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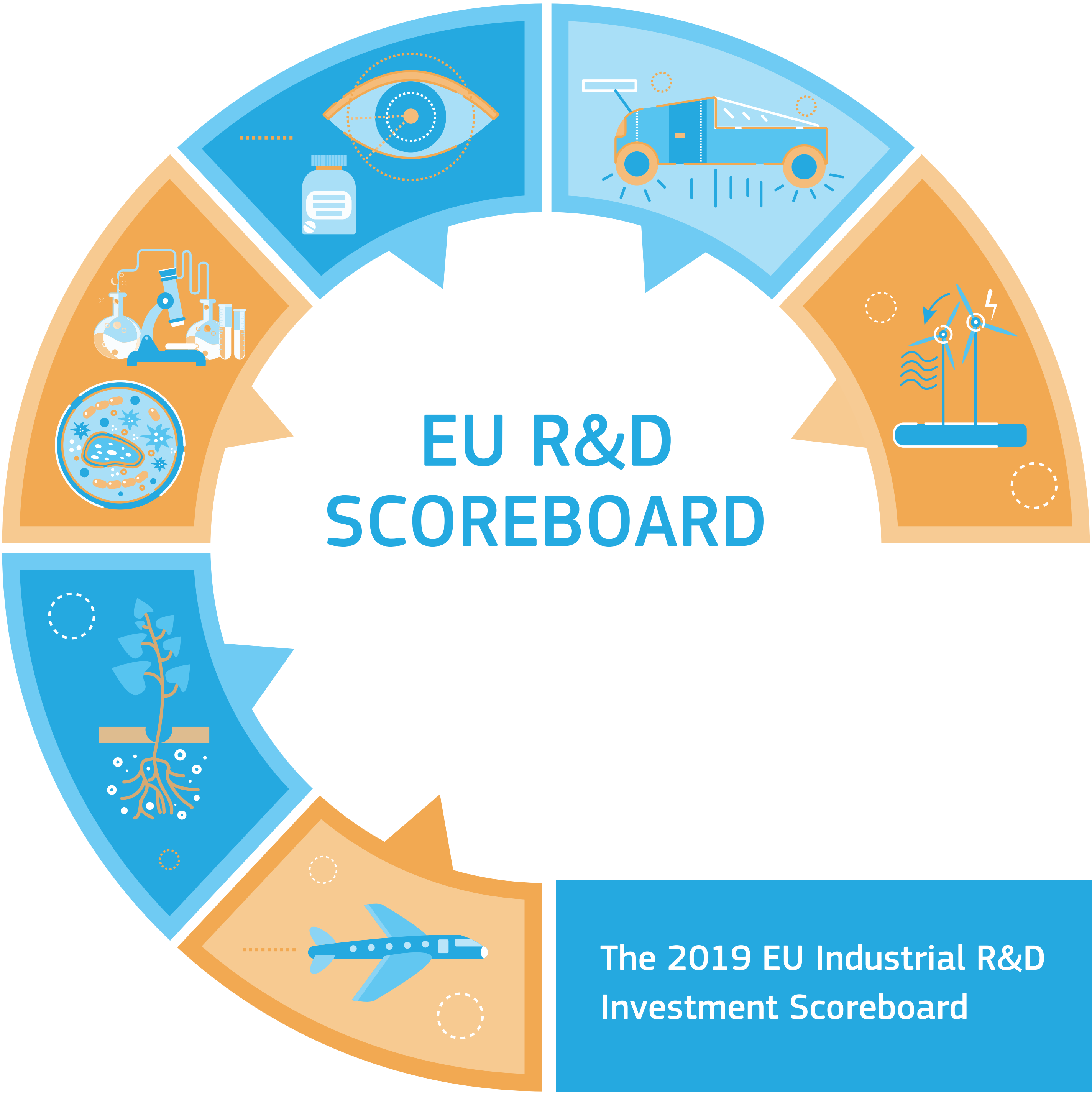

EU R&D SCOREBOARD

The 2019 EU Industrial R&D Investment Scoreboard

EUR 30002 EN

Acknowledgements

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EU R&D SCOREBOARD

THE 2019 EU INDUSTRIAL R&D INVESTMENT SCOREBOARD

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SUMMARY / INTRODUCTION

Summary

The 2019 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 2018. These companies, based in 44 countries, each invested over €30 million in R&D for a total of €823.4 billion which is approximately 90% of the world's business-funded R&D. They include 551 EU companies accounting for 25% of the total, 769 US companies for 38%, 318 Japanese companies for 13%, 507 Chinese for 12% and 355 from the rest-of-the-world (RoW) for 12%.

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 patent-based analyses aimed at characterising further the R&D efficiency of the business health sector and the activity of the *Scoreboard* companies in the field of environmental technologies.

Highlights

1 In 2018 the 2500 Scoreboard companies invested a total of €823.4 billion, 8.9% more than in 2017. The major contributors were the US with 38% of total R&D, the EU (25.3%), Japan (13.3%), China (11.7%), S. Korea (3.8%) and Switzerland (3.5%). The main change over the last few years has been China's increasing R&D share of the total. However, this is to be expected since China still has only 88% of Japan's R&D whereas its GDP is nearly three times that of Japan.

2 R&D is very concentrated in the larger companies with the top 10, top 50 and top 100 accounting for 15%, 40% and 52% of the total. Within the top 50 there are 17 from the EU, 22 from the US, 6 from Japan, 2 each from China and Switzerland and one from S. Korea. R&D is also concentrated by sector with three broad sectors accounting for 76.6% of the total: ICT for 38.7%, health for 20.7% and automotive for 17.2%.

3 The R&D sector specialisations of the four main regions are very different. The EU has 20% in ICT, 21.6% in health but 31% in automotive in contrast to the US with 52.8% of its R&D in ICT, 26.7% in health and only 7.6% in automotive. Japan has many similarities with the EU having 24.9% in ICT, 31% in automotive but only 12.1% in health. China has some similarities with the US having 47.1% in ICT and 11.5% in automotive but differs markedly in having only 4.8% in health.

4 These different regional sector specialisations lead to big differences in average R&D intensity (R&D/sales ratio) for the major regions. This is because three sectors have much higher intensities than the others – pharmaceuticals with 15.4%, software with 10.8% and IT hardware with 8.0% whereas automotive, for example, has an intensity of only 4.7%. Average R&D intensity for the EU is 3.4%, for the US 6.6%, for Japan 3.5% and China 2.7%. A region's R&D intensity depends on its sector mix. – China's average R&D intensity, for example, is low primarily because of its small pharmaceuticals sector and large low technology sectors which are not compensated for by its large ICT sector.

5 Worldwide R&D growth over the past year was 8.9% and driven by ICT services (16.9%), ICT producers (8.2%) and health (7.6%). Regional sector specialisation led to the EU growing R&D by 4.7%, the US by 10.3%, and Japan by 3.9%. China's R&D grew by 26.7% with big contributions from some of its largest companies. Average profitability also differs markedly between regions with the US leading with 13.7% followed by the EU (10.3%), Japan (7.8%) and China (7.4%).

