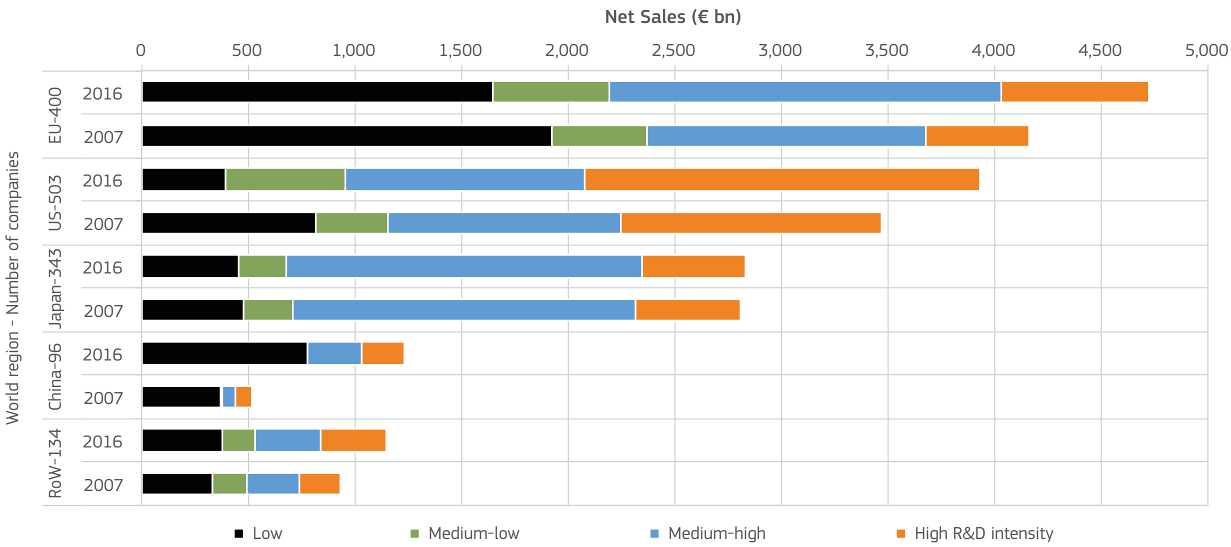

FIGURE 2.9: NET SALES IN 2007 AND 2016 BY MAIN REGION AND SECTOR GROUPS.
Note: figures displayed refer only to the 1476 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2007 and 2016).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.2.4 Employment changes 2007-2016 for groups of sectors and main regions

The employment levels in 2007 and 2016 are presented in figure 2.10 for groups of industrial sectors with characteristic R&D intensities (see definition in Chapter 1 – Table 1.3). The figures refer to a set of 1476 companies that reported R&D over the whole period 2007-2016 (EU-400, US-503, Japan-343, China-96 and RoW group-134).

Key points

- The world 1476 companies increased employment by 20%:
  - By sector, high tech 28%, medium-high tech 24%, medium-low tech 14% and low tech 5%.
  - By region, EU 14%, US 14%, Japan 17% and China 54%.
- For the 400 EU companies, the main employment increases were in high tech (36%) and medium-high tech (28%) and a slight employment decrease was in low tech (-5%).
- For the 503 US companies, the main employment increases were in medium-low tech (32%) and high tech (14%) and a significant employment decrease occurred in low tech (-24%).
- For the 343 Japanese companies, the main employment increases were in medium-low tech (40%) and low tech (26%).
- For the 96 companies based in China, main employment increases were in medium-high tech (85%) and medium-low tech (48%).

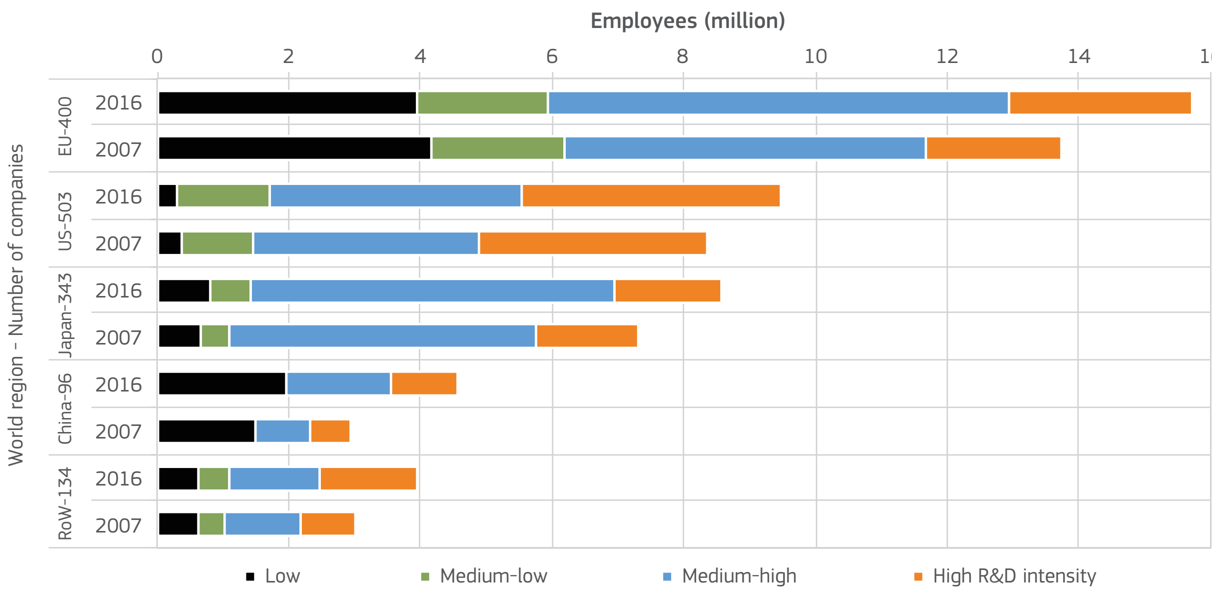

FIGURE 2.10: EMPLOYMENT IN 2007 AND 2016 BY MAIN REGION AND SECTOR GROUPS.
Note: figures displayed refer only to the 1476 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2007 and 2016).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

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).

Comparison EU/US in terms of R&D, net sales and employment

The comparison of 10-years changes in R&D, net sales and employment of the EU-400 sample with the US-503 one shows that:

- Both samples of EU and US companies increased employees by 14% and net sales by a similar amount (EU 14% vs US 13%).
- In low-tech sectors, both samples dropped net sales (EU -12% vs US -52%) and employees (EU -5% vs US -24%).
- US companies increased more their R&D (US 63% vs EU 55%) and, according to their specialisation, US's higher increase was in high tech sectors (72%) while that of the EU's in medium-high tech sectors (70%).
- In summary, altough the EU and US companies increased net sales and employment at a similar rate, they show contrasting differences in high tech and medium-high tech sectors:

In high tech, the EU companies' R&D increase of 44% is accompanied by 36% increase in employees while for the US' ones their 72% increase in R&D corresponded only to 14% increase in employees. However the US companies showed a much higher increase of the ratio net sales/employee.

In medium-high tech, the EU companies' R&D increase of 70% is accompanied by 28% increase in employees while for the US' ones their 36% increase in R&D corresponded to 11% increase in employees. However the EU companies showed a much higher increase of the ratio net sales/employee.

3

R&D TRENDS BY **INDUSTRY AND REGION**

3 R&D trends by industry and region

This chapter presents the main R&D trends among the 2017 Scoreboard companies for the major regions and main industrial sectors. Industries are presented at various levels of aggregation according to the R&D volumes and R&D intensity of companies in them and depending on the issues to be illustrated.

The first section discusses the main changes that took place over the past year for the major industrial sectors and world regions. The second section analyses and compares the R&D 10-year trajectories of leading EU and non-EU companies and their counterparts for selected industries.

3.1 | Main changes in indicators in 2016/17

Tables 3.1 and 3.2 provide the nominal one-year change of R&D and net sales for the main industrial sectors and world regions.

Key points

- Worldwide, R&D growth was driven by the performance of the high R&D investing industries, which increased R&D above the world average rate of 5.8%. These are ICT services (11.7%), Health industries (5.9%) and ICT producers (6.8%). The worse performance was shown by Chemicals (-1.9%) and Aerospace & Defence (2.2%).

- In terms of net sales, the average growth rate of the world sample (0.3%) was held back by low-tech sectors (-4.4%) and Chemicals (-2.2%) while most high R&D-investing sectors increased sales well above the world average of 0.3%, in particular ICT services (6.6%), Health industries (5.7%) and Aerospace & Defence (2.3%).

- The highest growth of profits was showed by the Industrials sector (+27%), followed by ICT services (16%) whereas decrease in profits were presented by ICT producers (-2.6%) and Health industries (-0.4%). The profitability level increased for sectors showing higher growth rate of profits than net sales. The highest levels of profitability are showed by high tech sectors such as ICT services (15.4%) and Health industries (14.5%).

- For the EU sample, R&D growth was also driven by the high R&D investing industries that increased significantly R&D, i.e. ICT producers (14.4%), ICT services (12.7%), Health industries (7.9%) and Automobiles (6.7%). However also important R&D sectors showed a decrease in R&D, in particular Aerospace & Defence (-5.4%) and to a lesser extent Chemicals (-0.8%).

  Among the largest EU companies, the twelve showing the biggest increases in R&D in 2016/17 were:

  NOKIA(96%), NXP(90%), SAP(13%), SHIRE(56%), ZF(40%), RENAULT(20%), DAIMLER(15%), CONTINENTAL(15%), GLAXOSMITHKLINE(12.9%), BAYER (7.6%), DEUTSCHE BANK (23.2%) and ROBERT BOSCH(7.4%). The high R&D growth of some of these companies was partly the result of mergers and acquisitions. Examples are Nokia (acquired both Alcatel-Lucent and Comptel in 2017) and Shire (acquired Baxalta in 2016).

And those showing the biggest R&D reductions were:

ERICSSON (-10.0%), AIRBUS (-9.2%), RABOBANK (-72.4%), SAFRAN (-18.8%), ELECTRICITE DE FRANCE (-19.5%), ROYAL BANK OF SCOTLAND (-21.8%), DASSAULT AVIATION (-32.7%), EYGS (-45.6%), SEAGATE TECHNOLOGY (-8.6%), TELEFONICA (-10.5%), SANOFI (-1.7%) and BASF (-4.2%).

These 24 companies altogether accounted for about 40% of the total R&D change of the EU sample.

- Regarding net sales, the EU sectors showing the highest increase were in ICT services and Health industries (7.7% and 7.2% respectively) followed by ICT producers (6.3%). Reduction in net sales were in Chemicals (-6.0%) and Industrials (-1.8%) and Other (-4.1%, mainly from low-tech sectors).

Among the largest EU companies, the following showed the highest increase in net sales: STANDARD LIFE (167%), AHOLD (30%), NOKIA (74%), HERAEUS (66%), ZF (21%), RENAULT (13%) and BT (26%). The large increase in Nokia's sales was partly the result of the acquisitions mentioned above.

And those that showed the biggest net sales decrease were (mostly oil-related companies): ENEL (-9%), ENI (-18%), BASF (-18%), TOTAL (-11%), CHRISTIAN DIOR (-44%), ROYAL DUTCH SHELL (-12%) and BP (-18%). The substantial decreases in sales for the four oil & gas companies reflect the lower oil price in 2016/17.

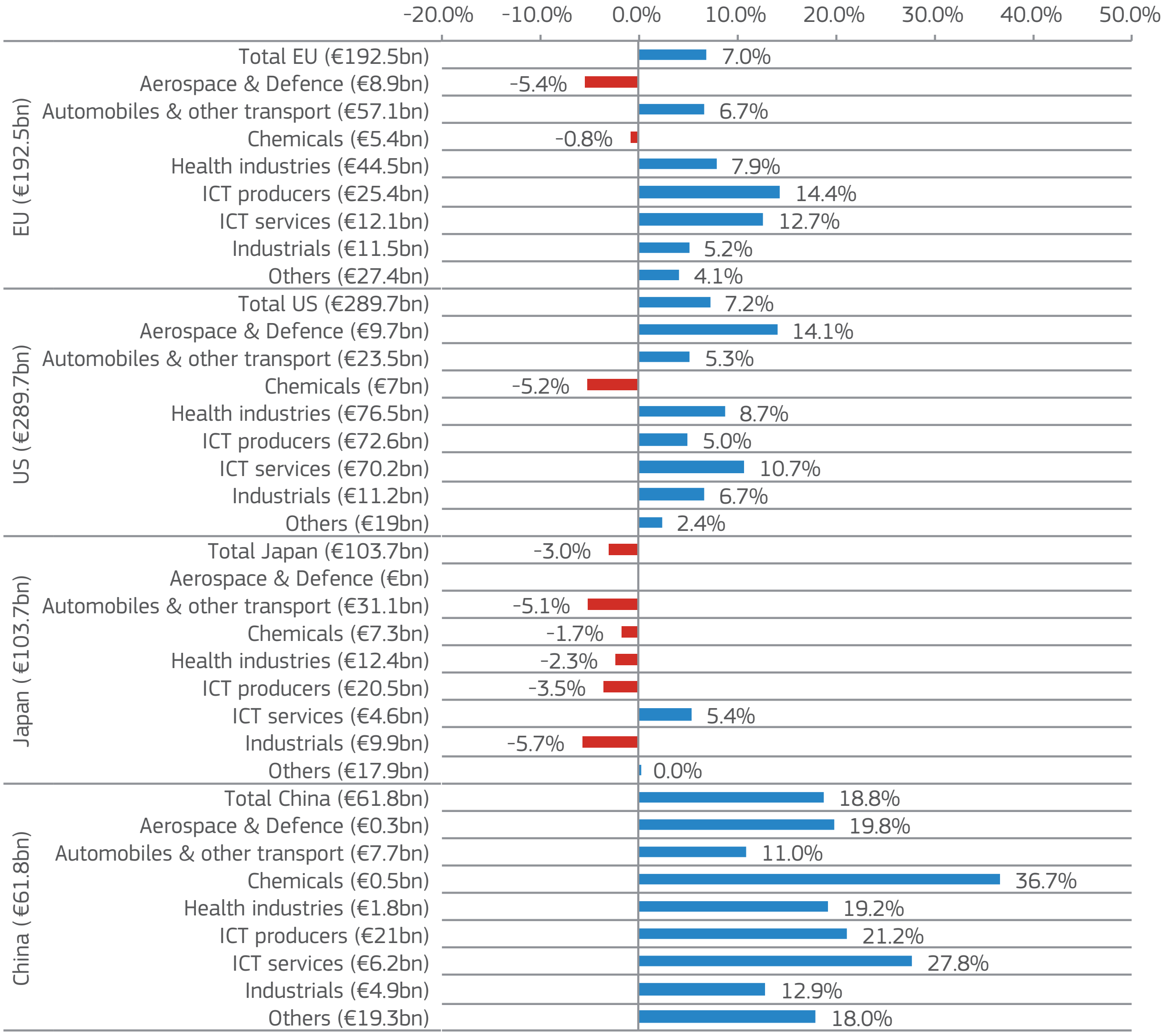

FIGURE 3.1: NOMINAL CHANGE OF R&D OVER THE PAST YEAR FOR MAIN INDUSTRIES AND REGIONS.
Note: growth rates have been computed for 566 EU, 818 US, 364 Japanese, 375 Chinese and 370 RoW companies for with R&D data are available for years 2015 and 2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

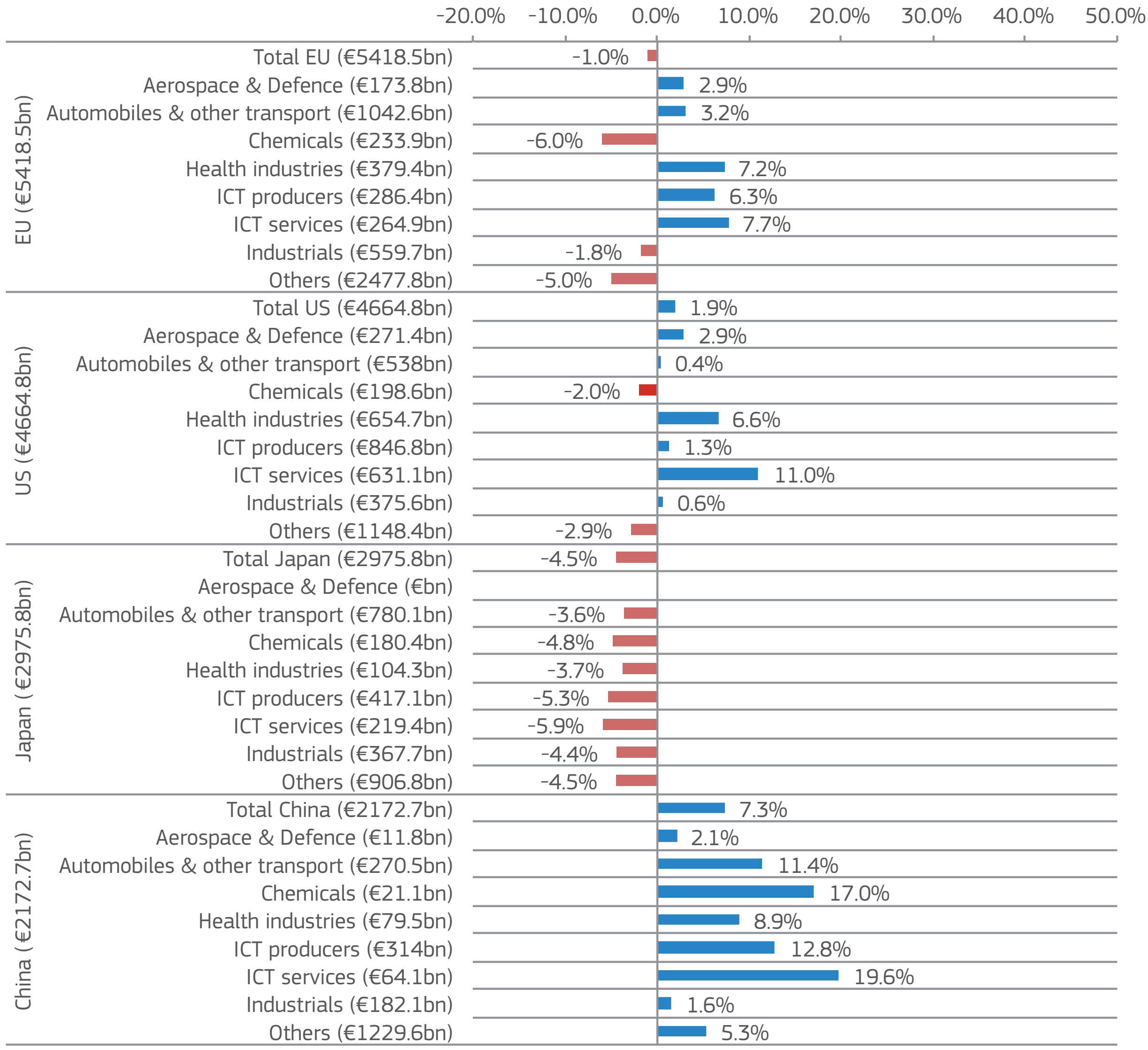

FIGURE 3.2: NOMINAL CHANGE OF NET SALES OVER THE PAST YEAR FOR MAIN INDUSTRIES AND REGIONS.
Note: growth rates have been computed for 557 EU, 761 US, 364 Japanese, 375 Chinese and 368 RoW companies for with data are available for both variables (R&D and Net sales) for years 2015 and 2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

- For the non-EU sample of companies, R&D growth was driven by the high tech industries, especially by high R&D increases in the US and China, i.e. ICT services (US 11%, China 28%), Health industries (US 9%, China 19%) and ICT producers (US 5%, China 21%). Important R&D reductions are observed in Chemicals and low tech sectors.

- Among the largest non-EU companies, high R&D growth was shown by companies such as HUAWEI (29%), APPLE (25%), GILEAD SCIENCES (55%), BROADCOM (155%), ALPHABET (13%) and DELL TECHNOLOGIES (116%); some of this growth was due to acquisitions - Broadcom acquired Brocade Communications during 2016/17 and Dell completed its acquisition of EMC for $67bn in 2016.

- And those showing the lowest R&D growth rates were TOSHIBA (-18%), NOVARTIS (-8%), TATA MOTORS (-35%), BRISTOL-MYERS SQUIBB (-16%), TOYOTA MOTOR (-13%) and HP (-65%).

- Regarding the growth of net sales by non-EU companies, the best performance were observed in Chinese companies across most of sectors and for US companies in high tech sectors, e.g. in ICT services (China 20%, US 11%). Japanese companies decreased net sales for most of industrial sectors.

Among the largest non-EU companies, the following showed the highest increase in net sales: AMAZON.COM (27%) CHINA PETROLEUM & CHEMICALS (8%), AT&T (12%), HUAWEI (37%), ALPHABET (20%), GENERAL MOTORS (9%) and CHINA STATE CONSTRUCTION ENGINEERING (11%).

And those that decreased significantly net sales: PETROLEOS DE VENEZUELA (-24%), STATOIL (-23%), JXTG (-20%), PETROCHINA (-6%), APPLE (-8%), CHEVRON (-15%) and EXXON MOBIL (-16%). The sales of these oil companies all decreased with the oil price.

3.2 | Ten-year change in sector composition

This section examines the changes on the distribution of the R&D investment of the *Scoreboard* companies across regions and industrial sectors over the past 10 years. The analysis shows characteristic differences and changes in the global R&D shares, reflecting the R&D speciality of regions and structural changes over 2007-2016. The Figure 3.3 shows the evolution of the global R&D shares for main industries and Figures 3.4 and 3.5 show respectively the contribution to the global industry-R&D shares by the EU and US companies.

Key points

- On the whole, only two sectors increased their R&D shares: ICT services (from 10.6% to 13.4%) and Health industries (from 20.7% to 21.6%). Main shares decreases were shown by low-tech sectors and also, to a lesser extent, Industrials and Automobiles sectors.

- EU companies reinforced its specialisation in medium-high tech sectors, increasing significantly their R&D contribution to the global R&D of Automobiles (from 35.9% to 44.4%) and Industrial (from 25.7% to 27.1%). On the other side, EU companies main reduction of global R&D share was in Aerospace & Defence (from 47.6% to 42.1%) and in ICT producers (from 19.3% to 16.5%).

- US companies strengthened their position in high tech sectors, increasing substantially their global R&D weight in ICT services (from 66.2% to 74.9%) and Health industries (from 40.5% to 44.8%). On the other extreme, US companies strongly reduced their R&D

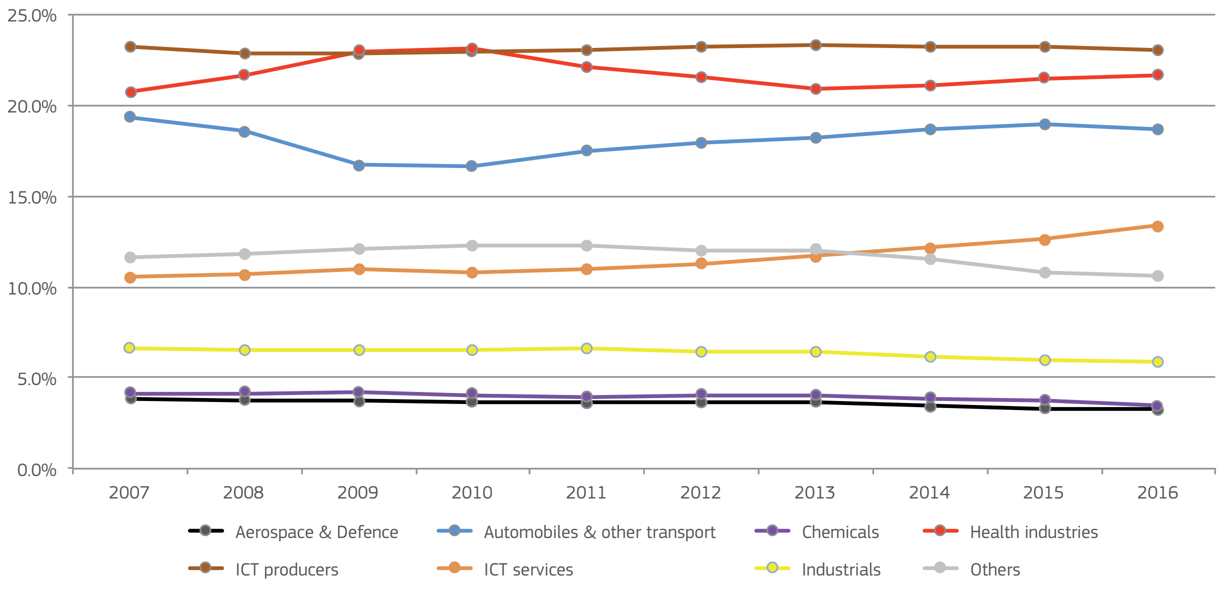

FIGURE 3.3: EVOLUTION OF THE GLOBAL R&D SHARE FOR INDUSTRIAL SECTORS.
Note: Calculated for a sample of 1697 companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

share in Automobiles (from 25.5% to 19.4%) and, to a lesser extent, in low tech sectors.

- For Asian companies, contrasting changes in global R&D shares are observed for those based in China and Japan. Chinese companies increased their golbal R&D shares for all sectors (mostly in low tech, ICT services and Industrials) whereas Japanese companies' global R&D shares fell across the bord (mostly in losw tech, ICT services and Automobiles).

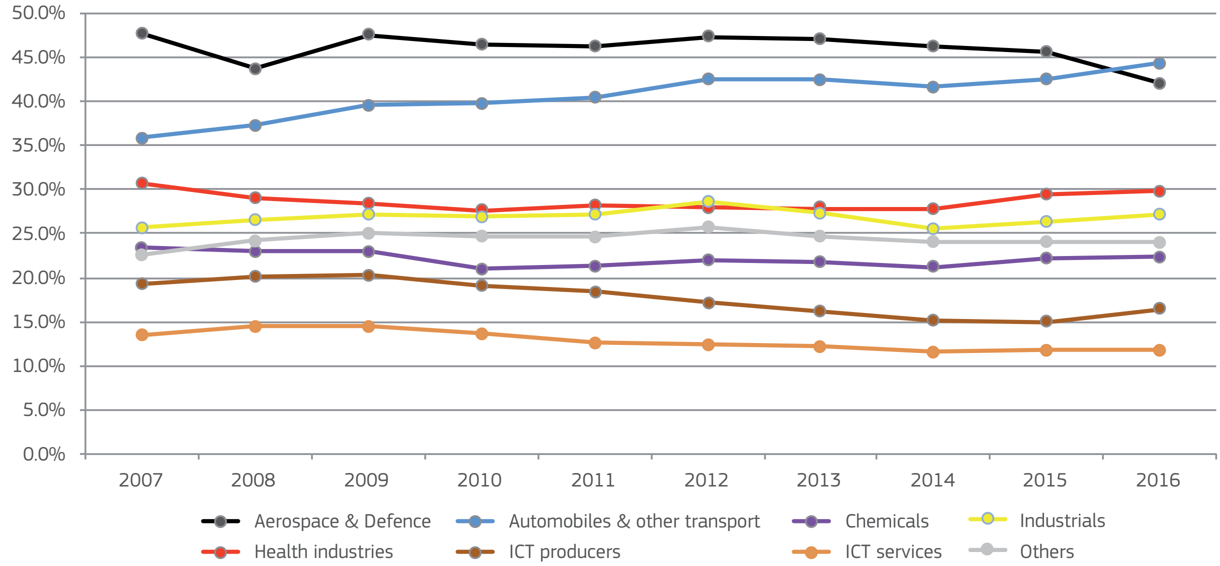

FIGURE 3.4: EVOLUTION OF THE GLOBAL R&D SHARE OF THE EU COMPANIES FOR MAIN INDUSTRIAL SECTORS.
Note: Calculated for a sample of 402 companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

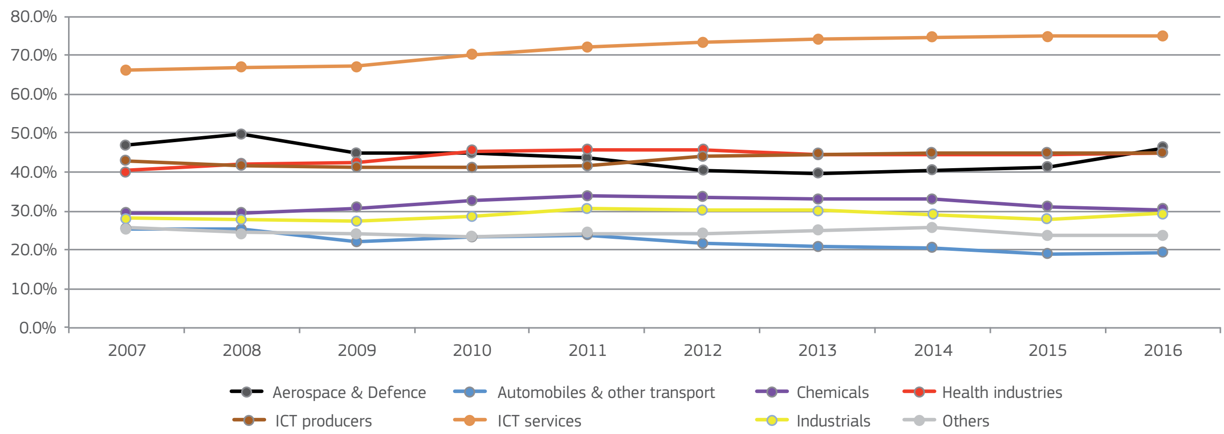

FIGURE 3.5: EVOLUTION OF THE GLOBAL R&D SHARE OF THE US COMPANIES FOR MAIN INDUSTRIAL SECTORS.
Note: Calculated for a sample of 549 companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

3.3 | Company dynamics of selected sectors

This section analyses the R&D trajectories of EU companies and compares their performance against their non-EU counterparts in selected industries among the large R&D investing sectors. Some of the sectors defined in chapter 1 are further broken down to explore the specific differences between EU and non-EU companies while keeping a meaningful number of companies.

Six sectors are analysed: three sectors where the EU and non-EU companies show comparable performances (Aerospace & Defence, Automobiles and Pharmaceuticals) and three sectors where EU companies show persistent underperformance when compared with their non-EU counterparts (Biotechnology, Software and IT-hardware). R&D is a critical factor for competitiveness of these 6 industries and especially for the last three sectors that show the highest R&D intensity among the *Scoreboard* companies (see distribution of high R&D-intensity companies in the *Scoreboard* in Box 3.1).

For each sector and region, the companies are separated into two groups, the **top** group consisting of (at least) two or more companies that together account for more than 25% of the total sector's R&D and the **bottom** group where the rest of companies of the sector are grouped. The idea is to look for specific characteristics of the top and bottom groups within each region, i.e. firstly to understand the role of each group in shaping the R&D profile of the sector and secondly to compare performance between the two regions.

Table 3.1 summarises the main characteristics of the selected sectors and related leading companies and figures 3.6 to 3.11 show the R&D trajectories for the top and bottom groups of EU and non-EU companies for the six sectors *(please be aware that for practical graphical reasons the figures on Biotechnology, Software and IT-hardware have substantially different scales for the EU and non-EU companies).*

Key points

Automobiles

- In general, EU companies outperform with respect to their non-EU counterparts in most indicators, i.e. larger ratios of R&D/firm, Sales/firm and R&D/net sales (R&D intensity). The ratios EU/non-EU for R&D (0.9) and sales (0.6) are very large as compared with the weight of the EU economy in the world. The profitability of the EU companies is slightly larger than that of the non-EU ones (6.4% vs 6.0%).
- Within the EU, the R&D trajectories of the top and bottom groups followed a similar path, recovering quickly from the effects of the crisis in 2008, and then following an uptrend that has been more pronounced for the bottom group for the last three years. However the R&D concentration of the sector has increased, i.e. the R&D share of the top group has increased by several percentage points.
- The comparison of EU/non-EU companies shows that non-EU companies have been more affected by the crisis, and then the bottom group having recuperated a significant R&D growth whereas the top group's R&D has stagnated. Over the past three years, both top and bottom groups of the EU showed higher R&D growth than the non-EU ones.

Aerospace & Defence

- On the whole, EU companies show higher ratios than their non-EU counterparts (although less so than those in Automobiles), i.e. larger R&D/firm, Sales/firm and R&D/net sales (R&D intensity). As for the Automobiles, the ratios EU/non-EU for R&D (0.7) and sales (0.6) are very large as compared with the weight of the EU economy in the world. The profitability of the non-EU companies is significantly larger than that of the EU sample (6.9% vs 9.6%).
- Within the EU, the top and bottom groups followed different but converging R&D trajectories (decreasing the R&D share of the top group). The top group recuperated quickly from the crisis but shows a downtrend since 2012. The R&D of the bottom group stagnated until 2011, grew at high rates until 2014 and then, like the top group, followed an R&D decreasing trend until 2016/17.
- The comparison of EU/non-EU companies shows that non-EU top and bottom companies have also followed a converging R&D trend, showing higher R&D growth than their EU counterparts in the last periods (as mentioned above, the EU's top and bottom companies reduced R&D over the most recent years).

Pharmaceuticals

- In general, EU companies show higher ratios than their non-EU counterparts (although less so than those in Automobiles), i.e. larger R&D/firm, Sales/firm and similar R&D/net sales (R&D intensity). The ratios EU/non-EU for R&D (0.5) and sales (0.5) are large as compared with the weight of the EU economy in the world, even though lower than those for the Automobiles and Aerospace. The profitability of EU companies (13.0%) is lower than that of the non-EU sample (16.9%)

- Within the EU, the R&D trajectories of the top and bottom groups followed a different path, the bottom group has followed an uptrend for most of the years, accelerating over the past three years, whereas the top group's R&D remained practically unchanged (thus leading to a significant reduction of the R&D concentration of the sector).

- The comparison of EU/non-EU companies shows that non-EU top and bottom companies have also followed a different path that led to higher relative R&D share of the bottom group which increased significantly R&D over the whole period whereas the top group increased it only slightly. However over the last two years the R&D growth of the bottom group stagnated while the top group continued to grow its share steadily.

Biotechnology

- On the whole, EU companies underperform with respect to their non-EU counterparts in most indicators (mostly due to US companies), showing much lower ratios of R&D/firm, Sales/firm. The EU and non-EU samples are only comparable in terms of R&D/net sales (R&D intensity). The EU sample also underperforms in terms of relative size, i.e. the ratios EU/non-EU for R&D (0.1) and sales (0.1) are low with respect to the weight of the EU economy in the world. In terms of profitability, the non-EU companies largely outperform their EU counterparts (non-EU 29.5% vs -0.3%).

- Within the EU, the top and bottom groups followed a similar R&D uptrend until 2014, and then the two groups diverged, the top companies breaking the R&D growth while the bottom ones continued to grow R&D at a larger pace. As a result of the fast R&D growth of the bottom companies over the last three years, their overall R&D investment became higher than that of the top group, thus reducing the R&D concentration of the sector.

- The comparison of EU/non-EU companies (*mind the different scales in figure 3.6*) shows the strength of the non-EU companies in this sector (in particular the US ones). Both non-EU top and bottom companies increased R&D significantly over the whole period, and particularly, since 2011 when their R&D investment accelerated. The latter effect was more pronounced for the top group of companies over the last three years, leading to an important increase of their R&D share in the non-EU biotechnology sector (from 15% to 40% of the total sector R&D).

Software

- Largely, EU companies underperform with respect to their non-EU counterparts in most indicators of the Software sector. As for the Biotechnology sector (and again mostly due to US companies), EU companies show much lower ratios of R&D/firm and Sales/firm and have a comparable ratio only in terms of R&D/net sales (R&D intensity). The EU sample shows also a much lower size in both R&D and net sales, about 10% of those of the non-EU sample, well below the weight of the EU economy in the world. The EU companies show a large profitability (15.6%) but lower than that of the non-EU companies (17.2%).

- Within the EU, the bottom group of companies followed an R&D uptrend for most of the 10 year period, practically doubling their R&D investment. The top group, with R&D share comparable to that of the bottom one in 2007, followed a similar trend but at somewhat higher pace. As a result, the R&D concentration of the sector increased, with the two companies of the top group having a 55% R&D share of the total sector's R&D.

- The comparison of EU/non-EU companies (*mind the different scales in figure 3.7*) shows the strength of the non-EU companies in this sector (in particular the US ones). Both non-EU top and bottom companies followed a similar R&D trajectory: their R&D investment stagnated over 2007-2009 (crisis effects) and then resumed to grow R&D at high pace for the rest of the 10 years period. The latter effect was more pronounced for the bottom group of companies over the last three years, however, the top (two US companies) still increased their R&D share in the non-EU Software sector (from 29% to 35% of the total sector R&D).

- Within the EU, the bottom group of companies followed an R&D uptrend for most of the 10 year period, increasing it by 55%. The top group followed an erratic trend[10], showing only a strong R&D growth over the past year to recover a level of R&D investment similar to the one in 2007. As a result, the R&D concentration of the sector reduced significantly, with the two top and bottom groups having similar R&D share of the total sector's R&D.

IT-hardware

- Overall, EU companies underperform with respect to their non-EU counterparts in most indicators. As for the Software and Biotechnology sectors (and over again mostly due to US companies), EU companies show much lower ratios of R&D/firm and Sales/firm, however, EU companies show much higher R&D/net sales (R&D intensity). The EU sample shows also a much lower size in terms of both R&D and net sales (about 15% R&D and 8% net sales of the non-EU sample), well below the weight of the EU economy in the world. EU companies show also a small profitability (4.6%), one-third than the profitability of their non-EU counterparts (13.8%).

- The comparison of EU/non-EU companies (*mind the different scales in figure 3.8*) shows the strength of the non-EU companies in this sector (in particular the US ones). Both non-EU top and bottom companies followed a similar R&D trajectory: due to the effects of the crisis, their R&D investment stagnated over 2007-2009 and then resumed to grow R&D at high pace for the rest of the 10 years period (except for the bottom group over the past year that showed a slight R&D decrease). However, altogether the R&D growth rate was steadily higher for the top group (two US companies) that have more than doubled their R&D share in the non-EU IT-hardware sector (from 12% to 26% of the total sector R&D).

SECTOR	Region	No. firms	R&D in 2016/17 (€bn)	Net sales in 2016/17 (€bn)	R&D intensity (%)	Top companies*
Automobiles	EU	36	53.8	971.1	5.5	Volkswagen, Daimler
	non-EU	126	60.4	1617.1	3.7	General Motors, Toyota
Aerospace & Defence	EU	16	8.9	176.5	5.0	Airbus, Leonardo
	non-EU	33	12.7	320.9	3.9	Boeing, United Technologies
Pharmaceuticals	EU	53	37.1	270.1	13.7	AstraZeneca, Sanofi Aventis
	non-EU	145	75.4	569.8	13.2	Roche, Johnson & Johnson
Biotechnology	EU	30	2.4	9.9	24.0	Novozyme, Qiagen
	non-EU	127	27.2	103.7	26.2	Gilead, Celgene
Software	EU	45	8.4	74.2	11.3	SAP, Amadeus
	non-EU	223	79.9	740.0	10.8	Alphabet, Microsoft
IT-hardware sector	EU	29	16.0	101.7	15.7	Nokia, Ericsson
	non-EU	246	104.1	1275.2	8.2	Intel, Apple

TABLE 3.1: MAIN INDICATORS FOR THE SELECTED SECTORS FOR THE EU AND NON-EU SAMPLES.
*Consisting of (at least) two or more companies that together account for more than 25% of the total sector's R&D. Only companies for which data are available for the whole period (2007-2016) are taken into account.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[10] This reflects Nokia's problems with its mobile phone business and its recent focus on telecom infrastructure with the acquisition of Alcatel-Lucent.

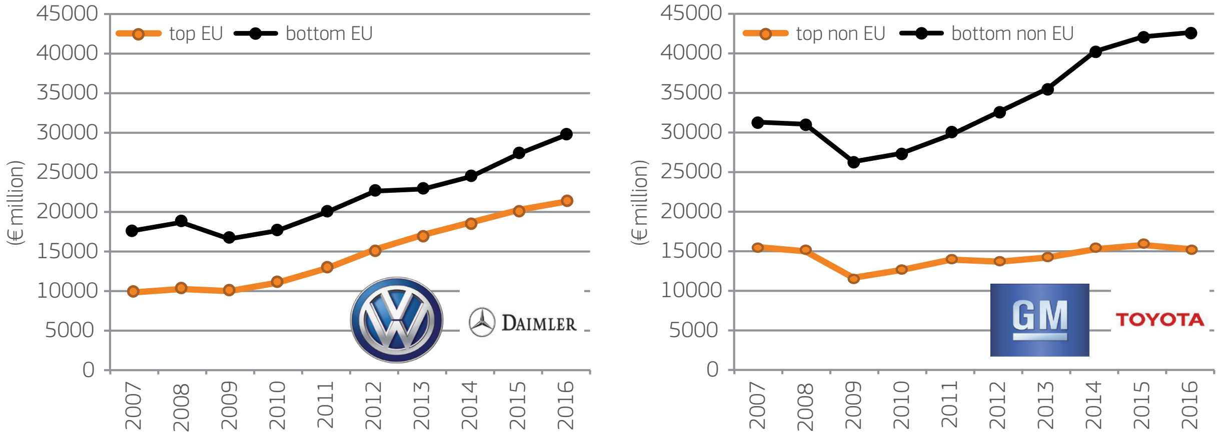

FIGURE 3.6: R&D TRAJECTORIES FOR THE TOP AND BOTTOM GROUPS OF EU AND NON-EU COMPANIES IN THE AUTOMOBILES SECTOR.
Note: For the 26 out of 36 EU and 96 out of 126 non EU companies with data available for all the ten years.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

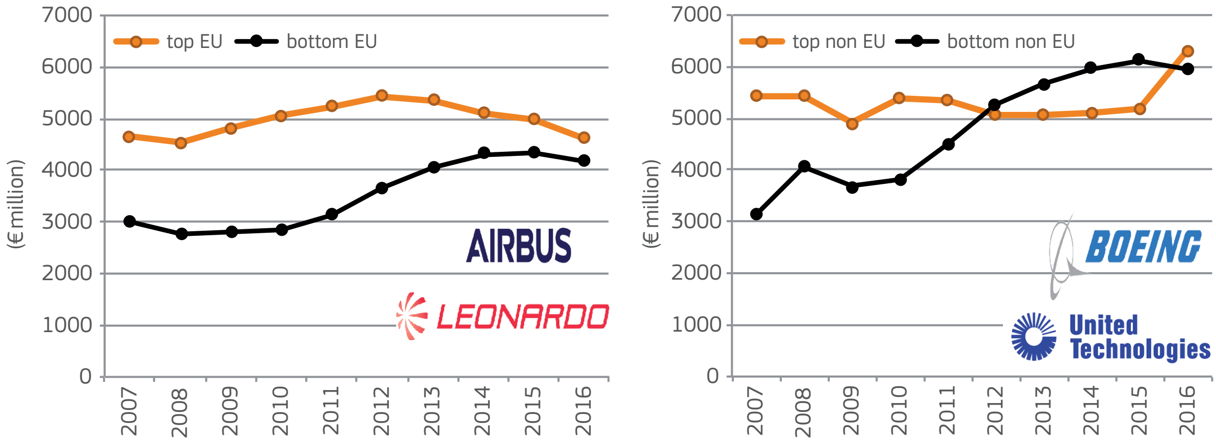

FIGURE 3.7: R&D TRAJECTORIES FOR THE TOP AND BOTTOM GROUPS OF EU AND NON-EU COMPANIES IN THE AEROSPACE & DEFENCE SECTOR.
Note: For the 15 out of 16 EU and 26 out of 33 non EU companies with data available for all the ten years.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

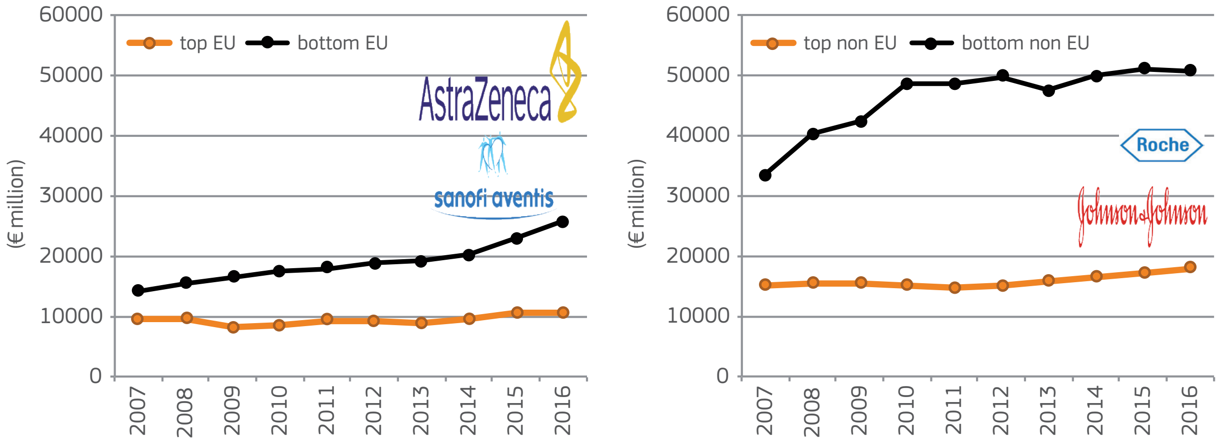

FIGURE 3.8: R&D TRAJECTORIES FOR THE TOP AND BOTTOM GROUPS OF EU AND NON-EU COMPANIES IN THE PHARMACEUTICALS SECTOR.
Note: For the 39 out of 54 EU and 87 out of 157 non EU companies with data on R&D available for all the ten years
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

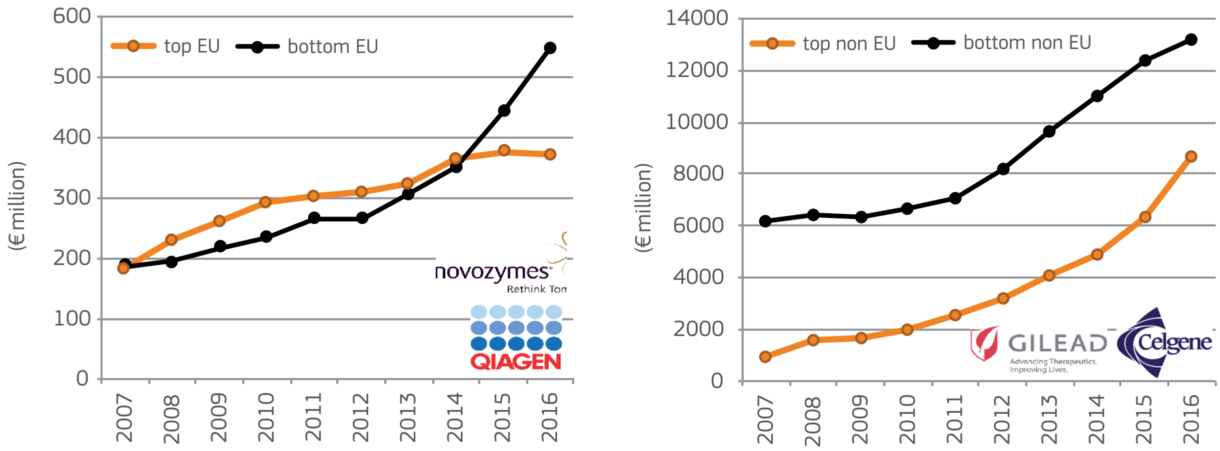

FIGURE 3.9: R&D TRAJECTORIES FOR THE TOP AND BOTTOM GROUPS OF EU AND NON-EU COMPANIES IN THE BIOTECHNOLOGY SECTOR.
SCALES OF THE TWO PANELS ARE DIFFERENT.
Note: For the 11 out of 32 EU and 62 out of 156 non EU companies with data on R&D available for all the ten years.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

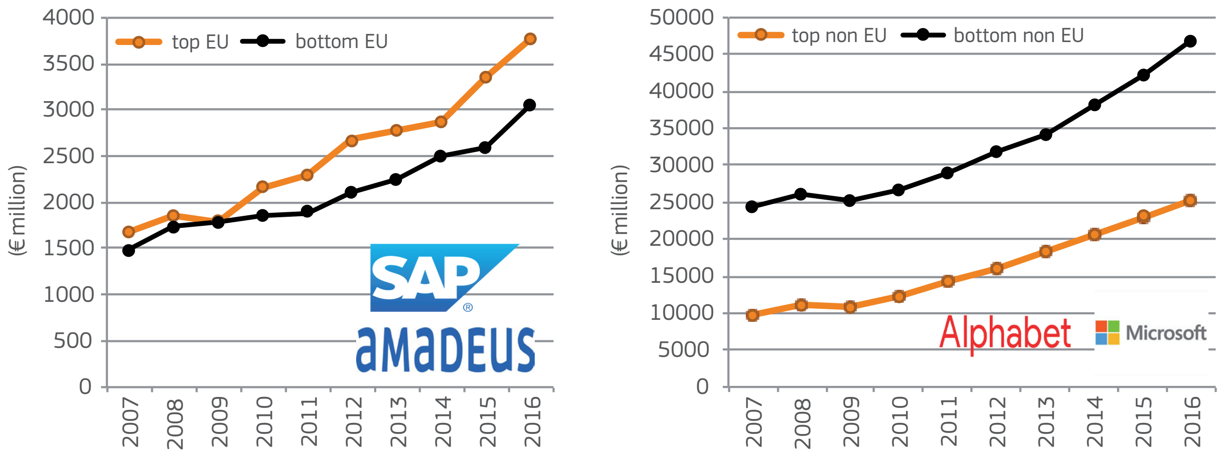

FIGURE 3.10: R&D TRAJECTORIES FOR THE TOP AND BOTTOM GROUPS OF EU AND NON-EU COMPANIES IN THE SOFTWARE SECTOR.
SCALES OF THE TWO PANELS ARE DIFFERENT.
Note: For the 34 out of 45 EU and 141 out of 224 non EU companies with data on R&D available for all the ten years.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

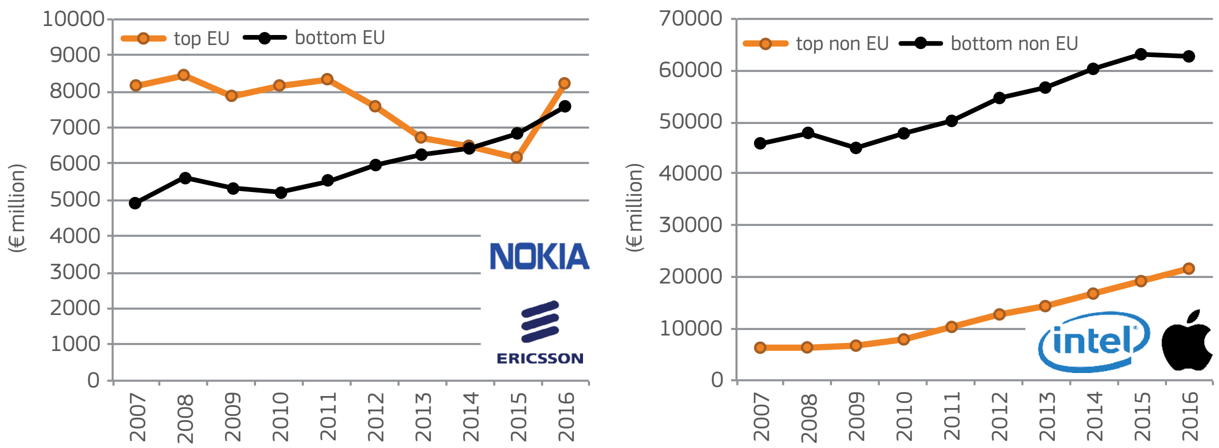

FIGURE 3.11: R&D TRAJECTORIES FOR THE TOP AND BOTTOM GROUPS OF EU AND NON-EU COMPANIES IN THE SOFTWARE SECTOR.
SCALES OF THE TWO PANELS ARE DIFFERENT.
Note: For the 24 out of 29 EU and 209 out of 247 non EU companies with data on R&D available for all the ten years.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Box 3.1 – Distribution of high R&D-intensity companies in the 2017 *Scoreboard*.