6 The four largest companies by R&D investment are Alphabet, Samsung Electronics, Microsoft and Volkswagen. Amazon would have been in first place had its annual report given a figure for R&D alone so it could be included in the *Scoreboard*. Over the last 15 years 8 companies have moved up in the global ranking by 70 or more places. These are Alphabet, Huawei, Apple, Facebook, Alibaba, Celgene, Gilead Sciences and Continental indicating the rising importance of ICT and biotechnology. The ranking of the top 50 large global companies by R&D intensity (all with intensity of 13.3% or more) also highlights the importance of these two technologies with 23 companies from biopharmaceuticals and 24 from ICT.

7 The *Scoreboard* contains a separate listing of the top 1,000 EU companies, all with R&D of at least €8.6m. R&D is highly concentrated with the top three EU countries (Germany, UK, France) accounting for 68.4% of EU R&D and the top 10 for 97%. Germany leads in automotive and industrial engineering with 37.4% of the EU 1000 companies while the UK leads in biopharmaceuticals, software and IT hardware with 35.9% of the companies. In 2018, R&D growth in the EU was driven first and foremost by the automotive sector, namely by French and German companies, and to a lesser extent by companies from the Health and ICT industries.

8 The 2019 *Scoreboard* includes a patent analysis for the R&D-intensive biotech & pharma sector. R&D in this sector has increased substantially over the last 10 years although the number of patents filed per year has declined. This reflects sector specific issues such as the move from small molecule drugs to biologic drugs which are more difficult to develop and obtain regulatory approval for. This trend has also driven a wave of mergers and acquisitions in the biotech & pharma sector. The analysis also shows a difference in the pharma and biotech sector between EU and US firms in terms of technological profile and is mainly driven by the low number of biotech companies in the EU compared to the US.

9 The 2019 *Scoreboard* highlights the important role industrial R&D is playing in the drive to meet the UN's sustainable development goals (SDGs). Specific examples are given of the way in which technologies such as AI, biotechnology, nanotechnology, graphene and improved clean energy generation & storage technologies are contributing to meeting most of the SDGs. In this context, a patent analysis included in this report shows that of all patents filed in the EPO and USPTO from 2012-2015, 50% belong to the *Scoreboard* companies and 9% of these are 'green' patents. Toyota had most green patents but the top 25 global companies by number of green patents comprise EU firms such as Bosch, Volkswagen, Airbus and Rolls-Royce.

10 Finally, the report also includes a patent analysis of the global automotive sector which accounts for 13% of total patents for the global *Scoreboard* companies. Of these, 35% are held by EU companies. Most of these patents refer to current automotive technologies but an increasing proportion refer to 'green' technologies including electric and autonomous vehicles and newer components such as novel batteries and fuel cells. For these technologies, the current automotive companies are being joined in patent filing by companies from the software, technology hardware, electronics and chemicals sectors.

Key findings

A. *Worldwide, companies continued to increase significantly their R&D investments in 2018 for the ninth consecutive year while showing good performance in most financial indicators.*

The top 2500 *Scoreboard* companies invested €823.4 billion in R&D during 2018, an increase of 8.9% with respect to the previous period. Companies also raised most of their financial indicators: net sales and profits grew at a similar rate to R&D investment (8.4% and 9.1% respectively); capital expenditures increased significantly (7.6%) and the number of employees continued to increase at a moderate pace (3.7%). See the evolution of key parameters over the past 10 years shown in Figure S1.

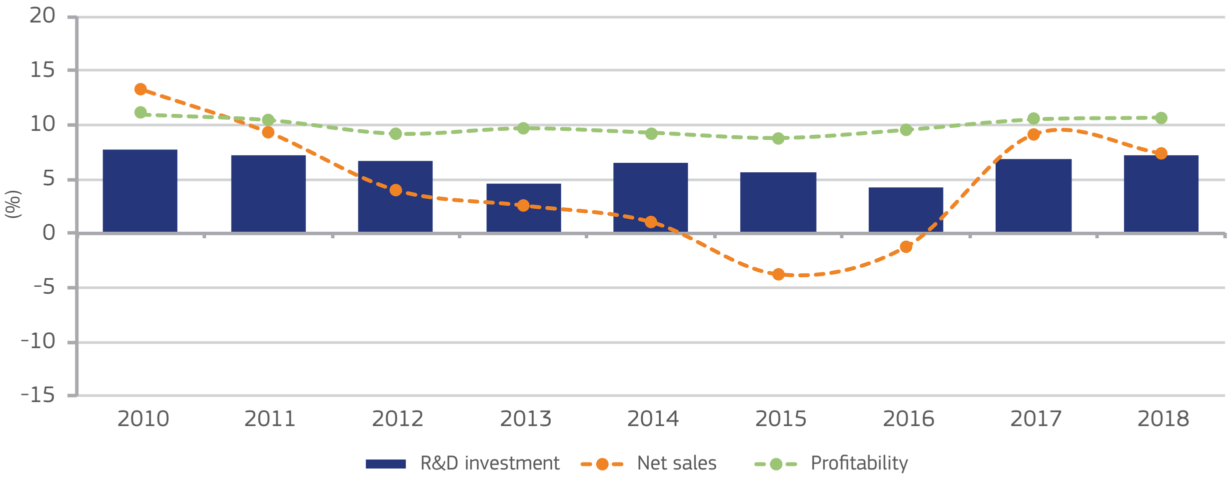

FIGURE S1: GLOBAL GROWTH RATE OF R&D AND NET SALES AND PROFITABILITY FOR THE PERIOD 2009-2018.
Note: Growth rates for the three variables have been computed on 1650 out of the 2500 companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2009-2018. These companies represent 84.6% of R&D, 84.1% of Net Sales and 79.8% of Operating Profits of the total sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

B. *The global technology race intensified in 2018with US and Chinese companies increasing sharply their R&D investments and EU companies following behind.*

Just as in the previous *Scoreboard,* the considerable increase of industrial R&D in 2018 (8.9%) was mostly due to the performance of US and Chinese companies that raised their R&D investment by 10.3% and 26.7% respectively. Companies from the other countries/regions increased R&D below the world's average rate with the EU 4.7%, Japan 3.9% and the rest of the world 4.8%.

Global R&D was driven by the ICT services sector (17%), followed by the ICT producers sector (8.2%) and the Health sector (7.6%). The lowest R&D growth was shown by the Aerospace & Defence sector (4%) across most countries.

For the EU sample of companies, the largest contribution to R&D growth (weighed by R&D size) was made by the Automobiles & other transport sector (6.4%), Health industries (3.8%) and ICT producers (5.5%). By member states, the largest contribution to the R&D growth was provided by the French and German companies (10.6% and 3.6% respectively) followed by companies from Sweden (11.9%), UK (3.6%) and Denmark (13.5%). Companies showing the highest R&D growth were automotive companies, e.g. BMW (13%), PEUGEOT (25%), RENAULT (19%) and VALEO 37%) and from other sectors SANOFI (8%), ERICSSON (11%) and SIEMENS (7%). The poorest R&D performance was shown by TELECOM ITALIA (-39%), FIAT CHRYSLER (-14%), BARCLAYS (-58%) and NOKIA (-6%). Acquisitions contributed to growth in several cases (e.g. Peugeot acquiring General Motors' European operations in November 2017).