The four high R&D sectors described above (pharmaceuticals, biotechnology, hardware and software) provide most of the higher intensity companies in the world top 2,500. It is therefore interesting to examine the prevalence of high intensity companies throughout the *Scoreboard* and for the various world regions. High intensity is defined as 5% or more in Chapter 1 – Table 1.3. A detailed analysis of the prevalence of such high intensity companies in the *Scoreboard* shows that:

- A larger proportion of EU companies in the *Scoreboard* are of high intensity (46.2% compared to the rest-of-the world except the US (RoWexUS) which has 39.3%. However, the US has 66.3% of its companies of high intensity reflecting its strong software, hardware and biotech sectors.
- All three regions have larger proportions of high intensity companies in the *Scoreboard's* top 500. Again the EU with 51.9% has a higher proportion than RoWexUS with 42.1% but the US alone has 77%.
- Proportions of high intensity companies are lower in the bottom 500 of the *Scoreboard* compared to the top for all regions with the EU having 44.7%, higher than RoWexUS with 41.5% but much lower than the US with 61.3%. The bottom 500 also has a lower proportion of all EU companies than the top 500 (18.8% vs. 25.8%) with non-EU companies having 81.2% vs. 74.2%. It is not clear why smaller EU companies by R&D are much less prevalent in the bottom 500 but some countries have fewer companies than expected (e.g. France with only 9 in the bottom 500).

4

PERFORMANCE OF
TOP R&D INVESTORS

4 Performance of top R&D investors

This chapter describes the performance of individual companies, with a focus on the results of companies at the top of the world R&D ranking, highlighting those companies that show considerable changes in economic and R&D performance. Due to data availability, R&D figures for some companies may be under- or over-stated (see explanations in Box 4.1).

4.1 | Main changes in 2016/17

In this section, the world's top 100 R&D companies are analysed, underlining those presenting important performance changes over the last reporting period.

Key points

- For the 4th consecutive year the top R&D investor is the German company Volkswagen (€13.7bn). The 2nd and 3rd positions are for the US companies Alphabet (€12.9) and Microsoft (€12.4bn). The other companies in the top-ten are Samsung from South Korea, Intel, Apple and Johnson & Johnson from the US, Novartis and Roche from Switzerland and Huawei from China.

- The top 100 companies account for 53.1% of the total R&D by the 2500 companies, showed growth of R&D (5.9%) similar to the world average (5.8%) but higher growth of net sales (1.7% vs 0.3%).

- Sixty-one companies in the top 100 have shown positive R&D investment growth. Among them, 30 companies had double-digit R&D growth, and of these, 17 companies also showed double-digit growth in net sales.

- Most of the top 100 companies showing double-digit R&D increases are in the ICT producers (8), Health industries (6) and ICT services (4). The 5 companies showing the largest increase in R&D are BROADCOM (154.9%), DELL TECHNOLOGIES (115.8%), NOKIA (96.0%), NXP SEMICONDUCTORS (90.1%) and GILEAD SCIENCES (54.8%). Broadcom, Dell and Nokia all made large acquisitions in 2016/17. Gilead acquired Nimbus Therapeutics in 2016 and NXP made a large acquisition in 2016 (of Freescale Semiconductor) but NXP has now been taken over by Qualcomm.

- As mentioned above, 17 companies had double-digit growth in R&D and net sales, the top 5 companies among them are Alphabet, Huawei Facebook, Nokia and Celgene.

- Thirty-nine companies in the top 100 have experienced a decrease in R&D investment. The companies with the largest decrease in R&D are TOYOTA MOTOR (-35%); TOSHIBA (-18%); BRISTOL-MYERS SQUIBB (-16 %); DUPONT (-13%) and TOYOTA MOTOR (-12%).

- The R&D intensity of companies in the top 100 (7.0%) increased, as in the previous year, due to a higher R&D growth (5.9%) than net sales growth (1.7%). The EU companies in the top 100 have slightly higher R&D intensity than that of non-EU companies (7.0% vs. 7.5%).

- Among the top 100 companies, 5 made losses (DELL, ALLERGAN, NOKIA, DEUTSCHE BANK and BROADCOM) with 23 showing profitability of only 5% or less but 25 showed profitability over 20%. All but two of the 25 operate in high R&D-intensive sectors (Procter & Gamble and Banco Santander).

4.2 | 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 2002-2016. Results of companies showing outstanding R&D and economic results are underlined.

The R&D ranking of the top 50 companies is presented in figure 4.1 and table 4.2 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 4.3, indicating the reasons for main changes observed over the last period. It is important to note, as stated in the previous reports, that the growth of companies is often accompanied by mergers and acquisitions.

Key points

- There are 16 EU companies (18 in 2004) and 34 non-EU companies (32 in 2004) with data available for the whole period.
- In the EU group, six companies left the top 50 (ALCATEL, ISTITUTO FINANZIARIO INDUSTRIALE, PHILIPS, RENAULT, BAE SYSTEMS and PEUGEOT) and four companies joined the top 50 (BOEHRINGER INGELHEIM, FIAT CHRYSLER, SAP and CONTINENTAL). Alcatel first merged with lucent and the combined entity was then acquired by Nokia.
- In the non-EU group, eleven companies left the top 50 (Fujitsu, Canon, Fujitsu, Matsushita Electric, NEC, Motorola, Nortel Networks (acquired), Wyeth (acquired), Delphi, Sun Microsystems (acquired), NTT and Toshiba) and thirteen companies joined the top 50 (AMGEN, APPLE, DENSO, GILEAD SCIENCES, ALPHABET, HUAWEI, LG ELECTRONICS, ORACLE, PANASONIC, QUALCOMM, TAKEDA PHARMACEUTICALS, FACEBOOK and ABBVIE- demerged from Abbott Laboratories).
- The distribution of the top 50 companies by main industrial sector and region changed from 2004 to 2017 as follows:
  - Automobiles & Parts, from 13 (EU 7) to 12 (EU 6)
  - Health industries, from 11 (EU 3) to 17 (EU 4)
  - ICT industries, from 13 (EU 3) to 15 (EU 4)
- Three EU companies improved in the R&D ranking by at least 20 places are Bayer (now ranked 29th), SAP (now 47th) and CONTINENTAL (48th).
- There are 13 non-EU companies that gained more than 20 places. They include Samsung (now 4th), ALPHABET (now 2nd), HUAWEI (now 6th), APPLE (now 7th), ORACLE (now 17th), QUALCOMM (now 28th), TAKEDA (now 49th), LG ELECTRONICS (now 50th), GILEAD SCIENCES (now 32th), BRISTOL-MYERS SQUIBB (now 30th), CELGENE (now 33st), FACEBOOK (19th) and BEING (36th).
- Two companies dropped twenty or more places but remained within the top 50: SONY (now 41th) and PANASONIC (now 40th).

Box 4.1 –
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. The figure of $511m used in the *Scoreboard* for Amazon's R&D is just the small capitalised element of R&D. Amazon also expenses 'Technology & Content' investment of $16.085bn but does not say how much of this is R&D. However, from information given in the Amazon annual reports for 2012-15, it is estimated that approximately $10.3bn of the $12.5bn of technology & content investment in 2015 was R&D. This 2015 figure needs to be raised by a proportion of the $3.55bn increase in technology & content investment from 2015 to 2016 and the capitalised R&D of $0.5bn for 2016. Consequently, an estimate of Amazon's R&D could be in the range of €12bn which would make Amazon #6 in the world ranking of companies by R&D (just below Intel at '#5)".

Companies showing the largest 10-years changes in R&D, net sales and employees

Companies among the top 100 R&D investors presenting remarkable results in terms of R&D, sales and employees over the past 10 years are listed in table 4.1.

The high growth companies, at the top of the table, simultaneously increased R&D (by more than 500%), net sales (by more than 400%) and employees (by more than 196%).

On the other extreme, the firms at the bottom of the table showed an important simultaneous drop of R&D, net sales and employees.

	Firm	R&D investment 2016 (€bn)	Change in R&D 2007-2016 (%)	Change in net sales 2007-2016 (%)	Change in employees 2007-2016 (%)
High growth firms	ALPHABET	12.9	539.6	444.0	328.8
	APPLE	9.5	1184.5	777.4	389.5
	GILEAD SCIENCES	4.4	689.5	618.4	202.1
	CELGENE	4.2	1081.1	698.8	323.3
	ALLERGAN	2.7	1848.0	483.6	196.1
	TENCENT	1.6	3704.5	3876.5	792.6
Low growth firms	NOKIA	4.9	-7.1	-53.8	-10.0
	PANASONIC	3.9	-14.5	-19.0	-15.8
	SONY	3.6	-14.0	-14.3	-28.9
	HITACHI	2.6	-24.3	-18.4	-12.6
	TOSHIBA	2.4	-24.9	-36.5	-22.5
	PROCTER & GAMBLE*	1.8	-15.8	-17.9	-28.0

TABLE 4.1: COMPANIES AMONG THE TOP 100 R&D INVESTORS SHOWING THE LARGEST CHANGES IN R&D, NET SALES AND EMPLOYEES.
*Procter and Gamble demerged several units over the 10-year period.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

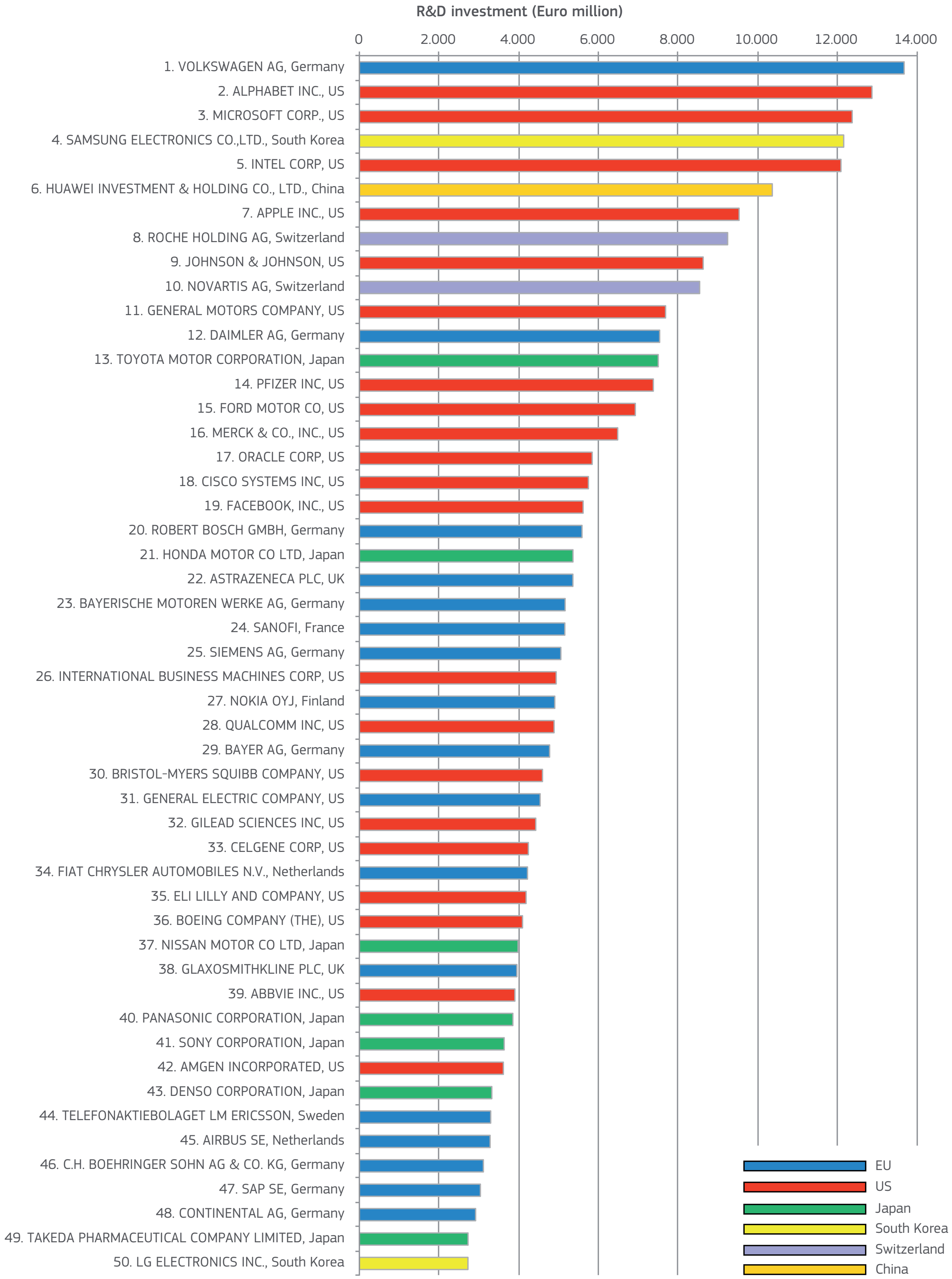

FIGURE 4.1: THE WORLD'S TOP 50 COMPANIES BY THEIR TOTAL R&D INVESTMENT (€million) IN THE 2017 *SCOREBOARD*.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Rank in 2017	Company	Country	R&D in 2016/17 (€bn)	R&D intensity (%)	Rank change 2004-2017
1	VOLKSWAGEN	Germany	13,7	6,3	up 7
2	ALPHABET	US	12,9	15,0	up > 200
3	MICROSOFT	US	12,4	14,5	up 10
4	SAMSUNG	South Korea	12,2	7,7	up 29
5	INTEL	US	12,1	21,5	up 9
6	HUAWEI	China	10,4	19,2	up > 200
7	APPLE	US	9,5	4,7	up 97
8	ROCHE	Switzerland	9,2	19,6	up 10
9	JOHNSON & JOHNSON	US	8,6	12,7	up 3
10	NOVARTIS	Switzerland	8,5	18,2	up 10
11	GENERAL MOTORS	US	7,7	4,9	down 5
12	DAIMLER	Germany	7,5	4,9	down 9
13	TOYOTA MOTOR	Japan	7,5	3,3	down 8
14	PFIZER	US	7,4	14,7	down 12
15	FORD MOTOR	US	6,9	4,8	down 14
16	MERCK US	US	6,5	17,2	up 13
17	ORACLE	US	5,8	16,3	up 29
18	CISCO SYSTEMS	US	5,7	12,6	up 12
19	FACEBOOK	US	5,6	21,4	up > 200
20	ROBERT BOSCH	Germany	5,6	7,6	up 8
21	HONDA MOTOR	Japan	5,4	4,7	up 10
22	ASTRAZENECA	UK	5,4	24,6	up 3
23	BMW	Germany	5,2	5,5	up 6
24	SANOFI	France	5,2	14,1	down 8
25	SIEMENS	Germany	5,1	6,3	down 20
26	IBM	US	4,9	6,5	down 16
27	NOKIA	Finland	4,9	20,8	down 17
28	QUALCOMM	US	4,9	21,9	up 64
29	BAYER	Germany	4,8	10,0	up 31
30	BRISTOL-MYERS SQUIBB	US	4,6	24,9	up 12
31	GENERAL ELECTRIC	US	4,5	3,9	up 6
32	GILEAD SCIENCES	US	4,4	15,4	up > 200
33	CELGENE	US	4,2	39,8	up > 200
34	FIAT CHRYSLER	Netherlands	4,2	3,8	up 10
35	ELI LILLY	US	4,2	20,8	up 6
36	BOEING	US	4,1	4,6	up 21
37	NISSAN MOTOR	Japan	4,0	4,2	down 3
38	GLAXOSMITHKLINE	UK	4,0	12,1	down 27
39	ABBVIE	US	3,9	16,0	new
40	PANASONIC	Japan	3,9	6,5	down 33
41	SONY	Japan	3,6	5,9	down 26
42	AMGEN	US	3,6	16,6	down 5
43	DENSO	Japan	3,3	9,0	down 8
44	ERICSSON	Sweden	3,3	14,1	down 27
45	AIRBUS	Netherlands	3,3	4,9	down 10
46	BOEHRINGER SOHN	Germany	3,1	21,0	up 16
47	SAP	Germany	3,0	13,8	up 23
48	CONTINENTAL	Germany	2,9	7,2	up 69
49	TAKEDA PHARMACEUTICAL	Japan	2,7	20,1	up 24
50	LG ELECTRONICS	South Korea	2,7	6,3	up 60

TABLE 4.2: THE TOP 50 COMPANIES IN THE 2017 *SCOREBOARD*: RANK CHANGE 2004-2017

Note: companies in "blue" went up more than 20 ranks and in "red" lost more than 20 ranks.

Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Ranking of large companies by R&D intensity

The previous section looked at the top 50 companies ranked by the size of their R&D investment. However, since some large companies have very large sales, their R&D intensities (R&D as % sales) may be quite modest and R&D may not be the key driver of growth. For example, in the world top 150 by amount of R&D we have NTT at #81 by size of R&D but with R&D intensity of 1.9%. Hon Hai Precision at #94 with intensity of 1.2% and Shell (oil & gas) at #148 with an intensity of only 0.4%. This section therefore examines the subset of larger companies in the *Scoreboard* having high R&D intensities, all in double digit percentages. The top 50 such companies all have R&D as a very substantial proportion of sales and profits and R&D is a key driver of growth. These companies are drawn from the top few highest R&D intensity sectors. The criteria for selection, the new entrants and leavers for the top 50, the make-up of the 2017 top 50 and the reasons for large rises/falls in the ranking are described below.

The two criteria for inclusion in the top 50 large companies with the highest R&D intensity are:

- R&D should be over €1bn which means that only the top 143 companies in the world by amount of R&D are eligible.
- R&D intensity should be a double-digit percentage so that R&D is a major investment and significant driver of growth. To enter the top 50 in 2017 R&D intensity needs to be 12.7% or more.

In the 2016 *Scoreboard*, it was possible to enter the top 50 by R&D intensity with an intensity of 10.2% or more so there are more high intensity large companies in the 2017 *Scoreboard* where an intensity of 12.7% or more is required.

The top 50 large companies by R&D intensity are shown in Table 4.3. The 50 companies are listed in order of R&D intensity, the highest first. The table also gives each company's sector, R&D investment and rank change from the 2016 top 50.

New entrants, leavers and large movers

There are 10 new entrants in the ranking of the top 50 by R&D intensity in the 2017 *Scoreboard* and therefore 10 companies that were in the 2016 top 50 but no longer qualify. Seven of the leavers are from the nine companies with the lowest R&D intensity in the 2016 top 50. These seven all have R&D intensities ranging from 10.2% to 12.6% and therefore are under the 2017 minimum intensity for entry of 12.7%. They are EMC, Cisco, Finmeccanica, Monsanto, Seagate Technology, SK Hynix and Syngenta. Two other companies were taken over – Alcatel-Lucent (now part of Nokia) and Yahoo! (now part of Verizon). The tenth company is GlaxoSmithKline whose R&D intensity fell because its sales increased more than its R&D to give a 2017 intensity of 12.1%, just below the 12.7% needed for entry in 2017. GSK's 2016 intensity was 12.9%. The reason for the sales increase was GSK's purchase of Novartis's consumer healthcare and vaccines businesses; the two companies' consumer healthcare businesses are now in a joint venture controlled by GSK which has the majority shareholding.

There are ten new entrants for the 2017 top 50. Six of these companies have increased their R&D from below €1bn to above €1bn from 2015/16 to 2016/17 and so meet the first criterion for entry mentioned above. These six are Broadcom, Ctrip.com International, Intuit, NXP Semiconductor (which has now been acquired by Qualcomm), Salesforce.com and Vertex Pharma. There is one company new to the *Scoreboard* – Altaba, a software/internet company. And there are three companies whose R&D intensity increased – eBay, Gilead Sciences and Micron Technology. Seven of the new entries are from the US with two from Asia and one from the EU. The leavers include four from the EU, four from the US, one from Asia and one from Switzerland.

Eight companies changed their ranking by nine or more places between the 2016 and 2017 top 50 tables. All eight fell between 9 and 11 places in the ranking, six of them because sales increased by more than R&D so the R&D intensity decreased (AbbVie, Facebook, Huawei, Johnson & Johnson, Mediatek & Merck DE). In the other two cases (Novartis & Sanofi), both R&D and sales decreased but R&D was down more than sales.

The top 50 by sector and by world region

Just three broad sectors account for 49 of the 50 companies with one company drawn from a fourth sector. The numbers in each sector are:

- Biotech & Pharmaceuticals: 23 companies
- Tech Hardware/Telecoms Equipment: 14 companies
- Software/internet: 12 companies
- Travel & Leisure: 1 company (Ctrip.com International, an internet company incorporated in the Cayman Islands but which is a major provider of travel-related services in China)

It is not surprising that these three broad sectors dominate the rankings since these are the sectors where R&D is crucial for growth and continued success. What is surprising, however, is that many of the large companies in the top 50 have R&D intensities well above their sector averages. Smaller companies frequently have R&D intensities above their sector average because their sales are modest but growing so the R&D needed to develop new products is spread over smaller sales volumes than for larger companies. The global average R&D intensity for the biopharma sector was 10.6% in the 2016 *Scoreboard* yet all the biopharma companies in the top 50 have R&D intensity well above this. The global average for tech. hardware was 8.4% yet again every hardware company in the top 50 exceeds this. For software/internet, the global average was 15% but just over half of the top 50 software companies exceed this.

The regional make-up of the top 50 as between the US, the EU, Asia and Switzerland is:

- The US contributes just over half the companies with 26 in the top 50
- The EU is the next largest region with 12 companies
- Asia contributes 10 companies (Japan 4, China 4 if we include Ctrip.com, Singapore 1 and Taiwan 1)
- Switzerland has 2 companies (Novartis & Roche)

The US accounts for 11 of the 23 biopharma companies in the top 50, 5 of the 14 tech. hardware companies but a massive 10 of the 12 software companies. The EU has 6 biopharma companies, 5 from tech. hardware and 1 from software. Asia has 4 biopharma companies, 4 from Tech. hardware, 1 from software and 1 from travel & leisure. These numbers reflect the relative strengths of the different regions with the US the world leader in software/internet but biopharma and tech. hardware are spread more evenly between regions although the US is particularly strong in biotech.

The US is particularly successful in the software/internet sector with 10 of the 12 companies in the top 50. These include household names such as Alphabet (Google), eBay, Facebook, Microsoft and Oracle.

The other area where the US excels is biotech and all five of the biotech companies in the top 50 are from the US. These are Amgen, Biogen, Celgene, Gilead and Vertex. The five companies labelled biopharma in the top 50 (which all have notable biotech drugs such as immunotherapies on the market) include 2 from the US (Bristol-Myers Squibb & Merck), 2 from Switzerland (Novartis & Roche) and one from the EU (AstraZeneca). Roche's biotech expertise arises from its early acquisition of Genentech of the US.

In many instances above average R&D intensity is a driver of sales growth since innovative and improved new products give a company an edge over competitors in the market. It is therefore not surprising that a number of the companies in the top 50 by R&D intensity have moved well up the *Scoreboard* rankings in both R&D and sales over the last five years. Examples include Alphabet (ranked #2 by R&D in 2017 but #26 in 2012), Baidu (#103 in 2017 but #450 in 2012, Facebook (#19 in 2017 but #295 in 2012), Gilead Sciences (#32 in 2017 but #112 in 2012), Huawei (#6 in 2017 but #41 in 2012), NXP Semiconductor (#98 in 2017 but #203 in 2012), Salesforce.com (#125 in 2017 but #493 in 2012) and Vertex Pharma (#142 in 2017 but #224 in 2012).

Rank by R&D int.	R&D (€bn) & R&D rank	Company	Industrial Sector	R&D int.2016 (%)	Rank change and reason for change
1* (new)	1.01bn (142)	Vertex Pharma	Health industries	62,5	R&D rose above €1bn
2‡ (new)	1.05bn (136)	Ctrip.com Int.	Others	40,0	R&D rose above €1bn
3* (1)	4.24bn (33)	Celgene	Health industries	39,8	-2
4* (2)	4.60bn (30)	Bristol-Myers Squibb	Health industries	24,9	-2
5† (8)	5.36bn (22)	AstraZeneca	Health industries	24,6	3
6* (5)	1.11bn (131)	Electronic Arts	ICT services	24,2	-1
7‡ (11)	1.74bn (79)	Daiichi Sankyo	Health industries	22,4	4
8* (10)	4.89bn (28)	Qualcomm	ICT producers	21,9	2
9* (new)	1.07bn (134)	Intuit	ICT services	21,8	R&D rose above €1bn
10* (9)	12.09bn (5)	Intel	ICT producers	21,5	-1
11* (3)	5.62bn (19)	Facebook	ICT services	21,4	-8
12* (4)	1.39bn (104)	Nvidia	ICT producers	21,2	-8
13† (12)	3.11bn (46)	Boehringer Sohn	Health industries	21,0	-1
14* (new)	1.03bn (140)	Altaba	ICT services	20,9	New to Scoreboard
15*= (13)	4.18bn (35)	Eli Lilly	Health industries	20,8	-2
15†= (19)	4.90bn (27)	Nokia	ICT producers	20,8	4
17*= (new)	2.54bn (55)	Broadcom	ICT producers	20,2	R&D rose above €1bn
17‡= (7)	1.64bn (84)	Mediatek	ICT producers	20,2	-10, %Sales↑>R&D ↑
19‡ (16)	2.73bn (49)	Takeda Pharma	Health industries	20,1	-3
20‡ (15)	9.24bn (8)	Roche	Health industries	19,6	-5
21† (22)	2.68bn (53)	Allergan	Health industries	19,4	1
22‡ (12)	10.36bn (6)	Huawei	ICT producers	19,2	-10, %Sales↑>R&D↑
23† (21)	1.23bn (119)	ST Microelectronics	ICT producers	18,6	-2
24‡ (14)	8.54bn (10)	Novartis	Health industries	18,2	-10, %R&D↓>Sales↓
25* (23)	6.48bn (16)	Merck US	Health industries	17,2	-2
26* (17)	1.83bn (74)	Biogen	Health industries	16,9	-9, sales ↑/ R&D ↓
27* (20)	3.61bn (42)	Amgen	Health industries	16,6	-7
28* (29)	5.84bn (17)	Oracle	ICT services	16,3	1
29*(18)	3.90bn (39)	AbbVie	Health industries	16,0	-11, %Sales↑>R&D↑
30† (new)	1.44bn (98)	NXP Semiconductor	ICT producers	16,0	R&D rose above €1bn
31‡ (26)	1.69bn (82)	Astellas Pharma	Health industries	15,9	-5
32* (new)	4.43bn (32)	Gilead Sciences	Health industries	15,4	R&D up, sales down
33† (25)	1.03bn (138)	ASML	ICT producers	15,1	-8
34* (27)	12.86bn (2)	Alphabet	ICT services	15,0	-7
35* (28)	7.38bn (14)	Pfizer	Health industries	14,7	-7
36*= (35)	12.37bn (3)	Microsoft	ICT services	14,5	-1
36*= (new)	1.15bn (125)	Salesforce.com	ICT services	14,5	R&D rose above €1bn
38‡ (30)	1.39bn (103)	Baidu	ICT services	14,4	-8
39* (32)	1.46bn (96)	Applied Materials	ICT producers	14,2	-7
40†= (34)	3.30bn (44)	Ericsson	ICT producers	14,1	-5
40‡= (36)	1.37bn (105)	Otsuka	Health industries	14,1	-3
40†= (31)	5.16bn (24)	Sanofi	Health industries	14,1	-9, %R&D↓>%Sales↓
43* (new)	1.19bn (122)	eBay	Others	13,9	Intensity rose
44† (40)	3.04bn (47)	SAP	ICT services	13,8	-4
45‡ (37)	1.86bn (70)	ZTE	ICT producers	13,5	-8
46† (44)	2.00bn (67)	Novo Nordisk	Health industries	13,3	-2
47† (38)	1.97bn (68)	Merck DE	Health industries	13,1	-9, %Sales↑>R&D↑
48* (new)	1.53bn (89)	Micron Technology	ICT producers	13,0	Sales ↓, R&D ↑
49* (43)	2.32bn (59)	Western Digital	ICT producers	12,8	-6
50* (41)	8.63bn (9)	Johnson & Johnson	Health industries	12,7	-9, %Sales↑>R&D↑

TABLE 4.3: RANKING OF LARGE COMPANIES BY R&D INTENSITY.
Note: The colours indicate world region (red for US, blue for EU, black for Asia & green for Switzerland.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

5

ANALYSIS OF THE TOP EU **1000 R&D INVESTORS**

5 Analysis of the top EU 1000 R&D investors

This chapter examines the R&D and economic trends of companies based in Members 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 567 EU companies included in the world top 2500 sample and 433 additional companies based in the EU. The distribution of the EU 1000 companies across industrial sectors and countries can be found in Annex 3.

As explained in chapter 1 for the world sample of companies, industrial R&D is very concentrated by country and sector. Among the EU 1000 sample, there are 906 companies based in the top 10 Member States accounting for 97.3 % of the total R&D. Moreover, the overall performance of the EU 1000 group is largely driven by the results of companies based in Germany, France and the UK, accounting for 67% of the total R&D and 68% of total net sales.

The first section presents the one-year changes in R&D and economic indicators of companies, especially those based in the top 10 largest Member States. The second section analyses long-term trends of company results, mainly in terms of R&D, net sales and employment.

5.1 | Changes in the main indicators in 2016/17

Key points

- The top 1000 R&D companies in the EU invested €198.3bn, 6.9% more than the previous year.

- The German companies made the largest contribution to the results of the EU 1000 sample. They increased R&D by 6.7% and net sales only by 1.1%. These results reflect to a large extent the performance of the German companies in the Automobiles sector (7.1% in R&D and 3.6% in net sales). *Companies from this sector showing the highest R&D growth were Daimler, ZF, Continental and Robert Bosch. German companies showing good performance in other sectors were SAP (ICT Services) and Bayer (Health industries).*

- The companies based in the UK increased R&D by 9.2% but showed a modest increase in net sales (0.6%). *The largest contribution to R&D growth was made by the Health industries (Largest contribution from Shire and GlaxoSmithKline), other industries (Lloyds Banking, Kemble Water Holdings), Aerospace & Defence (Rolls-Royce) and ICT Services (BT, Atlassian Corporation).*

- Companies based in France increased R&D by 3.4% and dropped sales by 3.6%. Among these companies, *the largest contribution to the R&D growth came from Automobile sector (Renault, Valeo), ICT Services (Ubisoft Entertaiment, Dassault) and other industries (Alstom, Vivendi, Technicolor, L'Oreal).*

- 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:
  - Finland by 63.8%, mostly *due to Nokia's acquisition of Alcatel-Lucent,*
  - Denmark by 7.5%, large contributions from Health industries (Novo Nordisk, Symphogen, Ascendis Pharma, Forward Pharma, Alk Abello) and Other industries (Vestas, Carlsberg),

– Belgium by 11.6%, large contributions from ICT industries (Proximus, Barco), Health industries (Mithra Pharma, UCB), Chemicals (Solvay) and Other industries (Anheuser-Busch, KBC).

- Among the large countries, only the group of Swedish companies decreased R&D (-1.2%). In this group, high R&D growth of companies such as Saab, Assa Abloy, Swedish Orphan Biovitrum, Lansforsakringar and Fingerprint Cards has been offset by reduction of R&D by companies such as Ericsson, Atlas Copco and Elekta.

- In term of net sales, companies from several countries showed negative results, Italy (-9.4%), Sweden (-4.1%), France (-3.6%) and Spain (-2.7%), *mostly due to oil-related companies such as Total, Eni, Enel and Repsol.*

- In 2017, for the fourth 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, 6.9% vs. -0.6%.

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% of the total R&D by the Swedish companies, Nokia for 77% of the companies based in Finland and Telecom Italia and Leonardo for 52% of the companies based in Italy.

Country	No. of companies	R&D in 2016 (€bn)	R&D Share within EU (%)	R&D one year growth (%)	Net Sales one year growth (%)
Germany	224	76.3	38.5	6.7	1.1
UK	290	31.0	15.6	9.2	-1.5
France	108	26.0	13.1	3.4	-3.6
Netherlands	46	18.5	9.3	3.2	3.1
Ireland	27	9.9	5.0	5.4	0.8
Sweden	82	9.5	4.8	-1.2	-4.1
Finland	36	6.4	3.2	63.8	7.8
Italy	38	5.9	3.0	4.0	-9.6
Spain	21	4.8	2.4	3.5	-2.7
Denmark	32	4.7	2.4	7.5	4.7
Top 10 countries	**904**	**192.9**	**97.3**	**6.9**	**-0.9**
Other EU	96	5.4	2.7	9.4	-3.2
Total EU	**1000**	**198.3**	**100**	**6.9**	**-1.0**

TABLE 5.1: R&D TRENDS FOR COMPANIES BASED IN THE TOP 10 EU MEMBER STATES.
Note: For the sample of 1000 EU companies.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Sector	R&D in 2016 (€bn)	Germany 1-year change (%)		France 1-year change (%)		UK 1-year change (%)	
		R&D	Net Sales	R&D	Net Sales	R&D	Net Sales
Aerospace & Defence	9.0	15.2	11.3	-13.1	2.3	11.2	7.9
Automobiles & other transport	57.4	7.1	3.6	11.0	5.2	3.0	10.1
Chemicals	5.7	-2.1	-10.9	4.3	8.9	6.1	29.0
Health industries	45.7	6.9	5.1	1.4	2.1	12.2	14.8
ICT producers	26.0	5.8	5.7	0.1	-4.7	8.4	17.8
ICT services	13.1	12.3	5.1	15.3	4.8	19.6	19.1
Industrials	12.3	5.4	1.6	11.9	-9.3	3.7	8.0
Others	29.1	7.7	-1.7	0.7	-6.2	3.9	-5.9
Total	**198.3**	**6.7**	**1.1**	**3.4**	**-3.6**	**9.2**	**-1.5**

TABLE 5.2: GROWTH OF R&D AND NET SALES FOR THE GERMAN, FRENCH AND UK COMPANIES - BREAK DOWN FOR 7 MAJOR INDUSTRIAL SECTORS.
Note: For the sample of 1000 EU companies.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

5.2 | Long-term trends for companies based in the large Member States

This section presents the evolution of the main company indicators over the past 10 years for the companies in the EU 1000 group.

5.2.1 Long-term trends

The annual growth rates of R&D and net sales and profitability for companies based in Germany, France and the UK over the past 10 years is provided respectively in figures 5.1, 5.2 and 5.3. These figures are based on our history database comprising these indicators over the whole 2007-2016 period for EU companies based in Germany (156), France (77) and the UK (290).

Key points

- Companies based in Germany continued the strong performance in terms of R&D shown since 2010, recovering to and then improving on levels of R&D growth prior to the crisis. However, the growth of net sales has not followed the same path, a slowdown from 2010 to 2013 has been followed by a hesitant recovery in 2014/15 but then again sales decreased from 2015 to 2016. On the other hand, German companies have maintained a stable level of profitability over the past 10 years although one that was lower than their French and UK counterparts.

- Companies based in France showed a low but positive trend in R&D growth after the decrease from 2011 to 2013, but at much lower levels than their EU or non-EU counterparts although growth increased from 2015 to 2016. However, the growth of net sales continued to be negative to 2013 but improved somewhat from 2015 to 2016. The average profitability of the French companies broke the decreasing trend showed since 2011 and has increased from 2015 to 2016.

- Companies based in the UK showed a strong recovery of R&D and net sales in 2010-2011 that then reversed 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 2014-15 the R&D level remained practically unchanged although with a significant decrease of net sales but both R&D and sales increased strongly from 2015-2016. The average profitability of the UK companies was the highest of the three countries throughout the period although, like their French counterparts, showed

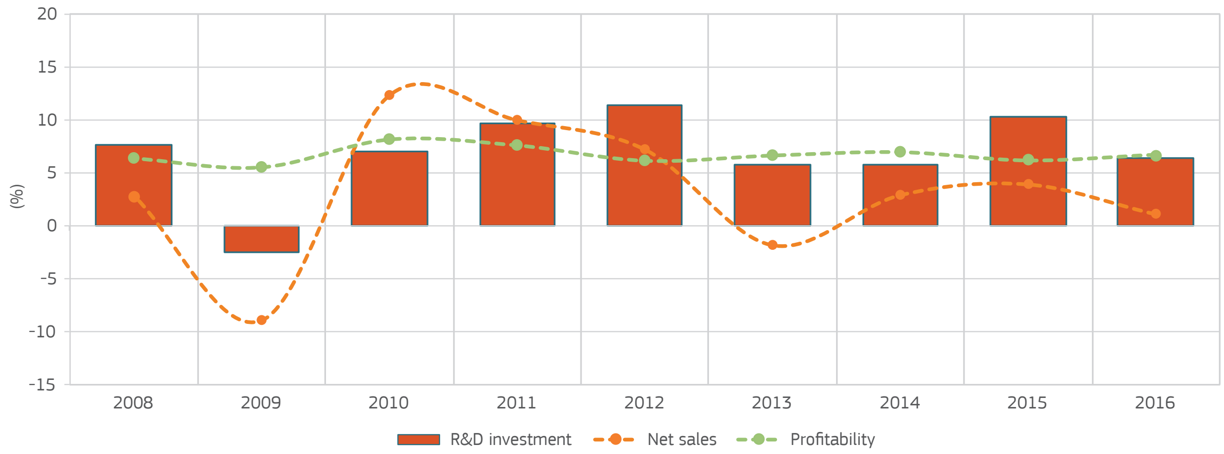

FIGURE 5.1: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE GERMAN COMPANIES.
Note: Note: growth rates for the three variables have been computed on 156 out of the 244 German companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

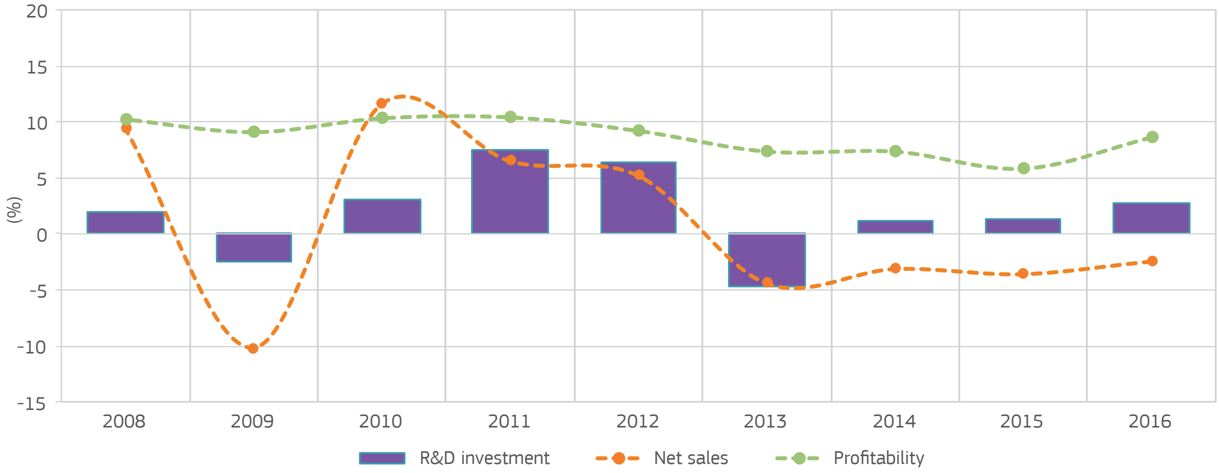

FIGURE 5.2: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE FRENCH COMPANIES.
Note: growth rates for the three variables have been computed on 77 out of the 108 French companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

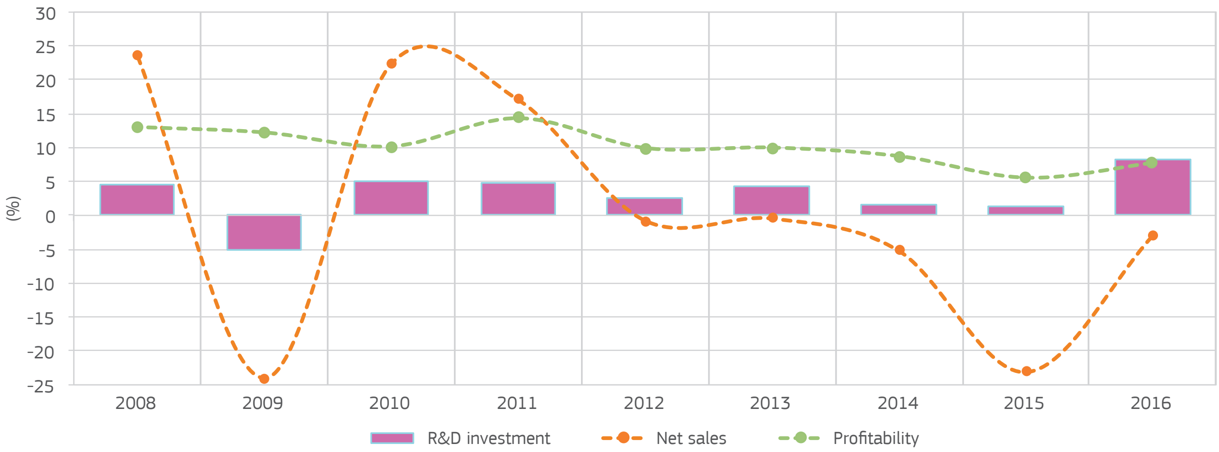

FIGURE 5.3: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE UK COMPANIES.
Note: growth rates for the three variables have been computed on 142 out of the 290 UK companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

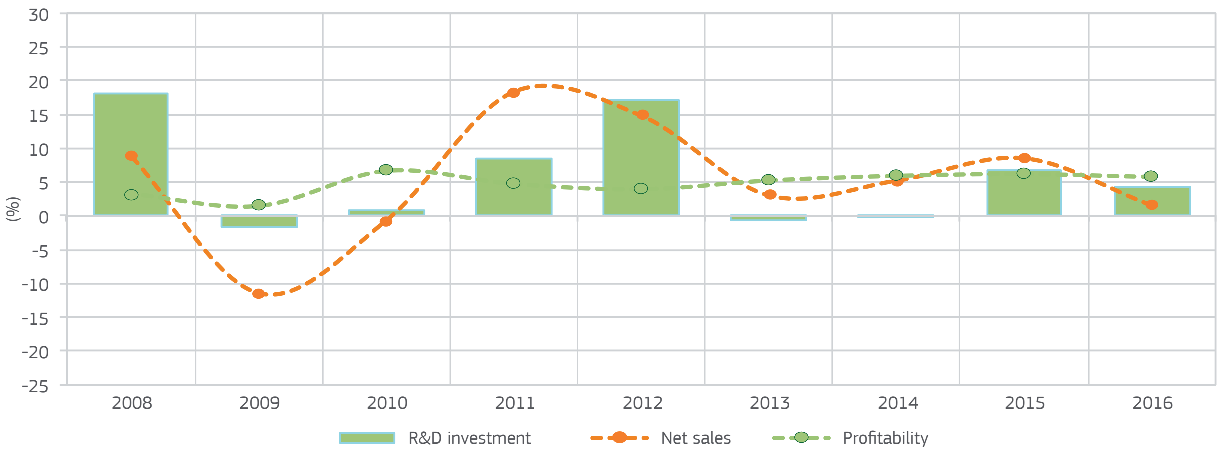

FIGURE 5.4: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE DUTCH COMPANIES.
Note: growth rates for the three variables have been computed on 28 out of the 46 Dutch companies for which data are available for the entire period 2007-2016.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

a decreasing trend from 2011-2015 but a strong increase in 2016/17.

- Companies based in the Netherlands registered an increase in R&D, Net Sales and profitability. The growth was less strong than last years but still positive, giving continuity to the recovery after the slowdown of 2013 and 2014.

5.2.2 Change in R&D over 2007-2016 for groups of sectors and main EU company aggregates

The levels of R&D, net sales and employment in 2007 and 2016 are presented in figures 5.5, 5.6 and 5.7 for groups of industrial sectors with characteristic R&D intensities[11] (see definition in Chapter 1 – Table 1.3). The figures refer to a set of 689 companies that reported R&D, net sales and number of employees over the whole period 2007-2016 (DE-166, FR-85, UK-158, NL-26 and Other-254).

Key points

- Over the past 10 years, the R&D, net sales and employment changes for the whole sample of 689 EU companies for which data are available are very similar to those of the EU 400 sample within the world set (concentration effect).