For the non-EU sample of companies, R&D growth was driven by the high tech industries, especially by large R&D increases from US and Chinese companies, i.e. ICT services (US 17%, China 39%), ICT producers (US 9%, China 15%) and Health industries (US 9%, China 57%). Companies showing the best R&D performance were all ICT companies, ALPHABET (30%), APPLE (23%), FACEBOOK (32%), MICROSOFT (15%), ALIBABA (64%) and HUAWEI (13%). The poorest performance was shown by SNAP (-51%), GENERAL ELECTRIC (-14%) and TEVA PHARMACEUTICAL (-34%). Divestments were a major factor in the negative R&D growth of GENERAL ELECTRIC.

See comparison of EU, US and Chinese companies' R&D performance in Figure S2.

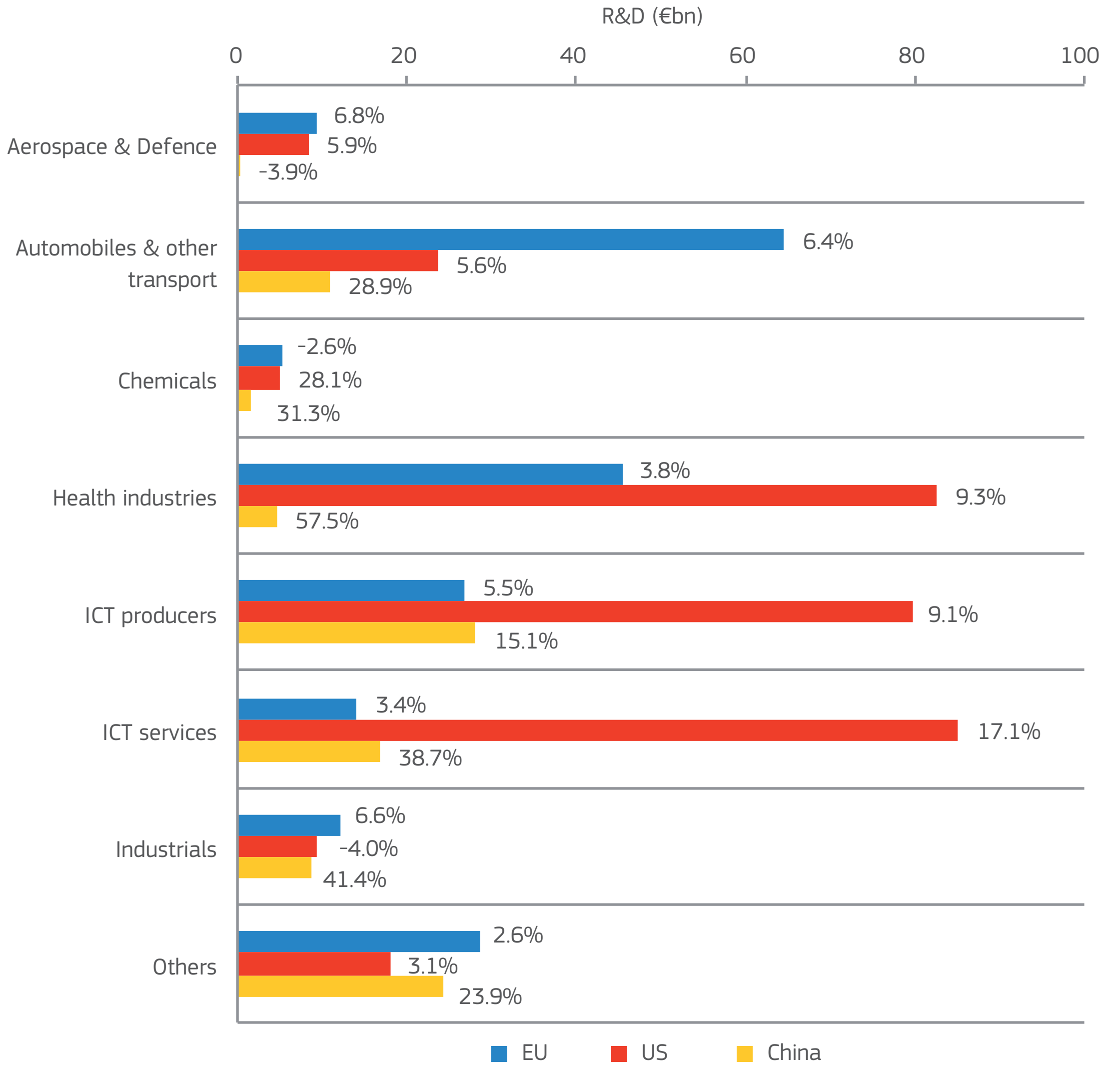

FIGURE S2: R&D INVESTMENT AND R&D ONE-YEAR GROWTH FOR THE EU, US AND CHINESE SAMPLES OF COMPANIES.
Note: R&D investment and growth rates (between brackets) have been computed for 549 EU, 760 US and 487 Chinese companies for which R&D data are available for years 2017 and 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

C. Companies' key economic indicators showed good performance in 2018.

The main economic indicators of the *Scoreboard* companies showed good results in 2018 across most countries/regions. The overall growth of net sales (8.4%) and profits (9.1%) continued the positive trend of the previous year, increasing at a similar rate to R&D investment. As observed in 2017, the growth in net sales and profits was mostly led by oil-related companies due to high oil prices, and, to a lesser extent, by the ICT and Industrials sectors. In the same vein, companies' capital investments (Capex) continued the significant recovery seen in the previous year. Capex increases are observed especially in oil-related companies, ICT services and Industrials. The number of employees for the 2500 companies continued to increase at a moderate pace (3.6%).

The net sales of the 551 companies based in the EU reached €6.0trillion, 4.7% more than in the previous year. Net sales increases were in oil-related sectors but also in other sectors such as Industrials (5.9%), Aerospace & Defence (6.1%) and Chemicals (3.6%). The EU companies continued to increase modestly capital expenditures and profits (2.0% and 3.2% respectively). The 551 companies based in the EU employed 19.4 million, 3.9% more than the year before.

D. Over the past 10 years, the rapid R&D growth in the Health, Automotive and ICT sectors reshaped the global industrial R&D landscape.

EU companies have maintained a stable share of global R&D around 25-27% over the past ten years. They have strengthened their position in medium-high tech sectors such as automotive and industrials, they have maintained their position in health but have lost ground in ICT (almost doubling the medium-high tech sector while growing the high-tech sector more slowly). The EU's lead in medium-high tech is challenged as ICT takes a higher proportion of the value added in sectors such as automotive with the advent of new developments such as electric self-driving cars (see H below on the results of a patent analysis for the automotive sector).