  The overall changes for each indicator are:
  - R&D 53%(high tech 44%, medium-high tech 69%, medium-low tech 37% and low tech 26%)
  - Net sales 14%(high tech 45%, medium-high tech 38%, medium-low tech 20% and low tech -12%)
  - Employment 14 (high tech 36%, medium-high tech 27%, medium-low tech -3% and low tech -5%).
- These three indicators changed in very different proportions across member states and sector groups. By sector groups the highest increases were:

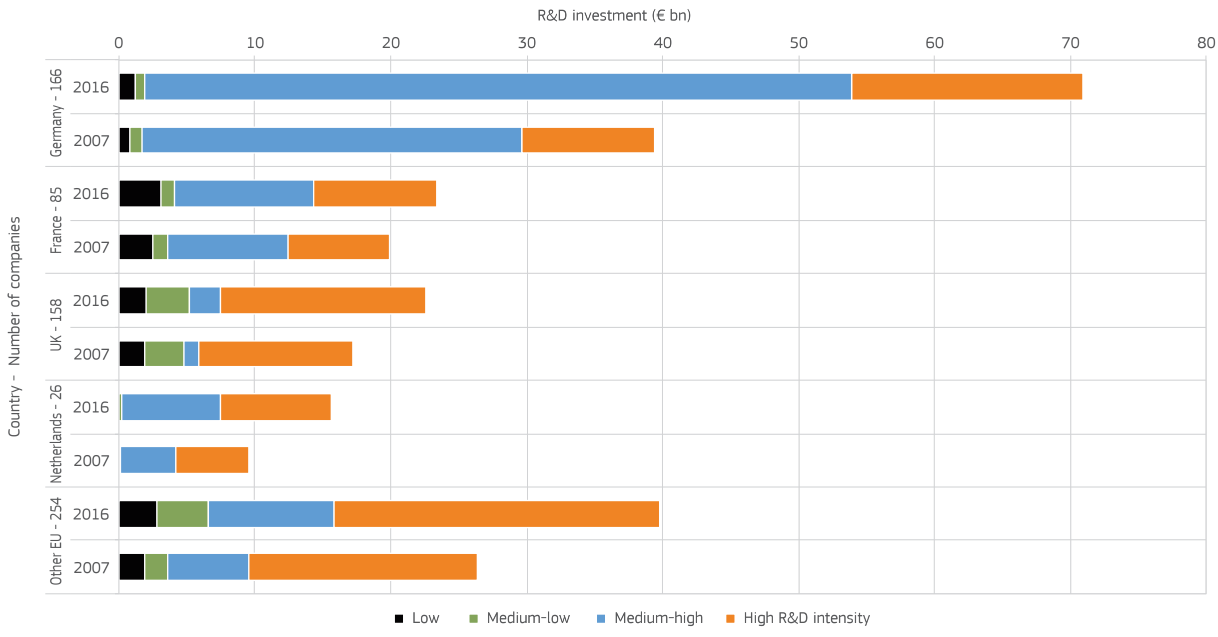

FIGURE 5.5: R&D INVESTMENT IN 2007 AND 2016 BY SECTOR AND MAIN EU GROUPS.
Note: figures displayed refer only to the 689 companies for which data are available for all variables (R&D, Net Sales and Employment) in both years (2016 and 2007).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[11] For simplification, in this section these groups are referred to as high tech, medium-high tech, medium-low tech and low-tech.

- In high tech (for R&D, DE 74%; for Net sales, DE 69% and for Employment, FR 58%)
- In medium-high tech (for R&D, DE 86%; for Net sales, UK 57% and for Employment, Other 40%)
- In medium-low tech (for R&D, NL 203%; for Net sales, NL 79% and for Employment, NL 113%)
- In low tech sectors (for R&D, Other 43%; for Net sales, FR -3%% and for Employment, FR 5%)

- The above results analysed by member state show distinct characteristics of the R&D investing companies in each country. For example,
  - German companies increased their R&D by 74% and employment by 52% in high tech whereas French companies grew R&D only by 20% but employment by 58% in high tech. This is due to the fact that the ratio R&D/employees in the high

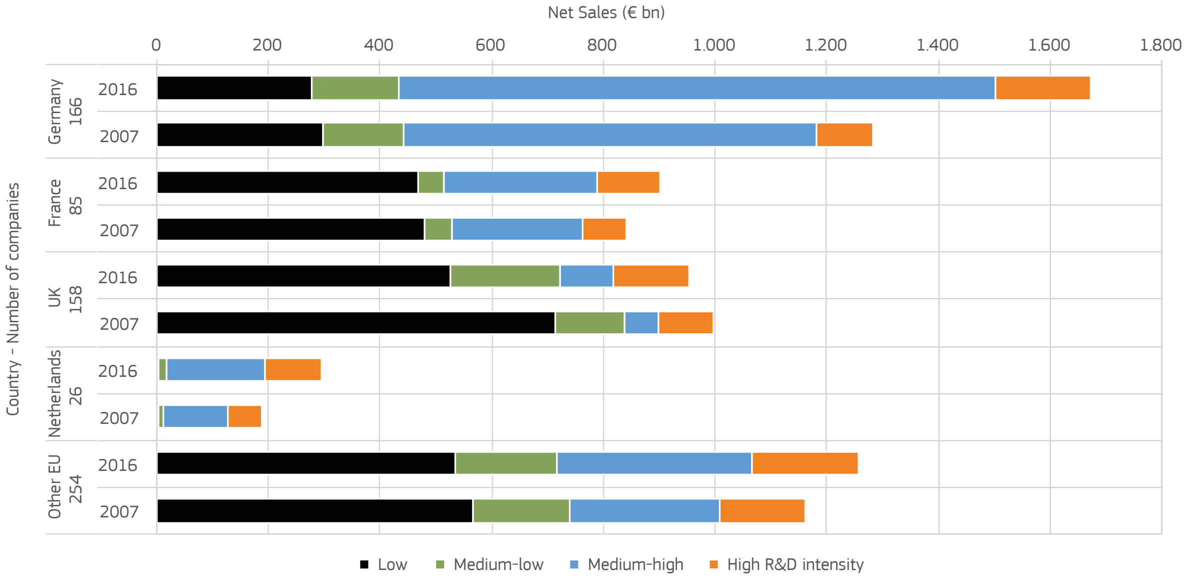

FIGURE 5.6: NET SALES IN 2007 AND 2016 BY SECTOR AND MAIN EU GROUPS.
Note: figures displayed refer only to the 689 companies for which data are available for all variables (R&D, Net Sales and Employment) in both years (2016 and 2007).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

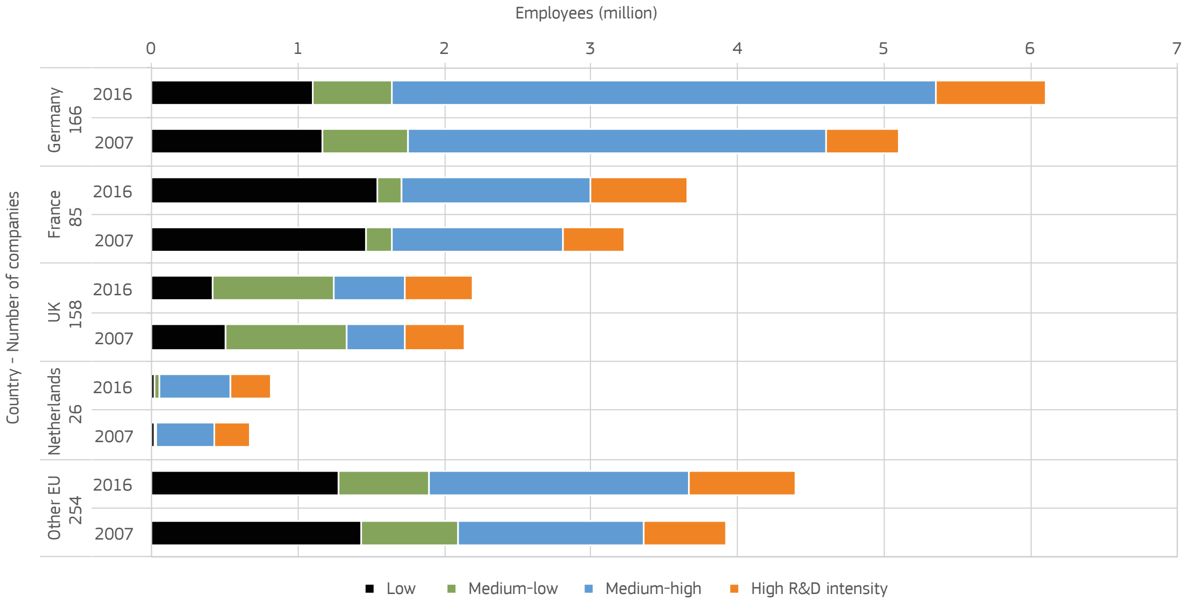

FIGURE 5.7: EMPLOYMENT IN 2007 AND 2016 BY SECTOR AND MAIN EU GROUPS.
Note: figures displayed refer only to the 689 companies for which data are available for all variables (R&D, Net Sales and Employment) in both years (2016 and 2007).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

tech sector increased for German companies but decreased for French ones. On the other hand, German companies increased the ratio sales/ employee more than the French companies for high tech and for the whole sample.

- UK companies showed overall stagnation in sales (-1%) although showing large net sales growth in 3 groups (high, medium-high and medium- tech groups). This is due to 21% sales decrease in the low tech sector which has companies with very large sales, e.g. oil & gas, mining and banks).
- Companies based in the Netherlands showed significant increases for the 3 indicators in all sectors.

6

DYNAMICS OF THE WORLD'S **MOST PRODUCTIVE COMPANIES**

6 Dynamics of the world's most productive companies

This chapter focuses on the performance and dynamics of the most productive firms as compared to lagging firms. We use a panel dataset that covers 10 years of R&D Scoreboard *data (from 2007 to 2016) with the main variables: R&D investments, Net Sales, Employment, Capital Expenditures.*

Top performing firms are those firms that are amongst the top 10% of firms with the highest labour productivity in each of the sector groups. Here, labour productivity is defined as net sales per employee. The main objective is to characterise the top firms and compare these to the bottom 90% of companies.

In a subsequent step, the dynamics of the top performers will be checked: to what degree do the most productive firms manage to maintain their lead over time? What is the regional (EU vs. US vs. others) composition of the top performers for each of the sector groups and how has this changed over the 10-year period of our dataset? What are the characteristics of the most productive firms compared to the rest of the firms?

Key points

- The productivity gap between the most productive and rest of the firms is significant, even in a dataset as used in this analysis where only the largest global firms are considered. Depending on the sector, the net sales per employee is between 3 and 7 times higher for the most productive firms.

- In some cases, like in Health industries, this is due to the existence of many small (biotech) companies that have considerable amounts of R&D funding (which is why these firms enter in the R&D *Scoreboard*) but do not report any or very little sales while researching a breakthrough medicine or component. In other cases, mainly for Industrials, no direct explanation can be given.

- Over the 10-year period of our sample, the top performers in the Aerospace & Defence and Health Industries seem to further increase the productivity gap with respect to the bottom 90% of the firms, while in the Other sector group the gap is declining. The other sector groups do not show a clear pattern.

- The top performers are not per se also the largest firms in terms of employees: only top performers in both ICT sector groups, Aerospace and Defence and Automobiles and Other Transport are larger than the lagging firms.

- Capital Expenditures the factor that differs most between top and bottom performers, although the magnitude of this difference varies between sector groups. For sector groups where firms rely on superior machinery, such as Automobiles and Other Transport and ICT Services, this embodies the importance of acquisition of state of the art technologies that are incorporated in the high-end production process of the top performers.

- The region of origin of the top performers over time is very sector specific. The EU hosts the largest shares of the most productive firms from the Chemicals, Industrials and Others sector groups.

- Most of the top performers from the Health Industries and ICT sector groups are located in the US. The location of the group of top performers from the Automobiles and Other Transport sector group has shown the most dynamic changes during the 10-year period.

- Chinese firms have not managed to gain a significant share amongst the top performers.

6.1 | Data

Firms are classified in 8 sector groups (see table 1.2 in chapter 1 for details). The number of firms is shown in Table 6.1, also displaying the number of firms per sector group for the year 2016:

Sector group	Number of firms
Aerospace & Defence	60
Automobile and other transport	219
Chemicals	155
Health	616
ICT Producers	589
ICT Services	401
Industrials	391
Other	693
Total	**3124**

TABLE 6.1: NUMBER OF FIRMS PER SECTOR GROUP.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

The data used in this analysis consists of a (unbalanced) panel data set with more than 3000 companies with at least 1 year of observation. The average number of available years for R&D investment, Net Sales and Employees is between 8 and 9 years, which indicate that it is a very richly filled panel data set.

The following Figure 6.1 reports the summary statistics of net sales, number of employees, R&D investments and intensity, capital expenditures, market capitalisation and operating profits for the top 10%, the bottom 90% and for all firms together.

On average, the top performing companies from Others sector group in our dataset are the largest based on net sales. This is mainly due to the presence of oil and other energy companies and banks that traditionally show a high turnover. Net Sales are also much higher for top performing companies in Aerospace and Defence and Automobiles and Other Transport. Top performing companies are on average more profitable, have higher capital expenditures and a higher market capitalisation than lagging firms, but are not always larger in terms of employees.

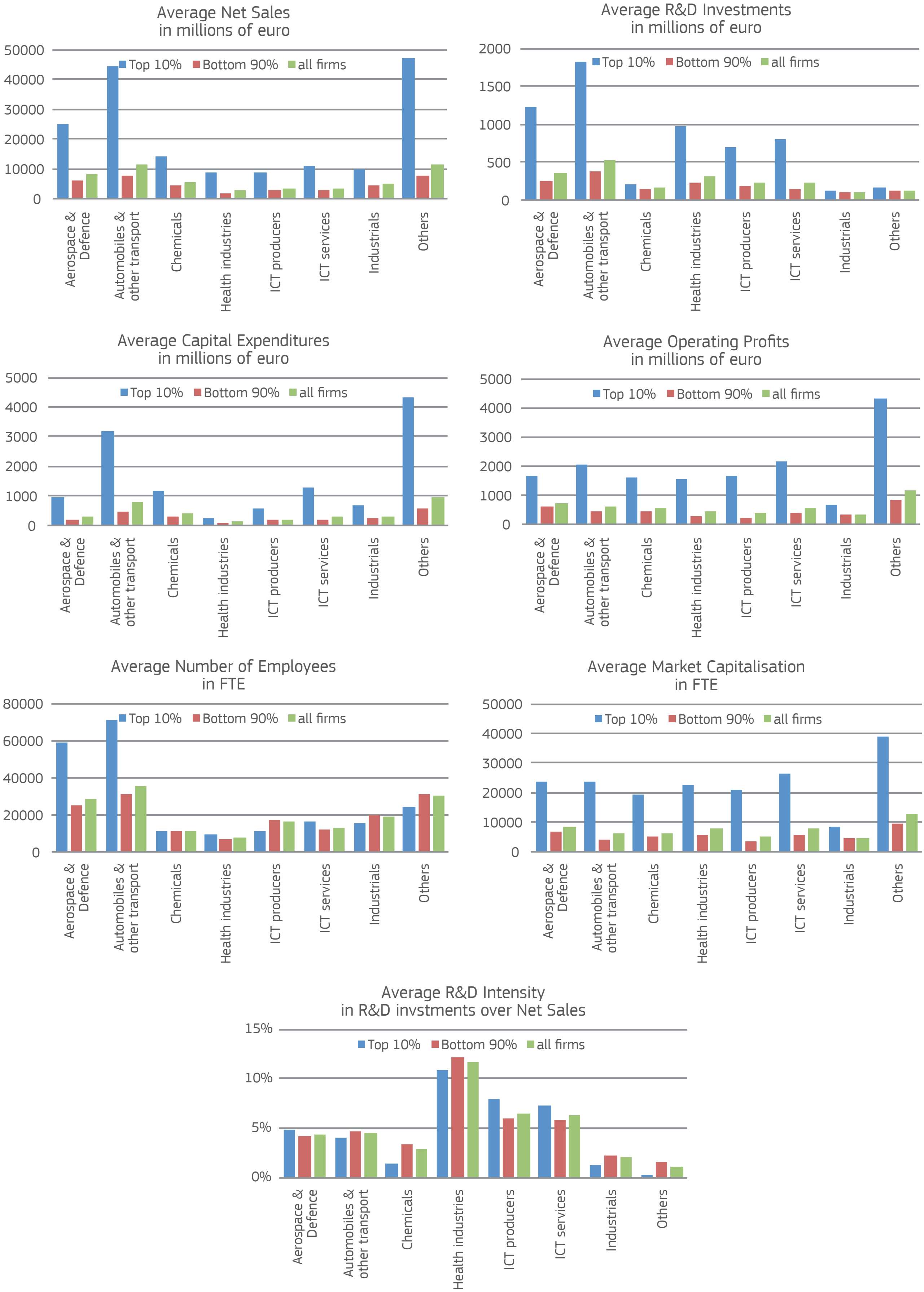

FIGURE 6.1: AVERAGES OF SELECTED VARIABLES OVER THE PERIOD 2007-2016 BY SECTOR GROUP: ALL FIRMS, TOP 10% AND BOTTOM 90%

Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

6.2 | Changes of labour productivity over time

Here we look at how labour productivity of the top vs bottom firms has been changing over the duration of the 10-year period, from 2007 to 2016. For our analysis, the top 10% and bottom 90% are calculated in each year so that the dynamics can be studied.

The comparison of labour productivity for the bottom 90% vs the top 10% per sector group over the last 10 years shows some interesting insights. The productivity gap seems to remain stable over this period in each of the sectors. For the bottom 90%, labour productivity is very similar amongst all sector groups (apart from Chemicals), around €200k per employee. The top performers display a broader range of productivity levels that are at least a multiple of 3 higher than the bottom 90%.

Especially for the Chemicals, Health Industries and Others, the productivity gap is very large and has increased since 2013. The large gap in the Health Industries can be (partly) explained by the presence of many smaller companies with very low sales – and subsequently low labour productivity – high losses and high R&D investments for a few years before either bringing a new drug to the market, being acquired by a large firm or disappearing completely.

FIGURE 6.2: COMPARISON OF LABOUR PRODUCTIVITY PER SECTOR GROUP (2007-2016).
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

6.3 | Other characteristics of top performers vs. bottom performers

For our analysis, it is also interesting to look at how other characteristics like Net Sales, R&D investment and intensity, Capital Expenditures, profitability and number of Employees differ between top performers and lagging firms and how it developed over the period 2007-2016.

For this, the ratio between the top and bottom firms' levels of Capital Expenditures, Employees, Net Sales, R&D investments and R&D intensity has been calculated. Results are shown in Figure 6.3. A logarithmic scale has been used for the graphs so that values between 0 and 1 (the bottom 90% has a higher average for the selected variable than the top 10%) are magnified and values above 1 (the top 10% has a higher average for the selected variable than the bottom 90%) are also displayed.

The greatest differences between top performers and lagging firms are in Capital Expenditures, Market Capitalisation and Operating Profit levels, where top performing firms have on average higher levels than the lagging firms in all sector groups.

For Capital Expenditures, especially top performing firms from the sector groups of Automobiles and ICT Services have significantly higher levels of capital expenditures than the rest. As earlier research showed (with R&D *Scoreboard* companies), technological change embodied in capital expenditures (such as superior machinery for production) is of importance for firm's productivity growth in low R&D intensive sectors.[12]

The high ratios for Market Capitalisation of ICT Producers and ICT Services firms show that firms from these sector groups are very highly valued on the stock market. Some companies that are in the top 10% performers of these sectors are APPLE, ALPHABET, CISCO, FACEBOOK, MICROSOFT and SAMSUNG.

If we look at firm size, in terms of the number of employees, we see that only in Automobiles and Other Transport firms and Aerospace and Defence the top performers are on average much larger than the lagging firms. These differences are much less pronounced for the other sector groups, and in some sector groups the lagging firms are larger (Industrials, Others and Health Industries).

For R&D intensity, the differences are much smaller and in many sectors the average R&D intensity for the lagging firms is higher than for the top performing firms. Here, several reasons can be thought of having an impact on this. First, more productive firms are more effective in turning R&D investments into productivity gains. Second, there is a size effect: the top 10% are on average larger than the rest of the firms and can perform similar research and development with a smaller share of the firm's sales. Third, less productive firms will need to invest more in R&D in order to improve productivity.

[12] See Ortega-Argilés, R., Potters, L. & Vivarelli, M. Empirical Economics (2011) 41: 817.

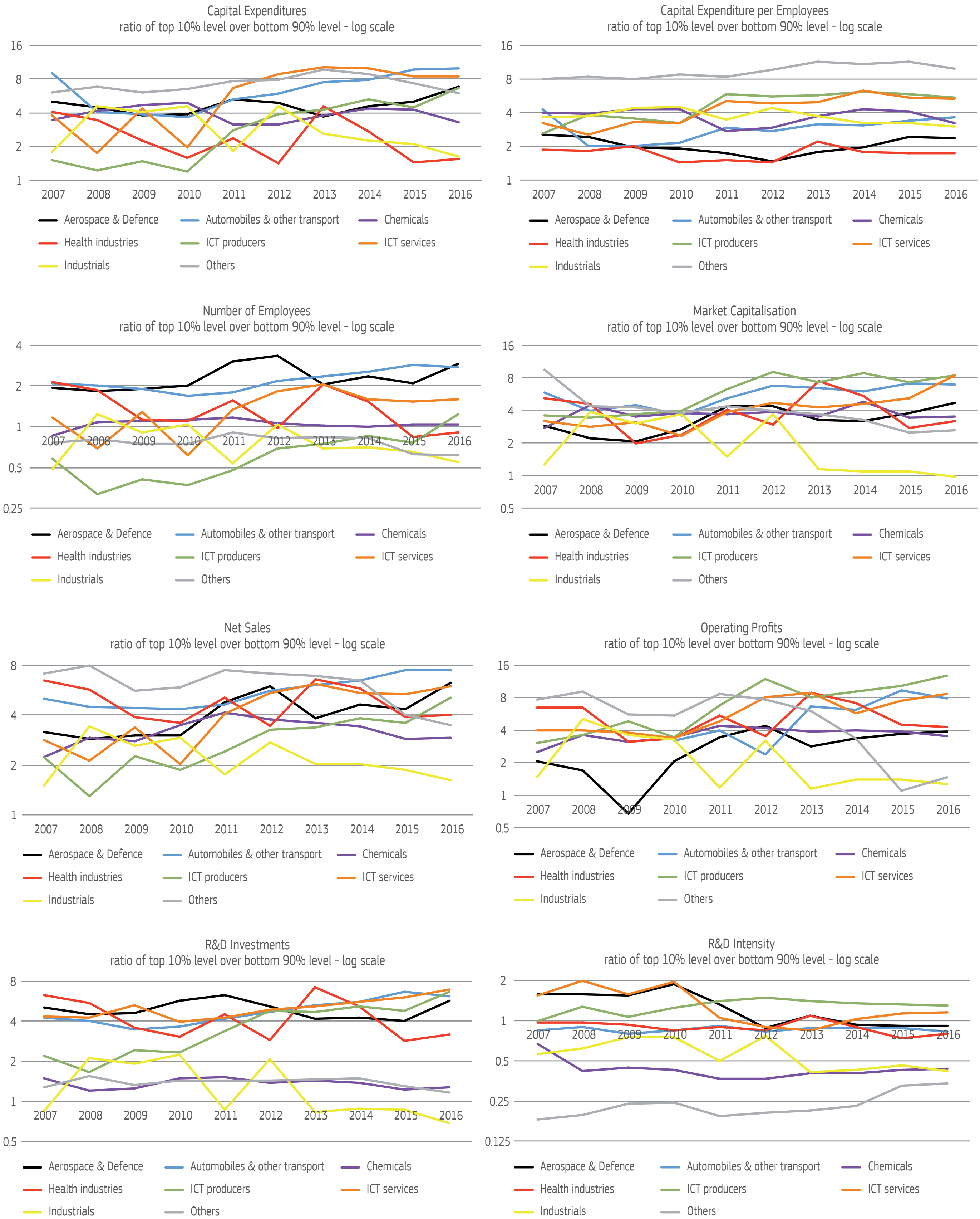

FIGURE 6.3: RATIOS OF TOP 10% OVER BOTTOM 90% FOR SELECTED VARIABLES.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

6.4 | Regional composition

In this section we look at the regional composition of the most productive firms and how this has changed over time. We group the home base countries into five regions, EU, the US, China, US and the Rest of the World (RoW). The *Scoreboard* data provides data on the location of the headquarters of the firms. Although these multinational enterprises are globally active, research does show that most firms have the principal R&D location in their home country.[13]

The graphs in Figure 6.4 below show that the regional composition of top performers differs both over time and per sector group. The top performers from the Aerospace & Defence sector group are basically shared between the EU and the US, where AIRBUS, BOEING and LOCKHEED are the main players.

The **EU** hosts a large share of the top performers from the sector groups Chemicals, Industrials and Others. The latter sector group includes many large EU oil firms like ROYAL DUTCH SHELL, TOTAL, REPSOL and BP.

We see that some US top performers from the Automobiles and Other Transport sector group disappeared after the US automotive industry crisis (2008-2010): the US share of top performers in this sector group has been declining since 2011. The top performing firms are mainly located in **Japan**, with large car manufacturers like NISSAN, TOYOTA, HONDA, MAZDA and SUBARU.

The strength of **the US** can be mainly seen in the Health sector group and the ICT sector groups (both Producers and Services), with around 60-70% of the top performing firms located there. For The US hosts many large pharmaceutical companies like MERCK, AMGEN and BRISTOL-MEYERS SQUIBB. For ICT Producers and Services we saw earlier that big firms like APPLE, ALPHABET, CISCO, FACEBOOK and MICROSOFT are located in the US.

Remarkably, although **China** has shown a remarkable economic growth during the last 10 years, Chinese companies continue to have only a small share of top performing firms and this share has not increased during the 10-year period either.

[13] See EU R&D Survey 2017.