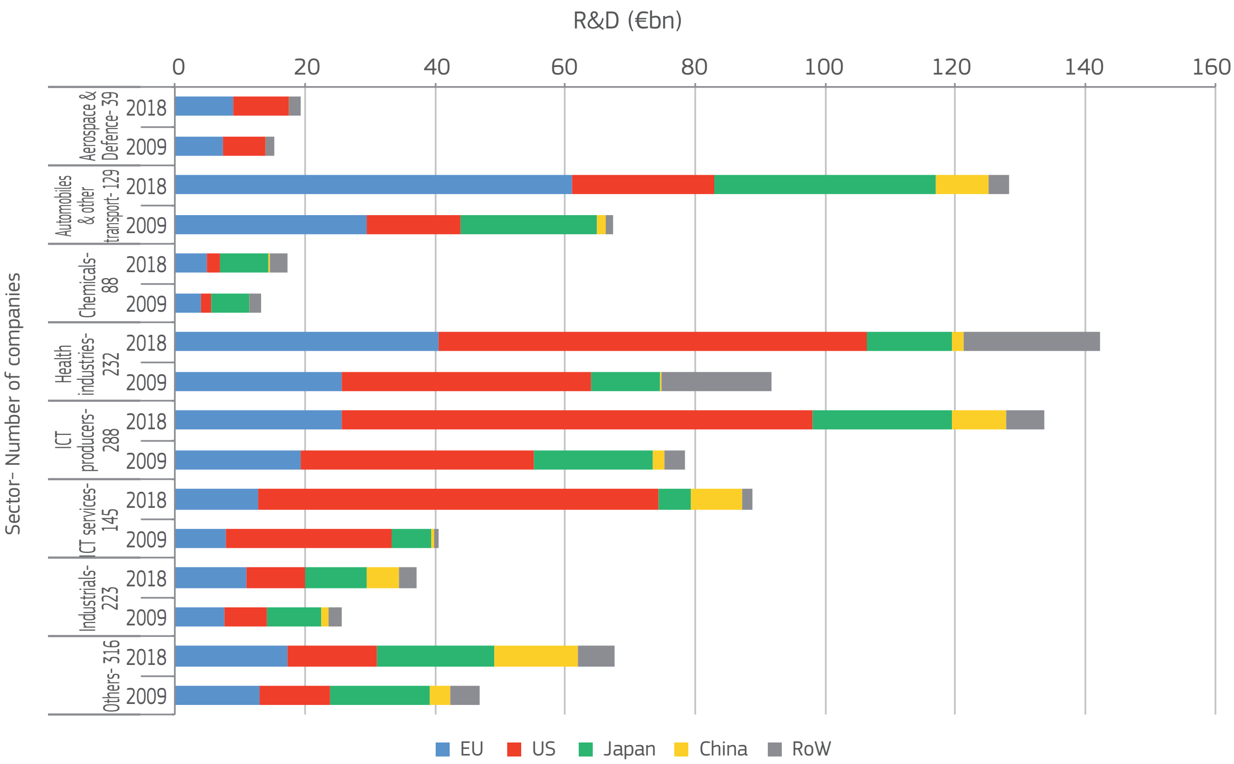

FIGURE S3: R&D INVESTMENT IN 2009 AND 2018 BY MAIN REGION AND SECTOR GROUPS.
Note: Figures displayed refer only to the 1460 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 77.0% of R&D of the total sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

US companies have been steadily increasing their share of global R&D to reach 38% in 2018 (doubling their high tech R&D from 2009 to 2018). The big driver for the US has been growth in its ICT sectors (particularly ICT services) and, to a lesser extent, in health. The US is well placed for the future in health as it is the clear world leader in biotechnology which is the basis of more and more new drugs. Chinese companies have been increasing their global R&D share at a fast rate but from a very low base to reach an 11.7% world share in 2018. China has grown its low, medium and high tech groups, especially the ICT sector. Japanese companies have an even larger proportion of their R&D in medium-high tech sectors and less in high-tech than the EU companies (growing significantly their medium-high tech group but barely changing the size of their high-tech group). See Figure S3.

E. *Over the past 15 years, three major industries continue to provide most of the R&D players in the top 100 group but newcomers in this group are mainly companies based in Asia.*

The profile of the group of top 100 *Scoreboard* companies reflects the concentration of global industrial R&D in a few companies, industries and countries. In the 2019 *Scoreboard*, this group accounts for 52% of the total R&D, 82 companies are from the three major sectors (ICT 34, Health 26 and Automotive 22) and 80 companies from 3 regions (EU 29, US 36 and Japan 15). Comparing with the first *Scoreboard* edition in 2004, the top 100 sample then comprised 8 less companies from the 3 largest sectors (ICT 34, Health 21 and Automotive 19) but 14 more companies from the main regions (EU 35, US 37, Japan 22).

In the past 15 years, most leavers from the top 100 group are from Japan and the EU (7 and 6 respectively) and newcomers are companies based in Asia (China 9, Taiwan 3 and S. Korea 2). See the profile of the top 100 group of companies in Figure S4.

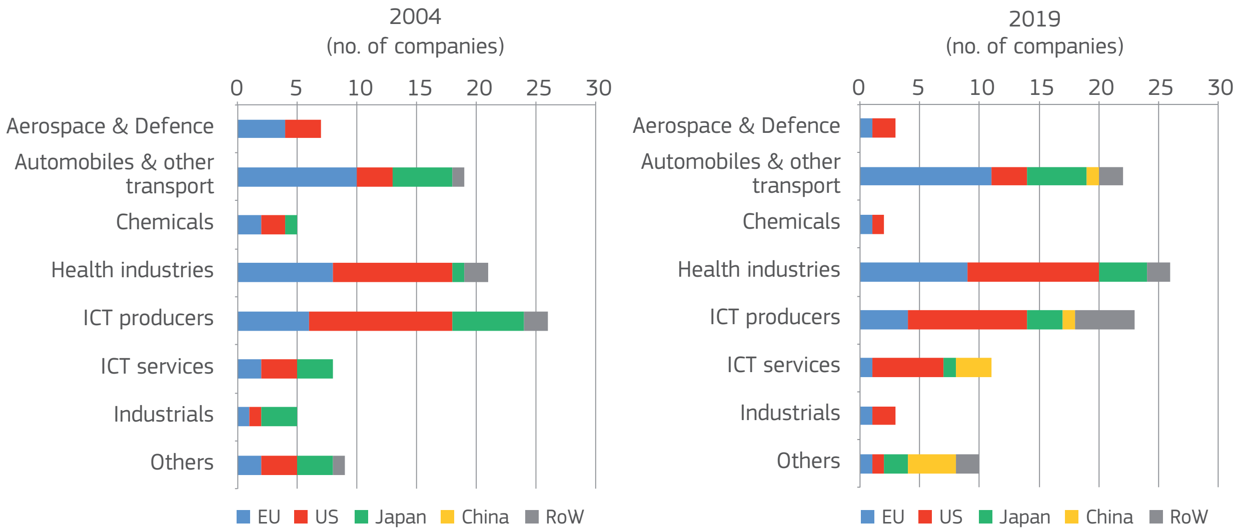

FIGURE S4: DISTRIBUTION OF THE TOP 100 R&D INVESTORS IN THE 2004 AND 2019 *SCOREBOARDS* BY MAIN REGION AND SECTOR GROUPS.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

F. *A patent analysis for the* Scoreboard *companies in the biotech & pharma sector shows a substantial increase of R&D investment over the last 10 years although the number of patents filed per year has declined.*

The 2019 *Scoreboard* includes a patent analysis in the R&D-intensive biotech & pharma sector. R&D in this sector has increased substantially over the last 10 years although the number of patents filed per year has declined (see Figure S5). This reflects sector specific issues such as the move from small molecule drugs to biologic drugs which are more difficult to develop and obtain regulatory approval for. This trend has also driven a wave of mergers and acquisitions in the biotech & pharma sector.

The analysis also shows a difference in the pharma and biotech sector between EU and US firms in terms of technological profile which is mainly driven by the low number of biotech companies in the EU compared to the US. The US leadership in biotechnology is a main challenge for the EU, as this subsector is the basis of more and more new drugs. Moreover, many of the larger US pharmaceutical companies are acquiring smaller US biotech firms to strengthen their new drug pipelines.

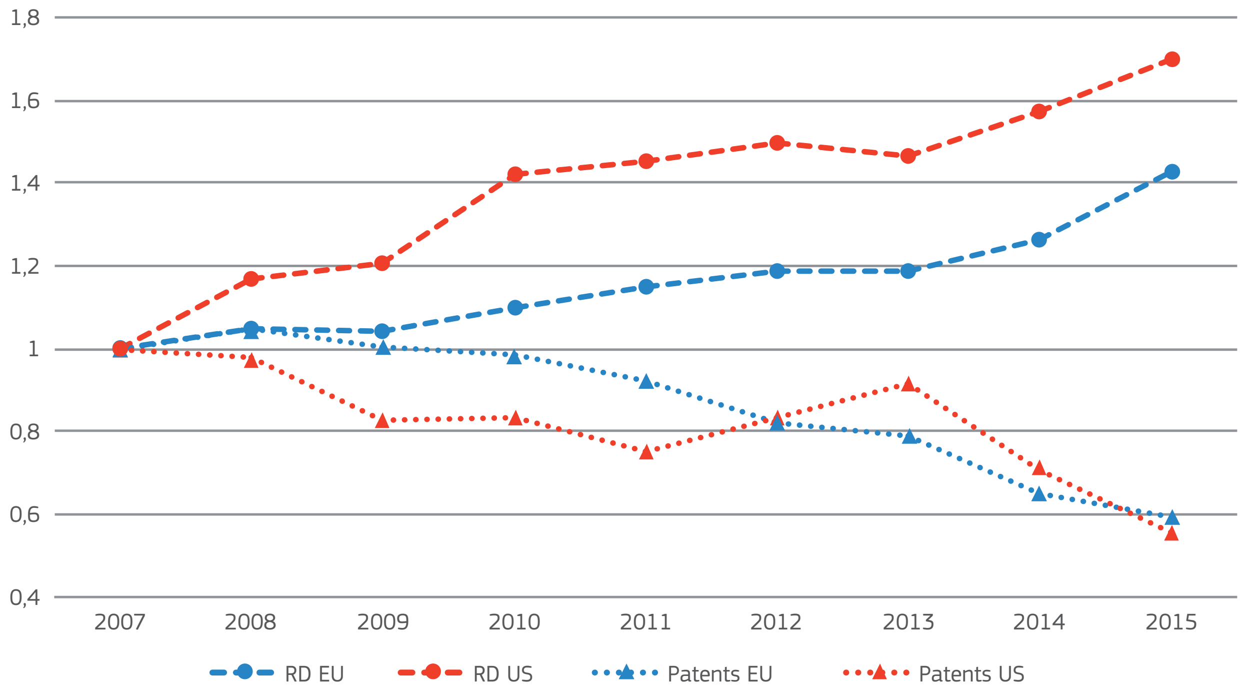

FIGURE S5: EVOLUTION OF THE R&D INVESTMENT AND NUMBER OF PATENTS IN THE PHARMA AND BIOTECH SECTORS FOR EU AND US COMPANIES (BASE YEAR 2007 = 1.0).

Note: Data computed 41 out of the 73 EU and 52 out of the 152 US Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

G. *The analysis of patents filed in the EPO and USPTO offices from 2012-2015 shows that 50% are owned by the* Scoreboard *companies and 9% are* green[1] *patents.*

A patent analysis included in this report shows that the top R&D investors own 50% of patents filed in the EPO and USPTO offices from 2012 to 2015. The share of *green* patents in the total is 9% of which 53% belong to the top R&D companies.

The highest shares of *green* patents are held by companies from regulatory driven sectors, energy and transport, but ICT producers follow a short distance behind. The bulk of *green* patents owned by the *Scoreboard* companies (about 80%) is concentrated in companies headquartered in Japan (30.9%), the US (26.8%), Germany (11.8%) and South Korea (10.5%).

EU companies show comparative advantages in most *green* technologies, with the exception of ICT applications for energy. Toyota had most *green* patents but the top 25 global companies by number of *green*

[1] According to WIPO's "IPC Green Inventory", developed to facilitate searches for patent information relating to Environmentally Sound Technologies (ESTs). https://www.wipo.int/classifications/ipc/en/green_inventory/.

patents comprise EU firms such as Bosch, Volkswagen, Airbus and Rolls-Royce.

Figure S6 shows the total number of patents and the distribution of *Scoreboard* companies' *green* patents by technological field and country.