FIGURE 6.4: REGIONAL COMPOSITION OF TOP PERFORMERS.
Source: The 2017 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

7

COMPANIES' DEVELOPMENT **OF PATENTED ICT-RELATED TECHNOLOGIES**

7 Companies' development of patented ICT-related technologies

Digital technologies are transforming our manufacturing and industrial systems. Understanding the capacity of EU companies to master ICT-related technologies is critical in the context of initiatives that aimed at improving the competitiveness of industry such as the so-called "Industry 4.0". This fourth industrial revolution, that brings together ICTs and traditional industries, yields major opportunities and challenges for the reindustrialisation of the EU, for instance in terms of automation, flexible production processes, manufacturing speed or the integration of users' needs. Hence, mapping the scale and features of corporate technological developments in the digital era is essential to inform policies aiming at a more digitized and stronger industry.

Key points

- With only one fourth of total patent families related to digital technologies, EU based companies lag behind in ICT technological development. US (37%) and Japan (33%) based companies show higher, but comparable, shares of digital related patents.

- The vast majority of patents from Chinese companies are related to digital technologies (81%), this holds true for about half of patents from the rest of the world. The particular high digital share for Chinese companies is coupled with a very small number of international patents.

- EU-, US- and China-based top R&D investors show close specialisation profiles within ICT technologies. They are specialised in High-speed network, Mobile communication, Security, and Large capacity information analysis. EU based top R&D investors also present specialisation in Electronic measurement and Sensor and device network.

- Sectoral specificities arise in the development of digital technologies. Large capacity information analysis is particularly relevant in the Software & computer services and Pharma & Biotech industries. The Aerospace and defence industry, very intensive in the development of digital technologies, shows a more distributed portfolio of digital technologies.

- US- and EU-based top R&D performers rely to the greatest extent to inventors located abroad. This is particularly true for ICT-related technologies where about one third and one fourth of patents rely on international inventors On the contrary, companies located in the rest of the world seems to rely more on international inventors for the development of non-ICT technologies.

This chapter examines the development of ICT-related technologies by top corporate R&D investors and addresses the following issues:

- Where does the EU stand in the development of ICT technologies? Which are EU's relative strengths in the development of specific ICT technologies?

- Which corporate R&D investors lead the development of ICTs? Which specific technologies do they target across different sectors?

- Where are most of the digital related patents owned and where are they actually developed? Which differences can be observed between the location of inventive activities related to ICT and non-ICT technologies?

To answer these questions, this chapter exploits the recent JRC/OECD COR&DIP© database, v.1. 2017 built in the framework of our collaboration with the OECD to investigate the development of digital technologies carried out by *Scoreboard* companies.[14] The patent statistics reported

[14] For further information, please see the report "World Corporate Top R&D Investors: Industrial Property Strategies in the Digital Economy" http://iri.jrc.ec.europa.eu/documents/10180/12268/JRC-OECD-WorldCorporateTopRDInvestors.pdf.

here are based on families of patent applications[15] filed between 2012 and 2014 at the five largest IP offices (IP5), namely the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO) and the United States Patent and Trademark Office (USPTO). Moreover, we use a recent classification for ICT-related patents[16] in order to analyse the importance of specific ICT-related technologies.

7.1 | Corporate patenting and specialisation in ICTs

This section looks at the patenting activity and specialisation profiles of top corporate R&D investors across selected world's regions of headquarters location. In particular, it looks at the absolute and relative performance of top corporate R&D investors in ICTs development.

Figure 7.1 shows the total number of patents families (left axis) and the share of ICT-related patents (right axis).

Japan-located corporate investors record an almost twice higher number of IP5 patents families than other major world regions as the EU and US. As for the levels of R&D investments, such differences in patenting volumes are often associated with specific structural and industrial features of the economies (major industries, industrial specialisation) as well as targeted patents regulation and support (for instance, R&D tax credit including patents and other IPRs). It should also be considered that average number of claims per family for Japanese firms is much smaller (2.5) than for firms based in the other areas (5.3 for US, 4.9 for EU, 4.2 for China and 4 for the RoW). This difference may be still the effect of the one patent one claim rule in place at JPO in the past.[17] This might be causing, at least partially, inflation in the number of JP owned patent families.

Chinese-based R&D performers display an overall low patenting activity compared to the other main world areas considered. Moreover, China-headquartered companies, with about 80% of their patenting activity relates to digital technologies, show a particularly high specialisation in ICT-related technologies. Companies

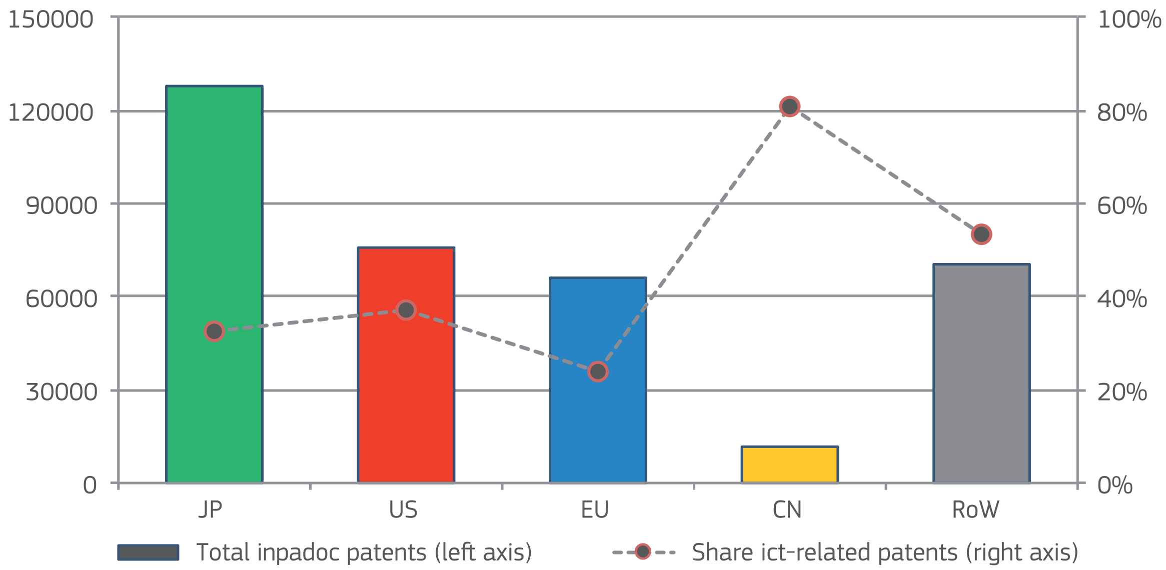

FIGURE 7.1: TOTAL PATENTS AND ICT-PATENTING SHARES BY SELECTED WORLD'S REGIONS.
Note: Patents counts refer to the number of fractionally counted patent families.
Source: JRC/OECD COR&DIP© database. v.1. 2017.

[15] Patent families refer here to IP5 families of patent applications with members filed in at least one of the five largest IP offices, provided that another family member has been filed in any other office worldwide (see Dernis et al., 2015 for further discussion of IP5 families).

[16] See Inaba, T. and Squicciarini, M. (2017). ICT: A new taxonomy based on the international patent classification", OECD Science, Technology and Industry Working Papers, 2017/01, http://dx.doi.org/10.1787/ab16c396-en.

[17] The claims define what the patent legally protects.

located in the rest of the world file more than 50% percent of their patents in ICT-related technologies. This high share is partly due to the specialisation of Korean companies, and Samsung in particular, which is by far the company with the highest number of patent families during the period considered (see Daiko et al., 2017 and Table 7.2 later in this chapter). Companies headquartered in the US, Japan and EU present lower shares of ICT-related technologies in their patent portfolio (37, 33 and 24 percent respectively).

Once assessed the overall importance of ICT-related technologies in different areas, we shift to the specialisation profiles of each geographical area across specific digital technologies. Table 7.1 shows ICT-related technological advantages in different digital subfields for the EU and the other major world areas. For this purpose, we compute an ICT-based technological specialisation index or $ICT\text{-}RTA_{ij}$:

$$ITC - RTA_{ij} = \frac{subict_{ij} / \Sigma_j \, subict_{ij}}{\Sigma_i \, subict_{ij} / \Sigma_{ij} \, subict_{ij}}$$

The numerator represents the share of ICT patents in subfield *j* over the total ICT patents of the region *i*, whereas the denominator represents the share of subfield *j* among the whole ICT patents. Values of ICT-RTA above 1 indicate a relative specialisation of the geographical area in the given ICT subfield, while for values lower than one reflect a relatively de-specialisation in that ICT sub-field.

Table 7.1 shows distinct patterns of ICT specialisation across world's regions. US- and EU-headquartered *Scoreboard* companies have the broadest profile in terms of relative specialisation within ICTs technologies. On the other side of the spectrum, Japanese companies show a very much focused specialisation profile. Indeed, they are relatively specialised in *Cognition and meaning understanding* (as US and EU companies), and *Imaging and sound technology* and *Information communication device* (as companies located in the Rest of the world).

Technology	EU	US	JP	RoW	CN
High speed network	1.42	1.36	0.72	0.72	1.58
Mobile communication	1.60	1.22	0.62	0.84	1.64
Security	1.63	1.42	0.74	0.64	1.29
Sensor and device network	2.07	0.99	0.78	0.92	0.50
High speed computing	0.77	1.76	0.82	0.77	0.82
Large-capacity and high speed storage	0.60	1.06	0.97	1.32	0.33
Large-capacity information analysis	1.34	1.69	0.78	0.54	1.17
Cognition and meaning understanding	1.08	1.08	1.19	0.75	0.79
Human-interface	0.51	0.65	0.82	1.59	1.34
Imaging and sound technology	0.71	0.63	1.40	1.02	0.76
Information communication device	0.80	0.63	1.20	1.20	0.75
Electronic measurement	2.75	1.38	0.78	0.44	0.18
Others	0.37	0.82	1.31	1.20	0.44

TABLE 7.1: TECHNOLOGICAL SPECIALISATION IN ICT SUB-FIELDS BY SELECTED WORLD'S REGIONS.
Note: Patents counts refer to the number of fractionally counted patent families.
Source: JRC/OECD COR&DIP© database. v.1. 2017.

EU-, US- and China-based top R&D investors show close specialisation profiles within ICT technologies. As illustrated in Table 7.1, the three economies are specialised in ICT subfields such as *High-speed network*, *Mobile communication*, *Security,* and *Large capacity information analysis*. In addition, EU- and US-headquartered R&D performers also present above-one $ICT\text{-}RTA_{ij}$ values in *Electronic measurement*, while this holds true for China in *Human interface*. EU-based companies shows, overall, the only specialisation in the development of technologies related to *Sensor and device network.*

7.2 | Top 10 ICT-patenting companies in selected ICT-oriented sectors

Do companies operating in different sectors target the development of specific technologies? In this section, statistics are broken down at the industry level in order to see in which ICT subfields top patenting companies are focusing their innovative efforts.

For these purposes, Table 7.2 reports the top 10 ICT patenting companies in a number of key sectors. For each company we report the total number of patents families filed over the period considered, the share of patents in ICT related technologies and the 3 ICT subfields where they file the highest number of patents.

Clearly, companies operating in ICT sectors (Software and Computer Services, Technology Hardware and Equipment and Electronic and Electrical Equipment) show very high concentration of patents in digital technologies; this share is close to 100% for companies such as SAP, Facebook, Autonavi and Ericsson. Among the non-ICT sectors considered, the Aerospace and Defence stands out in terms of digital patenting compared to Automobile & Parts and Pharmaceuticals & Biotechnology.

Overall, *Large-capacity and information analysis* and *High speed networks* are the ICT subfields that are the most frequently target by top corporate R&D investors. This highlights the importance of developing competences in big data analytics and data handling and transmission in the digital era. In particular, *Large-capacity and information analysis* appears often as the first subfield designated in industries such as Pharmaceuticals and Biotechnology and Software and computers services.

Besides these two ICT subfields, the companies considered in the present chapter often focus their digital patenting activities on *Information and communication device*; this is quite straightforward for companies operating in Electronic and Electrical equipment that mainly develop physical devices. These latter companies also dedicate much effort in the development of *Image and sound technology* subfield and to *Human-interface technologies* subfields. These technologies are key for the interactions between the digital and physical worlds.

Other important ICT subfields include *High speed network, Mobile communication, Electronic measurement, Cognition and meaning understanding* and *Security*. For instance, *High speed network* often feature among the top ICT subfields in industries such as Technology hardware and equipment and Software and computer services, as well as Automobiles and Parts. *High speed network* coupled with *Large-capacity and information analysis* are essential for real time data transmission and processing, like the ones needed for example in autonomous and connected cars. These two technologies, together with *Electronic measurement* appear to be very important also for companies in the Aerospace and Defence industries.

Rank	Company name	Country	category1	category2	category3	Patents	ICT share
Aerospace & Defence							
209	THALES	FR	High speed network	Electronic measurement	Information communication device	668	60%
615	IAI	IL	Information communication device	Mobile communication	Electronic measurement	55	54%
344	GENERAL DYNAMICS	US	Mobile communication	High speed network	Large-capacity information analysis	58	39%
1679	TRANSDIGM	US	Large-capacity information analysis	High speed network	High speed computing	61	37%
436	BAE SYSTEMS	GB	Information communication device	Electronic measurement	High speed network	261	34%
77	FINMECCANICA	IT	Electronic measurement	High speed network	Mobile communication	82	26%
52	BOEING	US	Large-capacity information analysis	Information communication device	High speed network	1475	26%
31	AIRBUS	NL	Large-capacity information analysis	High speed network	Electronic measurement	1857	15%
90	SAFRAN	FR	Security	Cognition and meaning understanding	Imaging and sound technology	1099	12%
57	UNITED TECHNOLOGIES	US	High speed network	Information communication device	Large-capacity information analysis	3517	3%
Automobiles & Parts							
276	HYUNDAI MOBIS	KR	Electronic measurement	Imaging and sound technology	Cognition and meaning understanding	839	20%
43	DENSO	JP	High speed network	Information communication device	Large-capacity information analysis	3351	19%
56	CONTINENTAL	DE	High speed network	Imaging and sound technology	Cognition and meaning understanding	1312	14%
17	ROBERT BOSCH	DE	High speed network	Information communication device	Electronic measurement	4727	13%
79	HYUNDAI	KR	Human-interface	Imaging and sound technology	Information communication device	3431	12%
11	GENERAL MOTORS	US	Large-capacity information analysis	Cognition and meaning understanding	Imaging and sound technology	3091	12%
1	VOLKSWAGEN	DE	Human-interface	Large-capacity information analysis	High speed network	2037	10%
9	TOYOTA	JP	Information communication device	Large-capacity information analysis	High speed network	4226	8%
20	HONDA	JP	Cognition and meaning understanding	Large-capacity information analysis	Imaging and sound technology	2488	7%
13	FORD	US	Large-capacity information analysis	High speed network	Human-interface	1769	7%
Pharmaceuticals & Biotechnology							
1486	TOWA PHARMACEUTICAL	JP	Information communication device	Imaging and sound technology		59	39%
69	MERCK DE	DE	Information communication device	Large-capacity information analysis	Others	258	15%
12	MERCK US	US	Information communication device	Imaging and sound technology	Large-capacity information analysis	511	10%
379	BIOMERIEUX	FR	Large-capacity information analysis	Large-capacity and high speed storage	Cognition and meaning understanding	53	8%
7	ROCHE	CH	Large-capacity information analysis	Cognition and meaning understanding	Security	804	5%
110	ABBOTT LABORATORIES	US	Large-capacity information analysis	High speed computing	Security	255	5%
8	JOHNSON & JOHNSON	US	Large-capacity information analysis	Imaging and sound technology	Information communication device	1277	3%
19	SANOFI	FR	Large-capacity information analysis	Imaging and sound technology	Human-interface	488	3%
29	BAYER	DE	Large-capacity information analysis	Large-capacity and high speed storage	Information communication device	706	2%
5	NOVARTIS	CH	Information communication device	Human-interface	Large-capacity information analysis	494	1%

TABLE 7.2: TOP 10 PATENTING COMPANIES IN KEY INDUSTRIES.
Source: JRC/OECD COR&DIP© database, v.1. 2017.

Rank	Company name	Country	category1	category2	category3	Patents	ICT share
Software & Computer Services							
50	SAP	DE	Large-capacity information analysis	High speed computing	High speed network	288	99%
55	FACEBOOK	US	Large-capacity information analysis	High speed network	Human-interface	233	98%
1310	AUTONAVI	CN	Large-capacity information analysis	High speed network	Security	580	98%
132	TENCENT	CN	High speed network	Large-capacity information analysis	Human-interface	1562	97%
3	MICROSOFT	US	High speed computing	Human-interface	Large-capacity information analysis	1595	94%
25	IBM	US	High speed computing	Large-capacity information analysis	High speed network	3248	91%
1885	TATA CONSULTANCY SERVICES	IN	Large-capacity information analysis	High speed computing	Security	294	91%
6	GOOGLE	US	Large-capacity information analysis	Imaging and sound technology	Human-interface	1166	86%
84	FUJITSU	JP	High speed network	High speed computing	Information communication device	5471	82%
137	NEC	JP	High speed network	Mobile communication	High speed computing	1582	82%
Technology Hardware & Equipment							
28	ERICSSON	SE	Mobile communication	High speed network	Imaging and sound technology	2121	98%
83	ZTE	CN	High speed network	Mobile communication	Imaging and sound technology	1524	95%
41	NOKIA	FI	Mobile communication	High speed network	Imaging and sound technology	1540	90%
23	QUALCOMM	US	Mobile communication	High speed network	Imaging and sound technology	3259	90%
4	INTEL	US	High speed network	High speed computing	Mobile communication	2507	89%
98	SK HYNIX	KR	Large-capacity and high speed storage	Information communication device	High speed network	2229	89%
40	HEWLETT-PACKARD	US	High speed network	Mobile communication	High speed computing	2985	84%
78	TAIWAN SEMICONDUCTOR	TW	Information communication device	Large-capacity and high speed storage	Large-capacity information analysis	2110	73%
58	CANON	JP	Imaging and sound technology	Others	Information communication device	10031	44%
172	RICOH	JP	Imaging and sound technology	Others	High speed network	3774	42%
Electronic & Electrical Equipment							
724	JAPAN DISPLAY	JP	Information communication device	Imaging and sound technology	Human-interface	958	81%
611	BOE TECHNOLOGY GROUP	CN	Information communication device	Imaging and sound technology	Human-interface	2478	75%
2	SAMSUNG	KR	Information communication device	Imaging and sound technology	Human-interface	21685	73%
394	AU OPTRONICS	TW	Information communication device	Imaging and sound technology	Human-interface	1135	69%
126	SHARP	JP	Information communication device	Imaging and sound technology	Mobile communication	1393	68%
94	HON HAI PRECISION INDUSTRY	TW	Information communication device	Human-interface	Imaging and sound technology	5235	45%
272	KYOCERA	JP	Imaging and sound technology	Human-interface	Mobile communication	2585	43%
112	FUJIFILM	JP	Imaging and sound technology	Information communication device	Others	4132	35%
95	MITSUBISHI ELECTRIC	JP	Information communication device	High speed network	Imaging and sound technology	3247	33%
51	HITACHI	JP	Information communication device	High speed network	Large-capacity and high speed storage	5350	29%

TABLE 7.2: TOP 10 PATENTING COMPANIES IN KEY INDUSTRIES.
Source: JRC/OECD COR&DIP© database, v.1. 2017.

7.3 | Geographical location of ICT versus non-ICT technological development

This section focuses on the geographical location patterns of inventive activities. It overviews the location patterns of top R&D investors and looks at the broad differences that emerge in the geography of ICT and non-ICT inventive activities.

Tables 7.3 show the applicant headquarters location (in row) and the distribution across inventor locations (in column) of the ICT and non-ICT patents (top and bottom panels respectively). The diagonal shows the extent to which top corporate R&D investors prefer the headquarters to locate their inventive activities. Commonly known as the home-bias, this tendency seems to be more pronounced for companies based in Japan, China and RoW, while it appears to be less frequent for EU- and US-based R&D performers. In relative proportions, for ICT this concerns around one forth of EU-made inventions and one third of US-made inventions. In non-ICT fields, the phenomenon is slightly less pronounced, with at least 20% of EU and 25% of US-made inventions relying on inventors located abroad.

ICT

		Inventor Region				
		EU	US	JP	CN	RoW
Region	EU	76.51%	13.11%	0.74%	3.58%	6.06%
	US	12.14%	66.69%	2.72%	8.29%	10.16%
	JP	2.24%	2.79%	93.19%	0.94%	0.84%
	CN	1.20%	4.31%	0.73%	90.58%	3.17%
	RoW	1.88%	3.85%	1.07%	6.38%	86.81%

non-ICT

		Inventor Region				
		EU	US	JP	CN	RoW
Region	EU	79.08%	13.95%	1.00%	1.41%	4.57%
	US	15.09%	73.21%	1.32%	2.13%	8.24%
	JP	1.55%	1.97%	95.64%	0.25%	0.59%
	CN	3.52%	3.00%	1.43%	90.27%	1.79%
	RoW	8.22%	4.73%	1.63%	7.73%	77.69%

TABLE 7.3: MATRIX OF PATENT APPLICANT-INVENTOR LOCATION, SELECTED WORLD'S REGIONS.
Note: Patents counts refer to the number of fractionally counted patent families.
Source: JRC/OECD COR&DIP© database. v.1. 2017.

Looking at the most frequent foreign locations, US often come up as the top location for ICT and non-ICT patents. Nevertheless, in non-ICT fields, EU seems to be preferred to the US for the location of inventive activities of China- and RoW-headquartered R&D investors. Noteworthy, more than 20% of US patenting in ICT (above 16% in non-ICT) rely on inventors located in RoW. Their second preferred foreign location is EU for more than one tenth of their patent portfolio. This later economy also relies importantly on inventors located in RoW; that concerns about 10% of EU-owned patents in ICT and also non-ICT.

Focusing on differences in ICT versus non ICT, EU companies seem to behave in a similar fashion, as shown by the distributions of shares across inventors' locations in ICT or non-ICT (EU in row). Differently from EU and Japanese firms, US, and to a much lesser extent, China shows a few differences across ICT and non-ICT. For instance, US-based companies rely in much lower proportions to China-located inventors for their non-ICT inventions. The related difference comes from a greater reliance to home- and EU-located inventors for non-ICT patents.

Figure 7.2 further details the geographical distribution of ICT patents' applicants and inventors. The top panel displays a network graph connecting the HQ locations of inventors to that of the applicants at the world level. The bottom panel focuses on the digital patenting of the EU28 both in terms of applicants and of inventors.

The size of the circles relates to the number of patents when only inventor-located countries are considered: the bigger is the circle of an area, the greater is the number of patents with inventors located in the given area. The colour of the circle reflects the number of patents from applicants that are located in the selected area (owned here *versus* invented here): the darker is the circle, the higher is the number of patents with applicants located in the area of interest. Only countries (regions in the case of

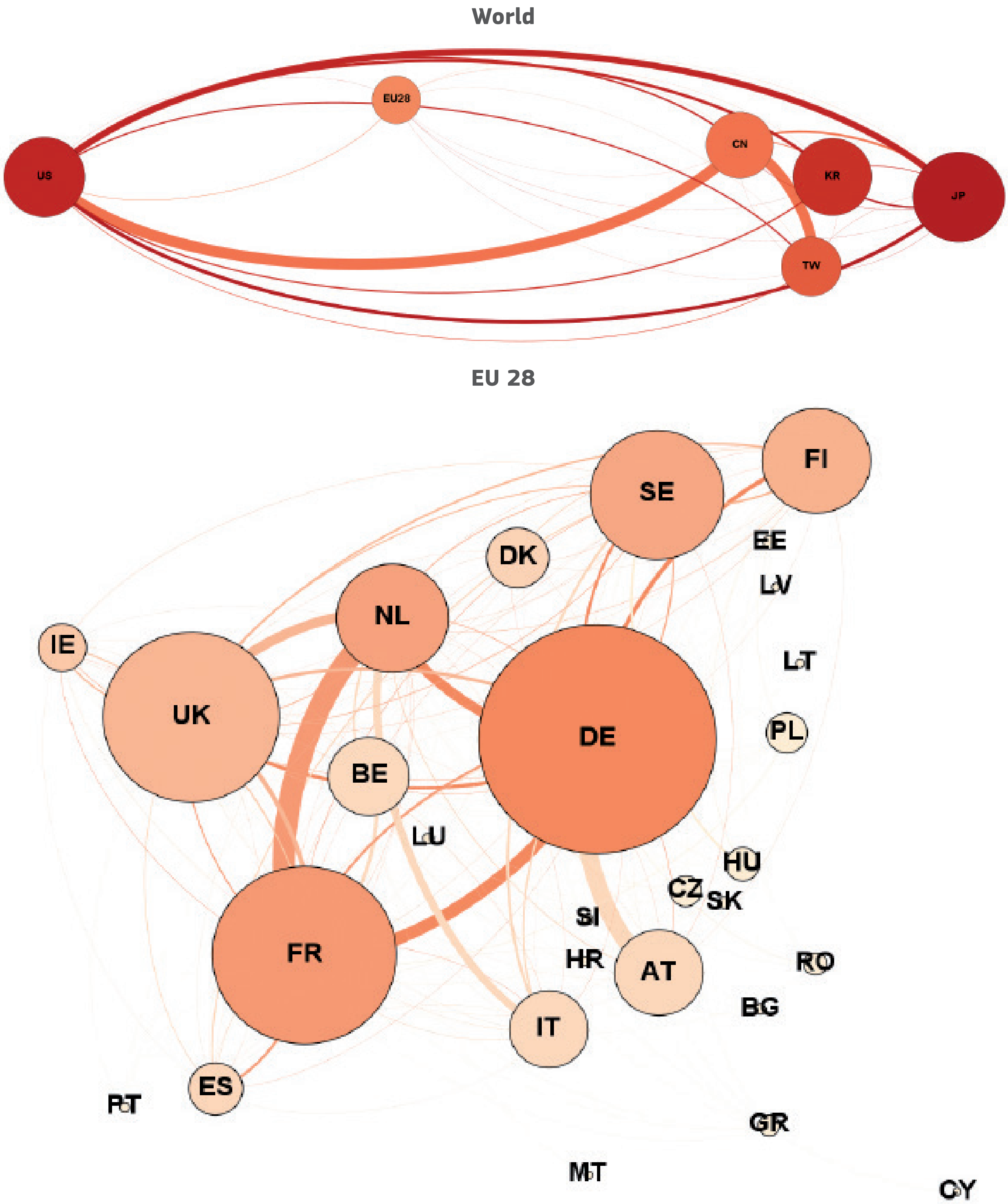

FIGURE 7.2: APPLICANT-INVENTOR LOCATIONS FOR THE DEVELOPMENT OF DIGITAL TECHNOLOGIES.
Source: JRC/OECD COR&DIP© database, v.1. 2017.

the EU) "owning" at least 3500 ICT related paten families were considered in the world network of ICTs. In addition self- edges were omitted.