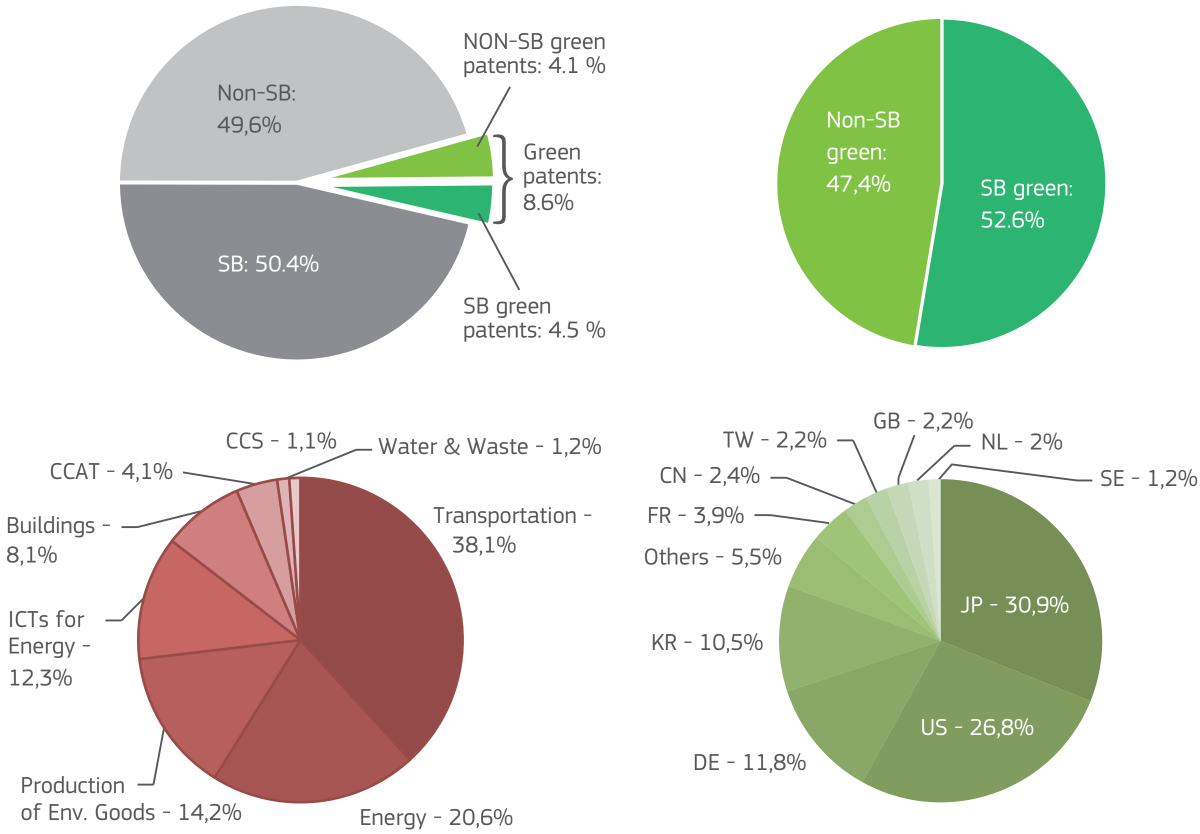

Figure caption:
Top left: Patents filed by *Scoreboard* (SB) and non-*Scoreboard* (Non-SB) companies and share of green patents (according to CPC classification)[2].
Top right: Green patents filed by *Scoreboard* and non-*Scoreboard* companies.
Bottom left: *Scoreboard* companies' green patents by technological classes (CCS= carbon capture and storage; CCAT= Climate Change Adaptation Technologies).
Bottom right: *Scoreboard* companies' green patents by country.

FIGURE S6: DISTRIBUTION OF TOTAL PATENTS FILED IN THE USPTO AND EPO OFFICES, 2012-2015.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

H. The automotive sector has 13% of total patents belonging to the Scoreboard companies of which 35% are held by EU companies. Green technologies in this sector are led by Japanese companies.

The *Scoreboard* includes a patent analysis of the global automotive sector which accounts for 13% of total patents filed by the global *Scoreboard* companies. Most of these patents refer to current automotive technologies but an increasing proportion refer to *green* technologies including electric and autonomous vehicles and newer components such as novel batteries and fuel cells. Of these patents, 35% are held by EU companies which appear highly diversified and competitive in most technological fields. But in green technologies related to hybrid cars, batteries and fuel cells their Japanese counterparts are leading the race. See patents of the automotive sector for main regions in Figure S7.

For emerging technologies, the current automotive companies are being joined in patent filing by companies from the software, IT hardware, electronics and chemicals

[2] The Cooperative Patent Classification (CPC) is an extension of the IPC and is jointly managed by the EPO and the US Patent and Trademark Office. https://www.epo.org/searching-for-patents/helpful-resources/first-time-here/classification/cpc.html.

sectors. This is a major challenge for the EU, whose lead in the automotive sector may be eroded as digital technologies take a higher proportion of the value added in this sector with the advent of new developments such as electric self-driving cars fitted with more electronics and communications accessories.

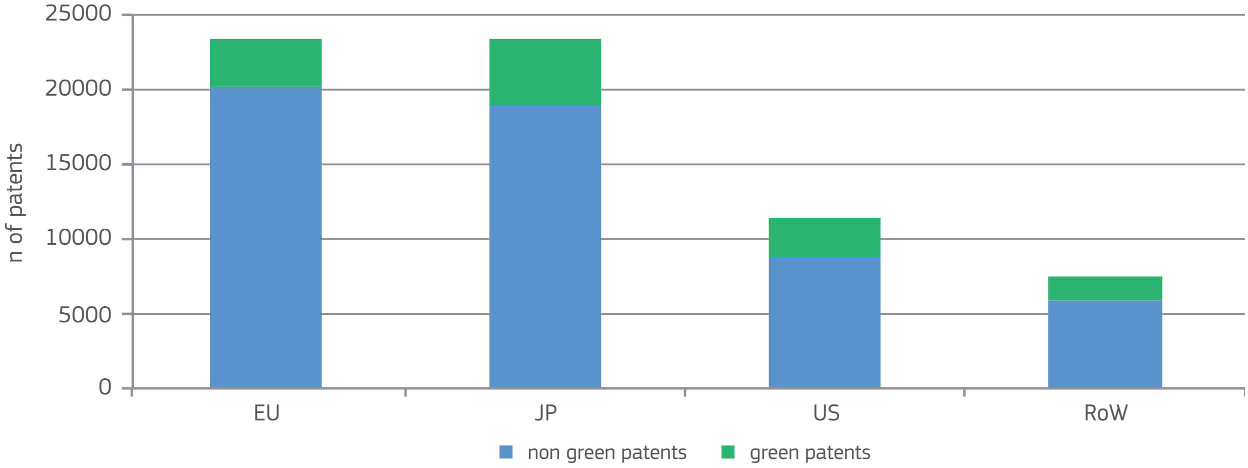

FIGURE S7: NUMBER OF PATENTS FILED BY *SCOREBOARD* COMPANIES IN THE USPTO AND EPO OFFICES, 2012-2015 FOR THE AUTOMOTIVE SECTOR.
Note: Data computed for 116 out of the 137 companies in the Automobiles & other transport sector for which patent data are available.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Introduction

The 2019 edition of the "EU Industrial R&D Investment Scoreboard" (the *Scoreboard*)[3] comprises this analysis report and the related dataset on top R&D investors worldwide. The *Scoreboard* dataset consists of the ranking of the **2500 companies investing the largest sums in R&D in the world** and a ranking of the **top 1000 R&D investing companies based in the EU**[4]. The latter consists of 551 EU companies included in the global ranking and an additional 449 companies, making a total of 2949 companies in the 2019 *Scoreboard.*

The *Scoreboard* is based on information taken from the companies' latest published accounts. For most companies these correspond to calendar year 2018, but a significant number of companies have financial years ending on 31 March 2018 (Japanese companies in particular but also many UK firms). There are few companies included with financial years ending as late as end June 2019 and a few for which only accounts to end 2017 were available[5].

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.

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 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 2019 *Scoreboard* (€823.4 billion) is equivalent to almost 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, number of employees and market capitalisation 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 across countries and industries and 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 2019, we have collected available indicators reported by about 700.000 subsidiary companies of the 2500 parent companies comprised 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 the patent data of parent companies and their subsidiaries allows the reassignment of many companies to countries where they perform their actual economic or innovation activity.

[3] The EU Industrial R&D Investment Scoreboard is published annually by the European Commission (JRC-Seville/DG RTD) as part of the GLORIA project (Global Industrial Research & Innovation Analyses). GLORIA is the follow-up of the IRIMA project (Industrial Research and Innovation Monitoring and Analysis). See: http://iri.jrc.ec.europa.eu/home/.

[4] 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).

[5] This is why we should refer to the data of the last available year as 2018/19, those of the previous one as 2017/18 and so on. However, and as stated in the text, for the majority of companies the last available year corresponds to calendar year 2018, the previous year to the calendar year 2017 (and so on). For reasons of clarity and consistency, we decide to refer to the last available year as 2018, the previous year as 2017 (and so on).

[6] According to the latest figures reported by Eurostat, (see Figure 1.1 in Chapter 1).

Report structure

In this edition, we follow a similar structure to that of previous *Scoreboard* reports. It includes an extensive description of the 2019 dataset, an overview of main changes in companies' R&D and economic performance over the past year and ten-year description of trends for main world regions and industrial sectors, benchmarking EU companies against their global counterparts. This year edition includes also three chapters, supported by the analysis of the patent activity of companies, aimed at examining sustainability issues and particularly the role of the *Scoreboard* companies in developing environmental technologies.

In chapter 1 we provide an overview of the main characteristics of the industrial R&D, including the main economic factors that have shaped R&D investments over the past year. This section comprises a description of the role of R&D in achieving sustainability goals and summarises related technology trends. The 2019 dataset is described in detail and, in particular, the geographic and sectoral distribution of R&D and its typical concentration at company, industry and country levels.

Chapter 2 presents a description of industrial R&D trends for the 2500 companies aggregated by main world region and industrial sector. It describes the main changes in R&D and economic indicators that took place over the past year and gives a ten-year analysis of their performance in terms of R&D, net sales, profitability and employment over the past 10 years.

The performance of individual companies among the top R&D investors is analysed in chapter 3. 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 15 years. It also includes an analysis of the ranking of the top 50 large companies by R&D intensity.

Chapter 4 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 5 presents the results of a patent-based study aimed at analysing the performance of companies from the Automobiles & other transport sector in terms of technological developments and particularly from an environmental viewpoint. This analysis underlines the capability of EU companies to develop sustainable technologies and includes a comparison of them against the main global players.

Chapter 6 analyses the economic and innovation performance of companies operating in the health sector over the past ten years. The objective is to assess the efficiency of R&D investments in these industries by comparing the trends in R&D investment against company results in terms of number of patents and profitability. The analysis focuses on pharma and biotech industries and compares the performance of EU companies against their US counterparts.

Finally, chapter 7 analyses the technological profile of the *Scoreboard* companies from an environmental technology viewpoint. It is based on an examination of the patent portfolio of the top R&D investors and focusses on assessing the capacity of EU companies to develop environmental technologies, to analyse their strengths and weaknesses in specific sub-fields and to compare them with companies from other economic areas.

The data have been collected by Bureau van Dijk – A Moody's Analytics Company, 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. Users of the *Scoreboard* data are advised to read in particular the summary of the methodological caveats explained in Box A2.1.

Annex 3 provides two complementary tables. The first one regarding main statistics for the world sample of companies aggregated by industrial sectors and the second one about the sector and country composition of the EU 1000 sample. The access to the full dataset is shown in Annex 4.

The complete data set is freely accessible online at: https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard#field_data.

1

THE INDUSTRIAL **R&D LANDSCAPE**

1 The industrial R&D landscape

The 2019 Scoreboard comprises the top 2500 global companies that invested €823.4bn in R&D in 2018, accounting for 90% of the world's business-funded R&D.

The Scoreboard 2500 sample includes companies based in the EU (551), the US (769), China (507), Japan (318) and a further 23 countries.

Industrial R&D is very concentrated in a few companies, industries and countries. The top 100 R&D investing companies are responsible for half of the total R&D and the four largest R&D investing sectors and countries account for about three quarters of the global 2500 R&D.

EU companies account for 25% of the total R&D, those from the US 38%, Japan 13% and China 12%.

The main change in the 2019 Scoreboard sample is the higher number of companies from China that becomes the 2nd country by number of companies and the 3rd by level of R&D investment.

Industrial R&D plays an important role in the drive to meet the UN's sustainable development goals (SDGs). Specific examples are given of the way in which technologies such as AI, biotechnology, nanotechnology, graphene and improved clean energy generation & storage technologies are contributing to meeting SDGs.

This chapter provides an overview of global industrial R&D issues and the main factors that are shaping corporate R&D investments, including the sustainability context. The last part of the chapter summarises the main characteristics of the 2019 *Scoreboard* dataset, comprising the distribution of companies and their R&D investments by country, world region and industrial sector.

1.1 | Economic context, sustainability goals and technology trends

This section summarises the main economic factors and technological trends that influenced companies' R&D investment in the period 2018 covered by this report. It comprises a section describing the sustainability context and the role that R&D-active companies are playing in tackling these issues as well as examples of the way in which companies' R&D investments contribute to achieving sustainability goals.

1.1.1 Economic context

The four major factors affecting *Scoreboard* companies in 2018 were interest rates, global GDP growth rates, oil prices and the trade dispute between the world's two largest economies – the US and China. Interest rates govern companies' cost of raising funds, GDP growth rates and oil prices influence company revenue growth and the likelihood of companies making new investments while the US/China trade tensions have raised tariffs, affected supply chains and clouded the growth outlook. We will take a brief look at each of these factors and then summarise their combined effect on companies and their R&D budgets.

Interest rates and exchange rates

The ECB is concerned about the health of the global economy and, at its September meeting, cut its forecast for Eurozone growth to 1.1% for 2019 and 1.2% for 2020 with forecasts for inflation of 1.2% and 1.0% for 2019 and 2020. The ECB deposit rate was cut from -0.4% to -0.5% in September 2019 and its QE programme of bond buying restarted for an unlimited period.

By September 2018, the Fed (US Federal Reserve) had ended QE and raised interest rates three times during 2018 following three rises in 2017. The rate was 2.25-2.5% in September 2018 and the Fed's aim had been to normalize rates to provide the ammunition to lower rates to help alleviate the effects of any future financial crisis. The Fed was expected to raise rates at least once more in 2019 but, instead, it cut its rate by 0.25% in July, September and October 2019 to reach 1.5-1.75% aiming to extend the record economic expansion in an increasingly uncertain economic environment where global growth is slackening and trade tensions with China are rising. These were the first rate cuts since the financial crisis of 2008 and Fed officials do not now foresee any more cuts. The Bank of England has kept its interest rate at 0.75% while the Bank of Japan at its July meeting left its key short-term interest rate unchanged at -0.1%. However, the IMF has warned that current low interest rates mean that central banks have little scope to fight any new financial crisis.

The interest rate environment for companies has therefore become benign and is likely to remain benign and this is helpful for companies wishing to raise funds to invest in new products and expansion. However, whether they choose to invest or not also depend on the outlook for growth and the likelihood of a recession. There are now serious concerns about the outlook for growth, on oil prices and over trade tensions and these are discussed further below.

Global growth forecasts

The IMF's October 2019 update on the world economy warned of a 'synchronised slowdown' and 'precarious outlook' with global growth estimated as 3.0% for 2019, the lowest since the financial crisis, with 3.4% for 2020. These growth figures are further downgrades from the IMF's April outlook because of rising trade barriers and increasing geopolitical tensions. The major country growth figures for 2019/2020 are US 2.4/2.1%, Euro Area 1.2/1.4%, Japan 0.9/0.5% and China 6.1/5.8%. However, the latest IMF growth estimates are still in most cases significantly more optimistic than the OECD's September outlook which saw global growth of 2.9% for 2019 and 3.0% for 2020 with the US at 2.4%/2.0%, the Eurozone 1.1%/1.0% (with the German government recently cutting its forecast for 2020 to 1%), Japan 1.0%/0.6% and China 6.1%/5.7%. In respect of China, Brookings Institution research reveals that Beijing statisticians do not correct inflated local figures so China's economy is 12% smaller than official figures suggest. Furthermore, Brookings found that China's growth rate has been overstated by around 2% in recent years so the 6.1/5.7% estimate quoted above may really be 4.1/3.7%. The OECD comments that the global outlook has become 'increasingly fragile & uncertain' with subdued GDP growth and global trade contracting.