Overall, US, Japan-, Korea-, and to a lesser extent, China-, EU- and Taiwan-based top corporate R&D investors clearly lead the development of ICT-related inventions at the world level. Looking at the two extreme cases, China stands out as an "inventor location" (lighter circle) rather than an applicant one, whilst US owns a great part of new digital technologies and, at the same time, plays a key role in their development or invention (inventors' location, circle size). For economies like the EU28 or Korea, the differences are less salient, as illustrated by the lighter colour of the related circles (Figure 7.2, top panel).

As illustrated in the bottom panel, all EU28 countries appear to be active in the development of ICT technologies, to different extent depending on HQ locations and on the applicants' vs. inventors' locations. This EU28-centered graph shows that Germany, France and the UK lead the inventive activities in digital technologies in the continent (the biggest circles); while Germany, France, the Netherland and Austria are countries with larger applicant-inventor patent flows (the thickest lines). These represent a cluster with high connectivity within the EU.

Looking again at the extremes of the spectrum, the UK seems to stand rather as an inventor location (the lightest circle), while the Netherlands exhibits important differences with a relatively higher proportion of applicants (the darkest circle) within the EU, as compared to the number of inventors that are based in the country. Other European economies such as France, Sweden, Finland, and to a lesser extent, Germany, Belgium, Austria and Italy feature relatively fewer differences when their role as applicants' location and inventors' location are compared.

8

SCIENTIFIC PUBLICATIONS **BY COMPANIES' AFFILIATE AUTHORS**

8 Scientific publications by companies' affiliate authors

This chapter presents results of an exercise[16] aiming to explore the publication activity carried out by authors affiliated to the Scoreboard *companies and their subsidiaries. We collected and analysed data on articles authored by affiliated to* Scoreboard *companies (and their subsidiaries) published in in peer reviewed journals in the period 2011-2015.*

Key points

- Article publication in peer reviewed journals is a widespread phenomenon among top R&D investors. Engaging in scientific publications does not seem to be a choice of a few firms, but quite common among firms actively engaged in R&D.
- It seems than corporate publishing is not only a prerogative of science-based sectors such as Pharmaceutical, Biotechnology and Chemistry, but it is widespread across sectors.
- If we consider the quality of publications (proxy by the number of citations), about 12% of these articles are within the top 10% cited articles in the corresponding research areas.
- Overall, collaboration with academia is extremely frequent. In the whole sample, 58% of publications are co-authored with one or more university based authors. Many of the sectors that collaborate the most with academia are low R&D intensity sectors. This may suggest some sort of knowledge seeking activity of firms in these sectors, reaching out to universities to source knowledge they don't have inside their boundaries.
- There is a positive correlation between a firm's R&D expenditure and the number of publications to which the firm contributed.

8.1 | Introduction

The number of publications in peer-reviewed journals is an increasingly used output indicator to evaluate the research activity of both individuals and organisations. While it's quite common to have studies on the publication output of academics and universities, publications at firm level have been rarely investigated. Having access to the data on the papers published by authors affiliated to the *Scoreboard* companies (through their headquarters or their subsidiaries) can help us to:

- have an additional output indicator to measure the results of the R&D investments done by *Scoreboard* companies;
- understand sectoral differences in terms of publication behaviour of top R&D investors companies;
- better understand the spillovers of the R&D investment analysing the firm-university collaborations;

[16] Full report available at (last access 30 Oct 2017): http://iri.jrc.ec.europa.eu/documents/10180/948317/Scientific%20Publication%20Activity%20of%20Scoreboard%20Companies.

- better characterise the location of the firm knowledge production activity by looking at the authors' affiliations address.

The data presented in the chapter represents the results of a joint study JRC- UNIT B.3 – SPRU (Science Policy Research Unit - University of Sussex). We collect data on the publication activity of the top 2,500 worldwide companies in terms of R&D investments (as listed in the "2014 EU Industrial R&D Investment Scoreboard"), including also around 570,000 subsidiaries of these companies, for the period 2011-2015. In order to identify publications authored by firms (including their subsidiaries) in our sample, we searched for firms' names in authors' affiliation addresses listed in publication data. Individual queries were built for all the 2,500 groups and downloaded the data from the Web of Science (WoS) by Thomson Reuters. After several round of data cleaning and queries redefinition, we end up with a final dataset of publications included 342,862 publications, including full bibliographic details and citations. We managed to retrieved data for 2,088 out of the top 2,500 worldwide companies R&D investing companies.

8.2 | Overall publication activities

Figure 8.1 shows the number of scientific publications produced in the top 15 sectors (in terms of number of publications). While the top publishing sectors comprise the 'usual suspects' (e.g. Pharmaceuticals & Biotechnology, and Chemicals), these also include some less expected sectors such as Electronic & Electrical Equipment and Software and Computer Services.

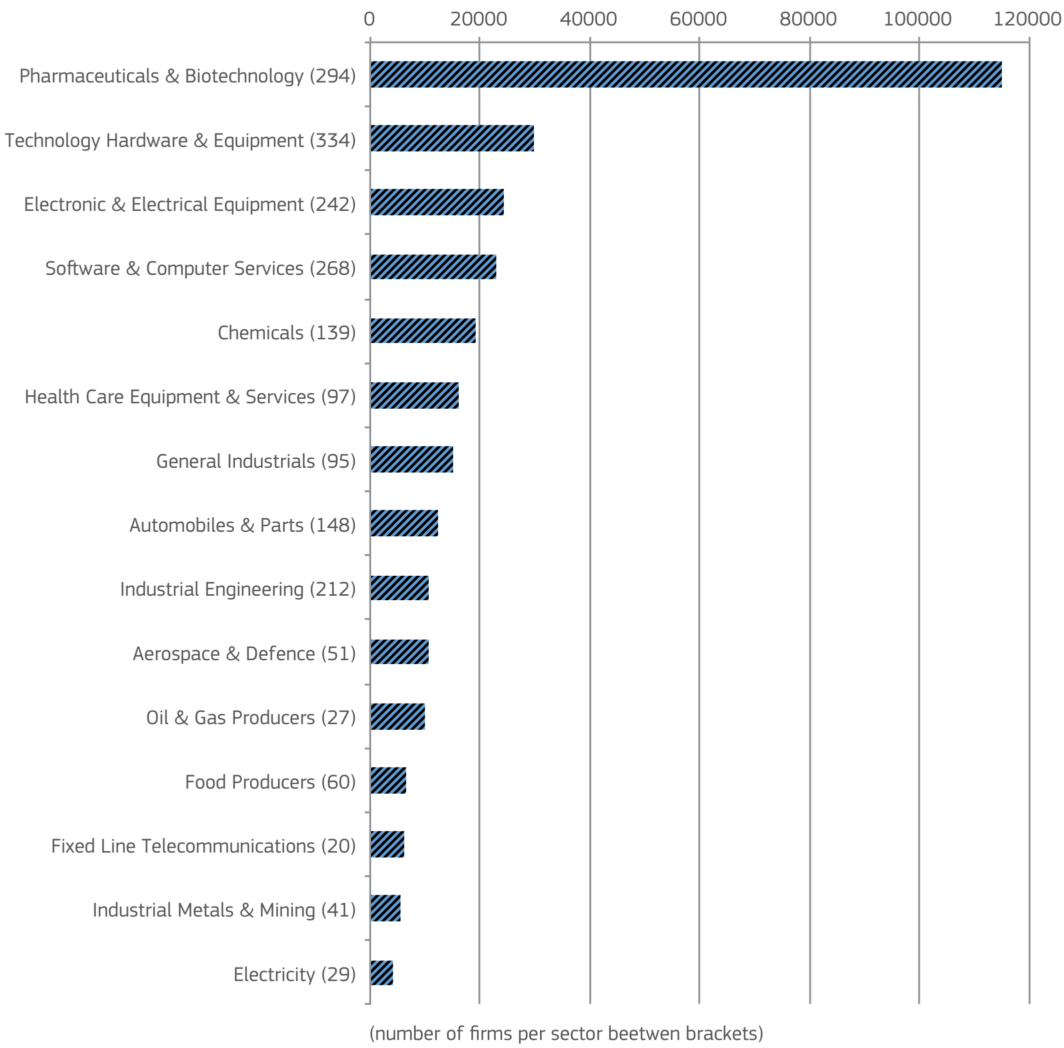

FIGURE 8.1: NUMBER OF PUBLICATIONS (2011-2015) - TOP 15 SECTORS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

The publication activity does not seem to be a prerogative of a few firms, but quite common among firms actively engaged in R&D. If we consider all the 40 ICB3 sectors in our sample, each of them features some publication activity.

Focussing on the top 15 sectors, no less than 80% of the firms in each of them produced at least one publication in the observation period (Figure 8.2). The only notable exception is the Software and Computer Services Sector, where the percentage of publishing firm is in fact lower (58.6%). It seems than corporate publishing is not only a prerogative of science-based sectors such as Pharmaceutical, Biotechnology and Chemistry, but it is widespread across sectors.

Moreover, the diffuse nature of the publication activity in the sample is confirmed looking at concentration indexes at sector level.

Apart from five sectors[17], the value of the C4[18] index in the 15 top publishing sectors is below 50%. Finally, the average number of publications per corporate (headquarter + all its subsidiaries) varies greatly across sectors, ranging from just few publications to more than 400 (Figure 8.3). However, also inside each sector there is a huge difference among firms (as suggested by the standard deviation values between brackets).

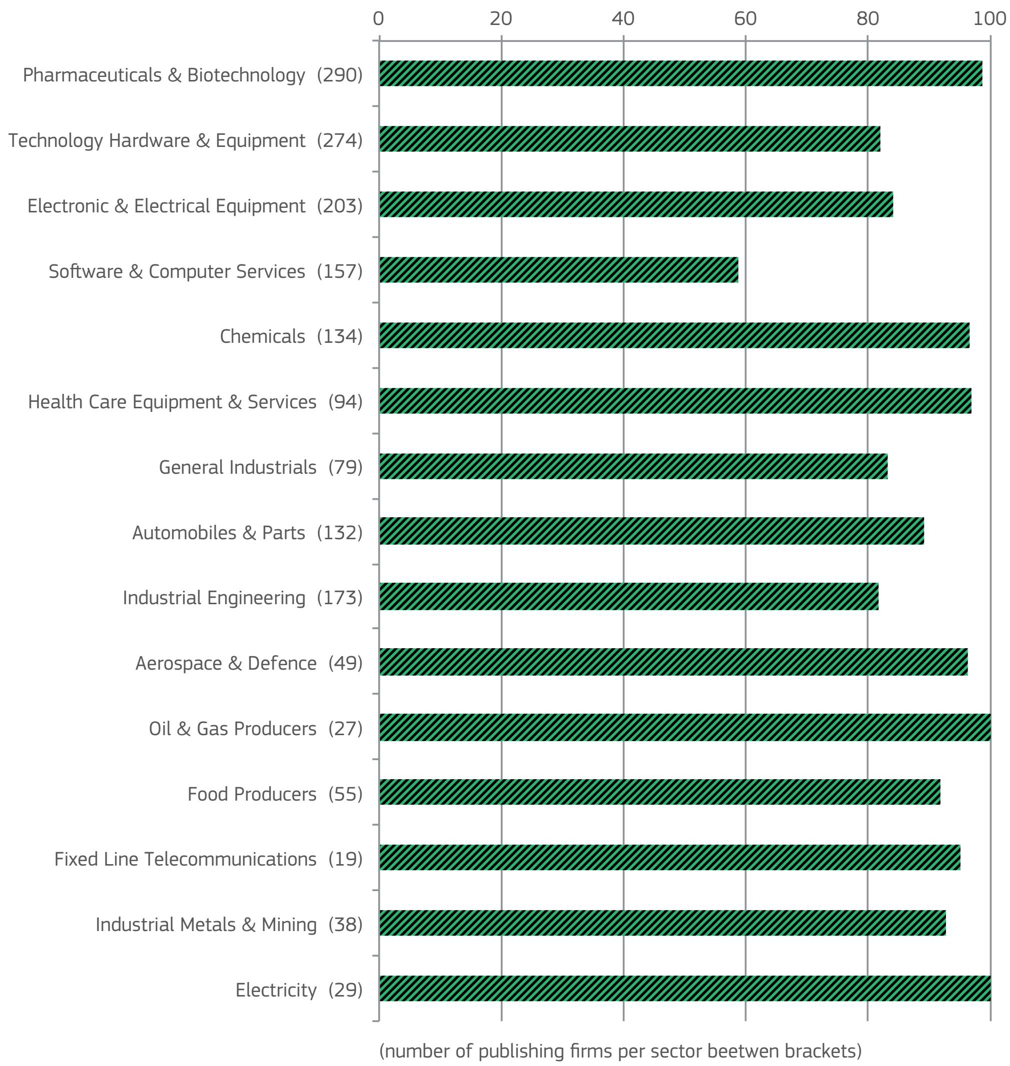

FIGURE 8.2: PERCENTAGE OF PUBLISHING FIRMS (2011-2015) - TOP 15 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

[17] Namely "Software & Computer Services"; "General Industrials"; "Food Producers"; "Fixed Line Telecommunications"; and "Electricity".
[18] C4 is a concentration index and its equals to the share of total publications for which the top 4 publishing firms in each sector are responsible.

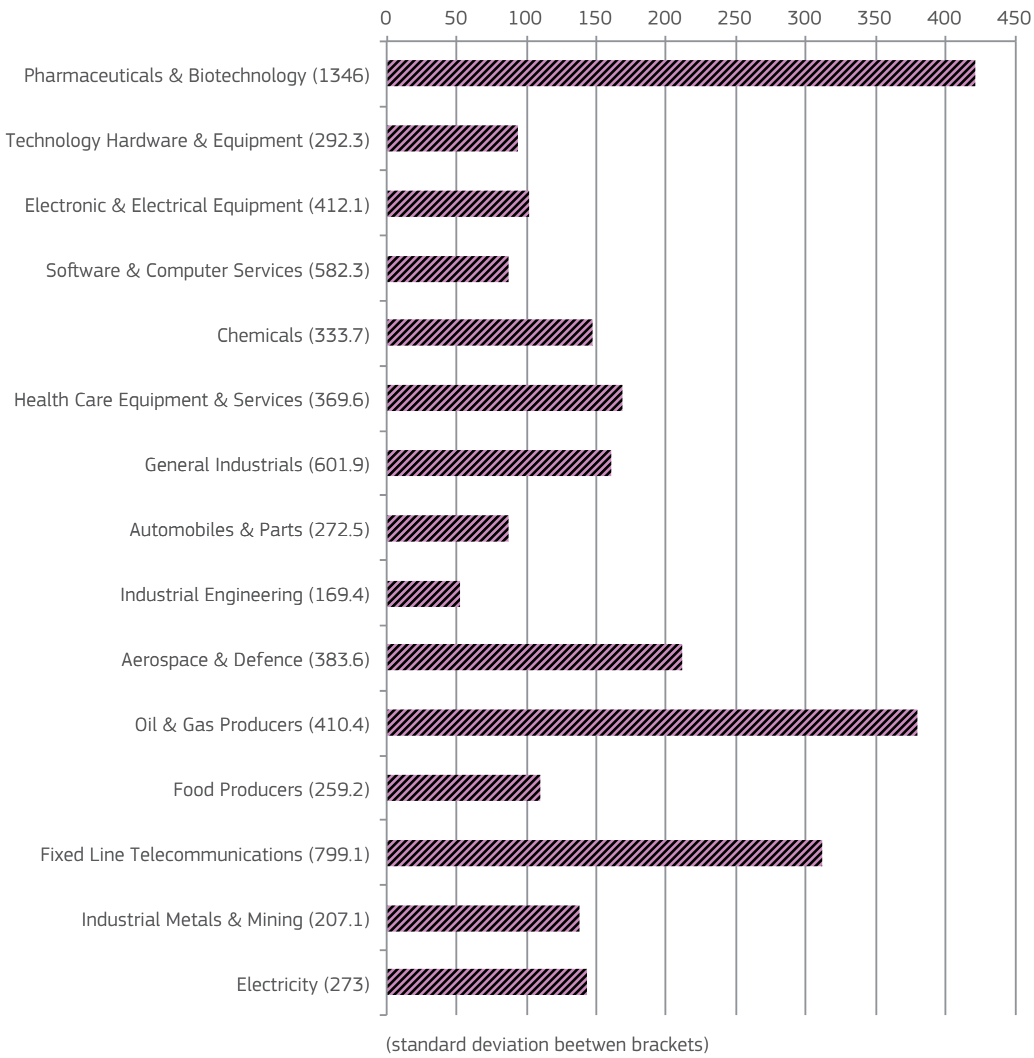

FIGURE 8.3: AVERAGE NUMBER OF PUBLICATIONS PER FIRM BY SECTOR (2011-2015) - TOP 15 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

In addition to looking at the data from a sectoral perspective, we can aggregate them according to where the *Scoreboard* headquarters of the publishing company are located.

Figure 8.4 reports the shares of the total number of publications per sector in five distinct geographical areas: EU, US, Japan, China and Rest of the World (RoW).

EU and US based companies are responsible for the bulk of the publications (69.8 combined share), which does not come as a surprise, consider they account jointly for 66.1% of the R&D in 2013.

Figure 8.5 disaggregates the data by sector and by region (for the top 5 publishing sector). In the Pharmaceuticals & Biotechnology sector, US and EU based companies jointly account for about 75% of the publications, while in the Electronic and Electrical Equipment and Chemicals the shares are more evenly distributed.

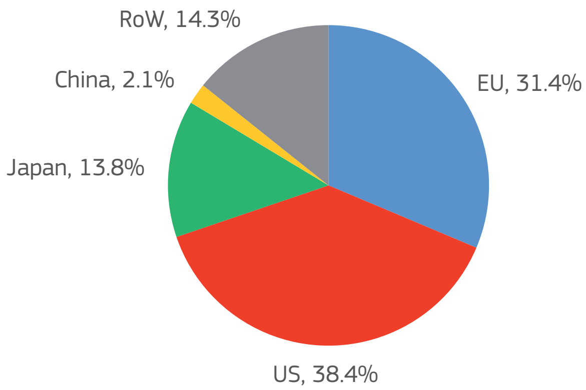

FIGURE 8.4: SHARE OF TOTAL NUMBER OF PUBLICATIONS BY REGION (2011-2015).
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

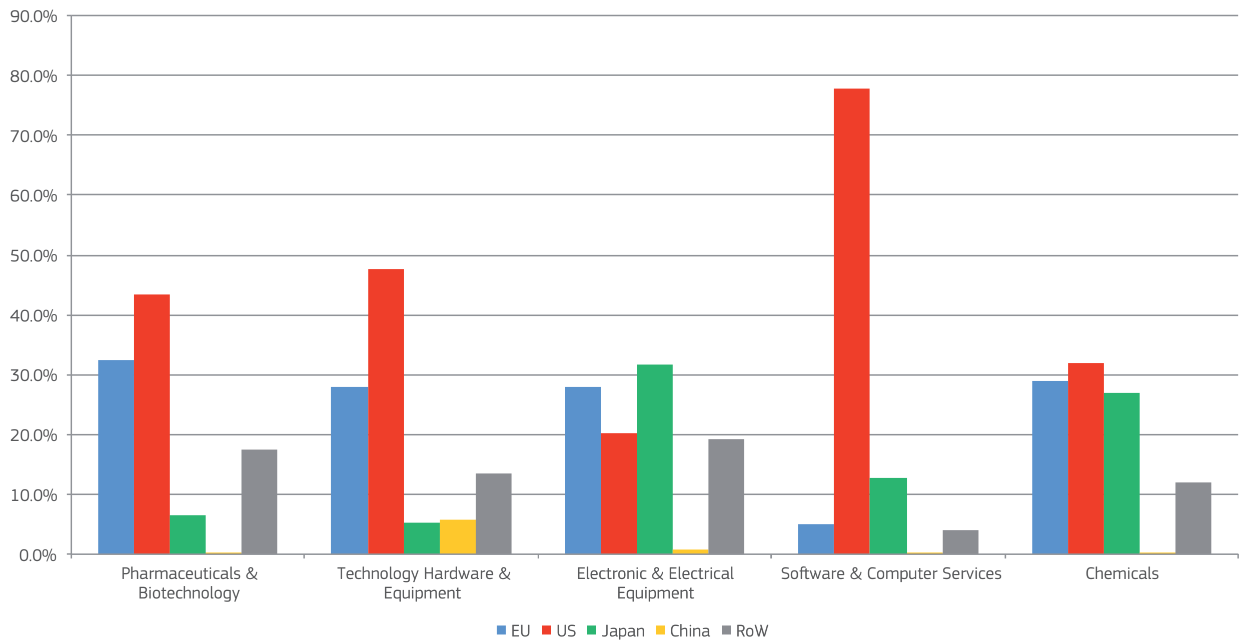

FIGURE 8.5: SHARE OF TOTAL NUMBER OF PUBLICATIONS BY SECTOR BY REGION (2011-2015) – TOP 5 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

Not surprisingly, US based companies have the lion's share in terms of publication in ICT related sectors, also given the high number of US companies in these sectors. The distribution is particularly skewed in the case of the "Software and Computer Services" sector, where US based companies account for almost 80% of all the publications.

8.3 | Quality of the research and collaboration with academia

The overall number of publication does not tell us much about the quality of the scientific output produced. To have a better understanding of it, we isolated in the sample the most cited publications, assuming number of citations as a proxy of the relevance/quality of a scientific output. More specifically, we first isolated the sample of articles published on peer reviewed journal. Of the 314,411 distinct publication records to which firms in our sample contributed, about 62% (i.e. 194,679 records) are articles. About 12% of these articles are within the top 10% cited articles in the corresponding research areas (defined on the basis of the WoS categories) and year of publication. Figure 8.6 reports the percentage of highly cited articles in the top 15 sectors in terms of overall publication activity.

The rank is not exactly the same as in Figure 8.1. "Pharmaceuticals & Biotechnology" still ranks first, but now is followed by "Health Care Equipment & Services", "Software & Computer Services" and "Food producers", all sector s with more than 10% of their articles that are highly cited, i.e. relevant.

Figure 8.7 gives us some insides on the collaboration activity (though publications) of firms in our sample by showing the average number of authors per publication by sector plus the number of distinct countries in which authors are located (between brackets). Collaborations and co-authoring seems to be extremely common, with the average number of authors ranging from 5 to 8.4.

These co-authorships, however, vary significantly within sectors.

In the top 15 publishing sectors, "Pharmaceuticals & Biotechnology", "Health Care Equipment & Services" and "Food producers" are those with the highest number of authors per publication. Not surprisingly, the first two sectors are also those with the highest number of countries the

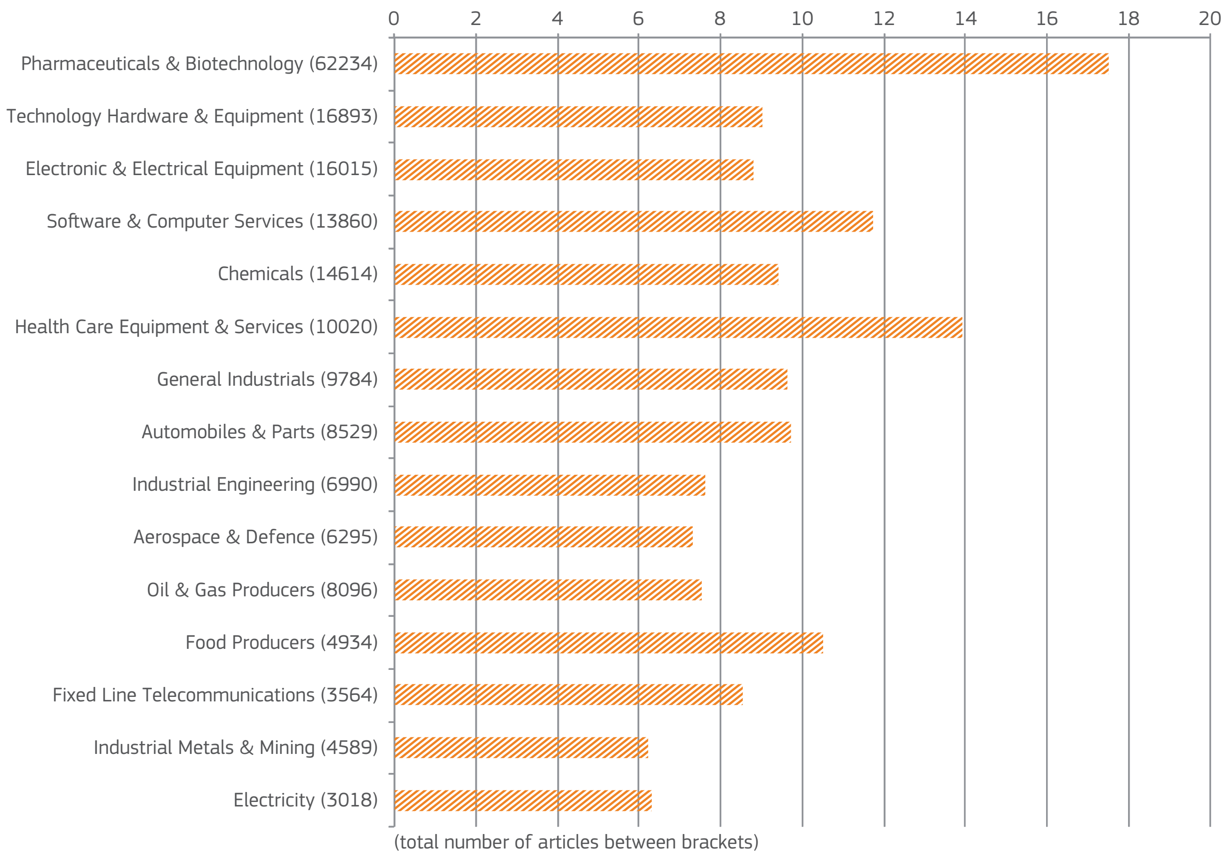

FIGURE 8.6: ARTICLES IN TOP 10% CITED (%) BY SECTOR (2011-2015) - TOP 15 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

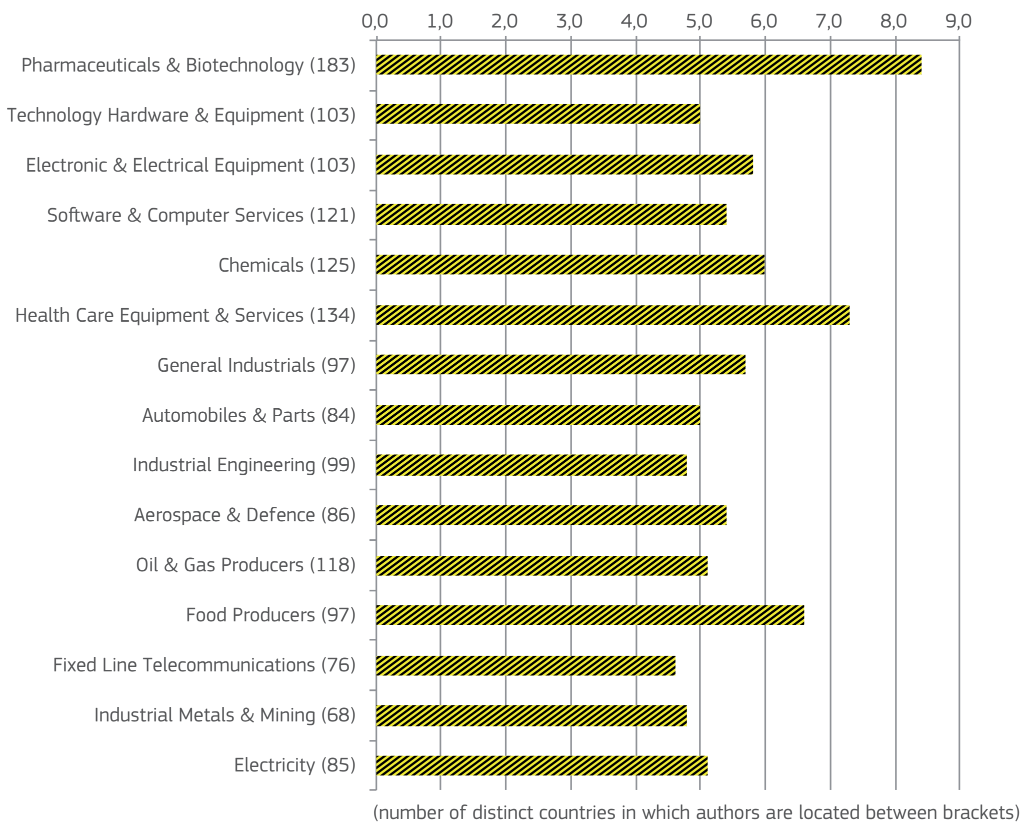

FIGURE 8.7: AVERAGE NUMBER OF AUTHORS PER PUBLICATION BY SECTOR (2011-2015) - TOP 15 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report

FIGURE 8.8: PUBLICATIONS WITH ACADEMIA (%) BY SECTOR - TOP 15 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.
Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

number of distinct countries in which the affiliations listed in *Scoreboard* firms' publications are located (181 and 134 respectively).

Once established that these firms do collaborate with other organisations to produce their knowledge, next question would be with whom they collaborate with. Figure 8.8 gives an initial reply by showing the percentage of co-authored publications with academia. Of the 342,862 publication-firm records in our sample, about 9% of these are co-authored by two or more firms (or subsidiaries of distinct firms) in our sample.

About 58% of the publications in our sample involved at least one academic institution. For the most prolific 15 sectors, this percentage ranges between 43.6% (fixed Line Telecommunications) and 70.5% (Food producers). Among the 40 ICB3 sectors considered in the analysis, for only 5 there the percentage of their publications involving one or more universities is below 50%.

Interesting to notice, many of the sectors collaborating the most with academia are low R&D intensity sectors. This may suggest some sort of knowledge seeking activity of firms in these sectors, reaching out to universities to source knowledge they don't have inside their boundaries. It also true these sectors occupy the bottom part of the publication chart, meaning they don't publish a lot, and if they do it, it's in collaboration with other organisations.

8.4 | Correlation with R&D investment

Given we are dealing with a sample of world top R&D investors; it's interesting to explore if there is some correlation between the R&D invested and the amount of publications produced. Figure 8.9 depicts the scatter plot between a firm's R&D expenditure and their number of publications for the top 15 most active sectors in terms of total number of publications.

This analysis focuses on the 2011-2013 period (the 2014 *Scoreboard* provides information about *Scoreboard*

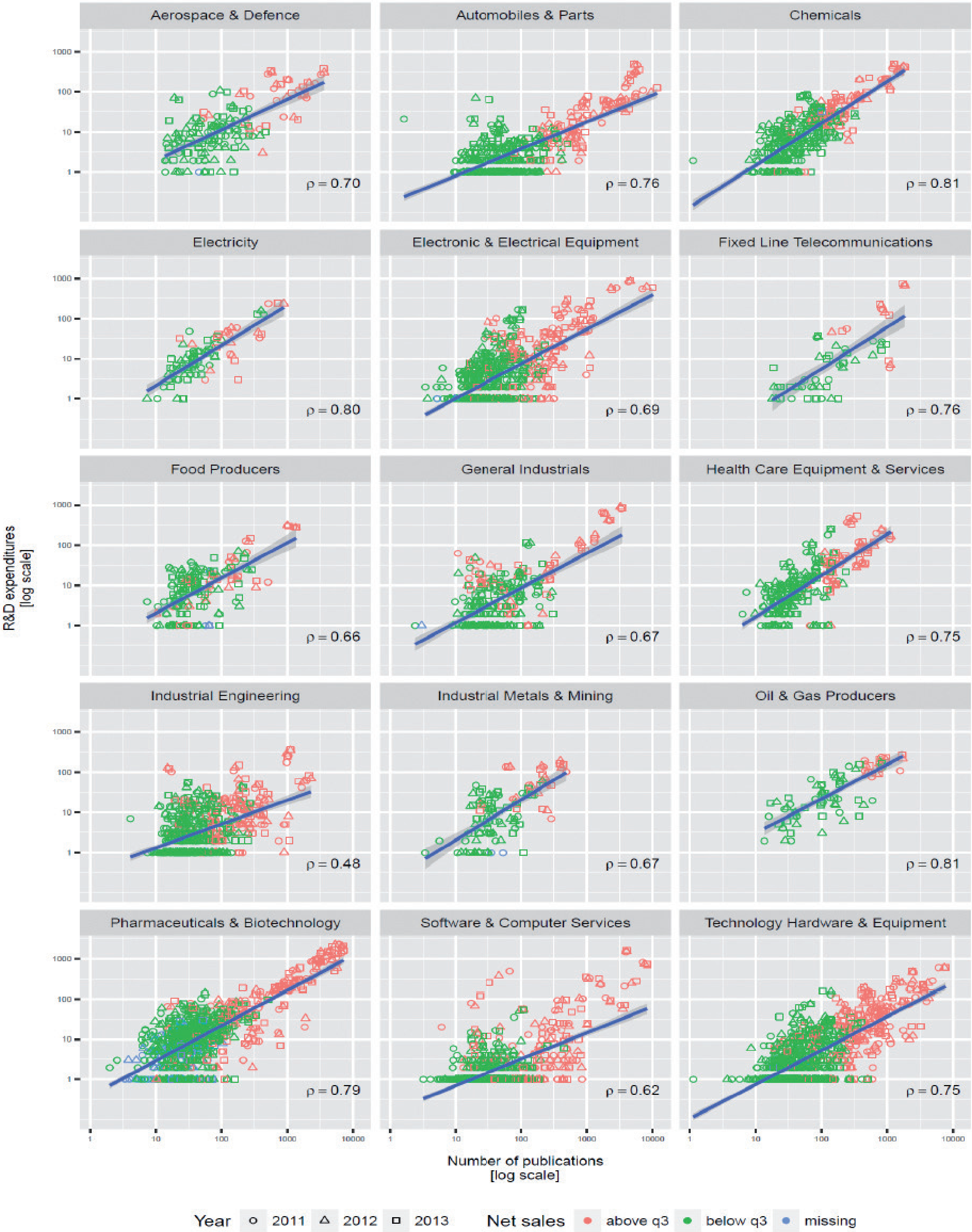

FIGURE 8.9: CORRELATION BETWEEN R&D AND PUBLICATIONS BY SECTOR (2011-2013) - TOP 15 SECTORS FOR OVERALL NUMBER OF PUBLICATIONS.

Source: "Scientific Publication Activity of Scoreboard Companies" – IRITEC technical report.

firms' R&D expenditure up to the end of the year 2013). Firm observations in Figure 8.9 are represented with different symbols and colours. While symbols represent firm-year observations (circles depict data for the year 2011, triangles data for the year 2012, and squares data for the year 2013), colours represent a firm's size. More specifically, we used firms' net sales in each year to define two groups of firms: "relatively large" firms (red colour) as those with net sales above the 3rd quartile of the net sales distribution of all firms in the same sector an year and "relatively small firms" (green colour) as those with net sales below the 3rd quartile of the net sales distribution of all firms in the same sector and year[19].

[19] We coloured symbols in blue when net sales data were missing.

ANNEXES

- **A1** – BACKGROUND INFORMATION
- **A2** – METHODOLOGICAL NOTES
- **A3** – COMPOSITION OF THE EU 1000 SAMPLE
- **A4** – 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[20] with a 3 % headline target for intensity of research and development (R&D)[21]. R&D investment from the private sector plays also a key role for other relevant Europe 2020 initiatives such as the Industrial Policy[22], Digital Agenda and New Skills for New Jobs flagship initiatives.

The Industrial Research and Innovation Monitoring and Analysis (IRIMA) project[23] 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[24]. 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 (BES-R&D) data, which are specific to a given territory[25] and include R&D carried out in that territory by companies headquartered and with their major operations in another territory. The *Scoreboard* data are primarily of interest to those concerned with benchmarking company commitments and performance (e.g. companies, investors and policymakers), while BES-R&D 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%[26] of worldwide R&D funded by the business enterprise sector and the *Scoreboard* data refer to a more recent period than the latest available official statistics. Furthermore, the dataset is extended to cover the top 1000 R&D investing companies in the EU.

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[20] 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.

[21] 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),

[22] 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.

[23] 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, Directorate Growth and Innovation (JRC-Seville; see: https://ec.europa.eu/jrc/en/science-area/innovation-and-growth).

[24] 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.

[25] The *Scoreboard* refers to all R&D financed by a company from its own funds, regardless of where the R&D is performed. BES-R&D 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 BES-R&D 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 (BES-R&D uses the percentage of R&D in value added, while the *Scoreboard* considers the R&D/Sales ratio).

[26] According to latest Eurostat statistics.

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 and in considering potential mergers and acquisitions.
- **Investors and financial analysts** can use the *Scoreboard* to assess 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 such as R&D tax incentives.

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 2017 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 2016 fiscal year accounts, although due to different accounting practices throughout the world, they also include accounts ending on a range of dates between late 2015 and mid-2017. 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 the 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 assigned to industry sectors according to the NACE Rev. 2[27] and the ICB (Industry Classification Benchmark). In the *Scoreboard* report we use different levels of sector aggregation, according to the distribution of companies' R&D and depending on the issues to be illustrated. In chapter 1, Tables 1.2 and 1.3 describe two typical levels of the industrial classification applied in the *Scoreboard*.

Limitations

Users of the *Scoreboard* data should take into account the methodological limitations, especially when performing comparative analyses (see summary of main limitation in Box A2.1 below).

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

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

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. There is a legal requirement to disclose R&D in company annual reports in some countries.

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 could be over-represented in the *Scoreboard*.

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

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. the R&D expenditures funded by the business enterprise sector (BES-R&D). 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. BES-R&D 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. BES-R&D 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 (BES-R&D uses the percentage of value added, while the *Scoreboard* measures it as the R&D/Sales ratio) and the sectoral classification they use (BES-R&D 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 a change in company accounting standards. For example, the first time adoption of IFRS[28], may lead to information discontinuities due to the different treatment of R&D,

[28] 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/).

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.

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 but will be removed for the following year's *Scoreboard*).

For companies outside the Euro area, all currency amounts have been translated at the Euro exchange rates ruling at *31 December 2016* as shown in Table A2.1. 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.

Table A2.1. Euro exchange rates applied to Scoreboard data for companies based in different currency areas (as of 31 Dec 2016).

Country	As of 31 Dec 2015	As of 31 Dec 2016
Australia	$ 1.49	**$ 1.46**
Brazil	4.25 Brazilian real	**3.43 Brazilian real**
Canada	$ 1.51	**$ 1.42**
China	7.07 Renminbi	**7.33 Renminbi**
Czech Republic	27.03 Koruna	**27.03 Koruna**
Denmark	7.44 Danish Kronor	**7.43 Danish Kronor**
Hungary	312.50 Forint	**309.6 Forint**
India	72.20 Indian Rupee	**71.63 Indian Rupee**
Israel	4.25 Shekel	**4.05 Shekel**
Japan	131.23 Yen	**123.15 Yen**
Mexico	18.73 Mexican Peso	**21.85 Mexican Peso**
Norway	9.59 Norwegian Kronor	**9.09 Norwegian Kronor**
Poland	4.25 Zloty	**4.41 Zloty**
Russia	79.37 Rouble	**63.94 Rouble**
South Korea	1282.05 Won	**1265.82 Won**
Sweden	9.19 Swedish Kronor	**9.55 Swedish Kronor**
Switzerland	1.08 Swiss Franc	**1.07 Swiss Franc**
Turkey	3.17 Turkish lira	**3.71 Turkish lira**
UK	£ 0.73	**£ 0.86**
USA	$ 1.09	**$ 1.05**
Taiwan	$ 35.88	**$ 34.05**
South Africa	16.95 ZAR	**14.42 ZAR**

Box A2.1 –
Methodological caveats

Users of *Scoreboard* data should take into account the methodological limitations summarised here, especially when performing comparative analyses:

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 (31.12.2016). 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 3.3% and 6.2% against the US dollar and the Japanese Yen respectively, and appreciated by 17.4% against the pound sterling. However, ratios such as R&D intensity or profitability (profit as % sales) are based on the ratio of two quantities taken from a company report where they are both expressed in the same currency and are therefore less affected by currency changes.

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 $1.09 to $1.05). 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 the growth rates of other indicators, such as net sales.

When analysing data aggregated by country or sector, be aware that in many cases, the aggregate indicator depends on the figures of 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 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 (8 years since 2012 and 10 years since this edition) 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 (or de-mergers) may sometimes underlie sudden changes in specific companies' R&D and 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)[29].

[29] 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).

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. R&D expenditures funded by the business enterprise sector (**BES-R&D**), provided by official statistics, refer to the total R&D expenditures within a territorial unit that have been funded by private or public companies (business enterprise sector).

3. **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.

4. **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. BES-R&D, where R&D intensity is based on value added instead of net sales.

5. **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.

6. **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.

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 5 applies an extended sample of 1000 companies based in the EU. It consists of 567 companies included in the world R&D ranking of top 2500 companies and additional 433 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																				
	AT	BE	CZ	DE	DK	ES	FI	FR	GR	HU	IE	IT	LU	MT	NL	PL	PT	SE	SI	UK	Tot
Aerospace & Defence		1	1	3		1		5				1			2			1		9	24
Alternative Energy				4	1								1								6
Automobiles & Parts	3	1		21			1	6				5			2			2		9	50
Banks		2		6	2	2			1		2	2			1		2	2		3	25
Beverages		1			1															2	4
Chemicals	2	3		14	1		3	2							3			3		11	42
Construction & Materials	2	4		7	1	4	2	4			2	1	1		1			2		4	35
Electricity		1	1	1		2	2	2				2					1	1		3	16
Electronic & Electrical Equip.	3	3		15	2		2	7			1	4	1		5			4		19	66
Equity Investment Instr.																				1	1
Financial Services				6				1										3		3	13
Fixed Line Telecom.				1	1	1						1						1		1	6
Food & Drug Retailers															1					2	3
Food Producers	1			2	1		2	3	2		2				3					10	26
Forestry & Paper							3				1							2		1	7
Gas, Water & Multiutilities	1			2				3				1								3	10
General Industrials	2	1		15			1	1			1	1	1		2			5		9	39
General Retailers				3				1												5	9
Health Care Equip. & Services		1		11	3			3			2				2			5		13	40
Household Goods & Home Constr.				5			1	2				2	1					2	1	4	18
Industrial Engineering	5	1		35	3	3	7	7			2	7	2		4			12		12	100
Industrial Metals & Mining	2	3		4		1	1	1					3		1			2		1	19
Industrial Transportation			1	1	1			3				2						1		1	10
Leisure Goods					2		1													4	7
Life Insurance				1				1												2	4
Media								5										2		7	14
Mining													1					2		2	5
Mobile Telecom.		1		2			1	1										1		3	9
Nonlife Insurance				1				1												2	4
Oil & Gas Producers	1					1	1	1				1								2	7
Oil Equip., Services & Distribution								1			1		1		1						4
Personal Goods				7				3				3	1								14
Pharmaceuticals & Biotechnology	1	9		16	10	4	2	21	1	1	10	5			9	1	1	9	1	50	151
Real Estate Investment & Services				3																3	6
Software & Computer Services	2	1		19	2	2	5	16					1		2	1		7		56	114
Support Services				11				1			1		1		1			3		18	36
Technology Hardware & Equip.	2	2		6	1		1	5	1		1				6			8		11	44
Tobacco																		1		1	2
Travel & Leisure	1			2				1			1			1				1		3	10
Total	**28**	**35**	**3**	**224**	**32**	**21**	**36**	**108**	**5**	**1**	**27**	**38**	**15**	**1**	**46**	**2**	**4**	**82**	**2**	**290**	**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 2017 *Scoreboard* comprises two data samples:

- The world's top 2500 companies that invested more than €24 million in R&D in 2016/17.
- The top 1000 R&D investing companies based in the EU with R&D investment exceeding €7 million.

For each company the following information is available:

- Company identification (name, country of registration and sector of declared activity according to the *Scoreboard* sector classification).
- R&D investment
- Net Sales
- Capital expenditure
- Operating profit or loss
- Total number of employees
- Market capitalisation (for listed companies)
- 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.
http://iri.jrc.ec.europa.eu/documents/10180/edefa311-3325-46fc-aca8-8bbac469afe6

R&D ranking of EU top 1000 companies.
http://iri.jrc.ec.europa.eu/documents/10180/bb866d5b-8722-4c65-96dc-31cc525949ab

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Abstract

The 2017 edition of the EU R&D Scoreboard (the *Scoreboard)* comprises the 2500 companies investing the largest sums in R&D in the world in 2016/17. These companies, based in 43 countries, each invested over €24m in R&D for a total of €741.6bn which is approximately 90% of the world's business-funded R&D. They include 567 EU companies accounting for 26% of the total, 822 US companies for 39%, 365 Japanese companies for 14%, 376 Chinese for 8% and the rest-of-the-world (RoW) for 13%.

Worldwide, companies' R&D investment increased by 5.8% over the previous year, the sixth consecutive year of significant increases. The companies headquartered in the EU increased their R&D investments more than the global average up to 7.0%. This increase is similar to the US (7.2%) and substantially above Japan (-3.0%). Chinese companies increased their R&D investment by 18.8%.

R&D growth was driven by ICT services (+11.7%), followed by Health and ICT producers (6.9% and 6.8% respectively). These three sectors, together with Automobiles, account for 75% of the total R&D of the 2500 companies in the *Scoreboard*. R&D investment of companies in the Automobiles and Aerospace & Defence sectors grew at a lower pace (2.7% and 2.2%, respectively), whereas that of Chemicals companies decreased (-1.9%).

In the EU, R&D growth was driven by the same sectors as worldwide, i.e. ICT producers (+14.4%), ICT services (+12.7%), Health industries (+7.9%) and Automobiles (+6.7%). However, companies from a few important sectors for the EU economy decreased their R&D, in particular Aerospace & Defence (-5.4%) and to a lesser extent Chemicals (-0.8%).

The 2017 *Scoreboard* includes an analysis of the 10-year economic and R&D performance of the top R&D investors showing that:

- The EU share of world R&D remained constant at 26%, whereas at sector level, significant changes in EU's R&D shares are observed, namely an increase in the Automobiles sector (from 36% to 44%) and a decrease in Aerospace & Defence (from 48% to 42%).

- Compared to their non-EU counterparts, EU companies outperform or perform comparably in size (of R&D and sales) and R&D intensity for Aerospace & Defence, Automobiles and Pharmaceuticals. But in Biotechnology, Software and IT hardware the EU shows persistent weaknesses in most indicators such as size and R&D/firm or sales/firm (in particular compared to US companies). The EU/non-EU gap in these latter three sectors has widened over the last ten years.

- In terms of productivity (net sales/employee ratio), EU and US companies showed similar overall performance (ca. 14% increase in both net sales and employment). However, at sector level, contrasting productivity changes are observed, e.g. in Automobiles, EU 17% vs. US -15%; in ICT sectors, EU -1% vs. US 31% and in low tech sectors, EU -10% vs. US -33%.

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