It is apparent that the 0.1% increase predicted by the OECD for world 2020 growth depends on several fair winds most of which are looking increasingly doubtful. These include financial market sentiment remaining supportive, the Eurozone stabilising, stressed emerging market economies stabilising, China applying policy stimulus, US/China trade tensions not escalating, no disorderly Brexit and no substantial rise in oil prices. The risks to global growth are therefore clearly on the downside.

Oil prices

A substantial rise in oil prices can reduce global growth as happened with the oil crises of the 1970s. The situation is better now both because of the large output from US fracking (which makes the world less dependent on Middle East oil) and the greater energy contribution now made by renewables. The oil price (Brent crude) was in the range $71-80 from May to October 2018, fell sharply from October to December and then stayed in the range $60-74 from January to September 2019. However, the attack on Saudi Arabia's oil fields and processing facilities in September, reduced global output by around 5% and caused a sharp spike in oil prices in mid-September although the price was back around $60 in late October. This attack provided a warning that serious conflict in the Middle East and/or blockage of the Strait of Hormuz could substantially reduce oil supplies. That is another downside risk for the global economy.

Trade tensions

The US/China trade tensions arose because the US felt that US companies were treated less fairly in China that Chinese companies were in the US where they raise substantial sums on US stock markets. Specific US concerns include asymmetrical tariffs, government subsidies to Chinese companies, restrictions on foreign investment in Chinese companies and the requirement that US companies are forced to hand over technology to Chinese partners. In addition, China does not enforce protection of US intellectual property rights (IPR) and fails to curb gross Chinese piracy of branded and copyrighted goods. The US claims theft of its intellectual property including by state-sponsored hacking. Both IPR theft and forced technology transfer are against WTO rules. Nor are these new problems – for example, the Obama administration in 2010 challenged illegal Chinese government subsidies to Chinese alternative energy companies.

By October, the US had put tariffs on $550bn of Chinese exports with China placing retaliatory tariffs on $185bn of US exports. The difference reflects the trade imbalance which the US says reflects the problems listed above together with currency manipulation by China. It is still possible that the dispute can be settled by negotiation and, at the time of writing (October) there is talk of a Phase I mini-agreement possibly being signed soon. However, if there is no early agreement or a very modest one, there will be further risks to global growth. These risks would increase due to trade friction between the US and EU caused by the recent WTO ruling authorising the US to put 100% tariffs on $7.5bn of EU goods because of 'illegal' EU support to Airbus. The EU is expecting a WTO decision in early 2020 over its contention that the US gave illegal aid to Boeing.

Summary

The discussion in the sections above shows that the risks to the global economy are now almost all to the downside and this will still be true even if there is a preliminary Brexit deal and a Phase I mini-agreement between the US and China. Company CEOs are therefore likely to be planning their 2020 budgets under the assumption of slowing growth with higher tariffs for at least some major countries and are therefore likely to focus on cost-cutting. In this environment many R&D directors are likely to find it difficult to persuade their CEOs to increase 2020 R&D budgets significantly. Such an outcome would be mistaken since history shows that those companies that raise R&D investment in difficult economic times to fund worthwhile projects reap the benefits during the next upturn. This is because the new and improved products and services such companies launch as a result of their increased R&D give them a competitive edge as their markets improve and sales rise.

1.1.2 Sustainability goals

Growing sustainability concerns comprise a wide range of issues from climate change and environment protection to human rights and governance. These issues are at the top of policy agendas such as the United Nations' 2030 sustainable development goals (SDGs)[7], the Paris Agreement[8] and the EU environment and climate action framework[9].

Two key EU policy tools in this context are the EU Taxonomy[10] that allows corporations and investors to identify businesses opportunities that contribute to environmental policy objectives and the Circular Economy Action Plan[11] aimed at boosting growth and investment while developing a carbon-neutral, resource-efficient and competitive economy.

Companies have a key role to play to address sustainability challenges as is increasingly recognised by managers and investors[12]. Business leaders are becoming aware of the importance of delivering not only profits and wealth creation but of contributing positively to society. In line with this, there are a number of initiatives aimed at setting standards to measure effectively companies' contributions to sustainability. For example, in a similar vein to the UN's SDGs, there is the Global Compact Initiative encouraging businesses to adopt sustainable policies and to report on their implementation and the Global Reporting Initiative (GRI) aiming to help businesses to understand and communicate their impacts on ESG issues (environment, social and governance). Another organisation is the Sustainability Accounting Standards Board (SASB) which has developed standards adapted to each sector and industry to connect businesses and investors on the financial aspects and *materiality* of ESG issues raised by the sector/industry. In some countries companies are required to include sections on corporate social responsibility and corporate governance in their annual reports.

Beyond the need to meet corporate responsibility standards or to comply with stricter regulations, companies can take advantage of the many business and investment opportunities arising from the need to adopt more sustainable business practices. In particular, tackling environmental problems creates market needs requiring new innovative and technological solutions. For example, digital and communication technologies, artificial intelligence (AI), big data, nanotechnology, internet of things and advanced manufacturing show great potential for the development of clean technologies[13]. AI offers a wide range of applications for environment protection, health care and agriculture; Nanotech is applied for developing new batteries, water treatment tech, desalination processes and lower cost clean energy. See specific examples of company innovations aimed at improving sustainability issues in the next section.

1.1.3 Technology trends

This section highlights key technological trends being developed by *Scoreboard* companies and gives examples of the role of companies' R&D in achieving sustainability goals.

The two main technological areas showing both fast growth and a wide range of applications are biotechnology and software/AI (artificial intelligence). They are supported by developments in new materials and materials processing

[7] The 17 Sustainable Development Goals are a blueprint to achieve a better and more sustainable future for all (https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

[8] Agreement signed by 195 countries within the United Nations Framework Convention on Climate Change (UNFCCC), dealing with greenhouse-gas-emissions mitigation, adaptation, and finance, signed in 2016.

[9] The Treaty of the Functioning of the European Union requires "Environmental protection requirements must be integrated into the definition and implementation of the Union's policies and activities, in particular with a view to promoting sustainable development".

[10] Financing a Sustainable European Economy 'TAXONOMY', Technical Report, June 2019.

[11] COM (2019) 190 final.

[12] The Investor Revolution, Eccles R.G. and Klimenko S., Harvard Business Review, July 2019.

[13] Financing for Sustainable Development Report 2019, United Nations, New York 2019.

such as novel battery materials, graphene products and 3D printing. In addition, global R&D investment has led to a whole range of new products, processes & services that are contributing to most of the UN's 17 sustainable development goals. We briefly discuss these four topics below.

Artificial intelligence and quantum computing

AI has an increasing number of applications in a wide range of sectors. Examples include agriculture (e.g. predicting ripening time for crops or automated greenhouses), education (e.g. personal AI tutors, adaptive learning), finance (e.g. algorithmic trading, data mining, robo-advisers), health (e.g. AI diagnostics, data mining of medical records, companion robots for elderly care), cybersecurity, intelligent robots and transport (e.g. self-driving cars, optimized traffic systems). Just one example is the use of AI in diagnosing idiopathic pulmonary fibrosis from CT scans – the AI software equals the performance of a group of 91 world-leading specialists. And DeepMind's AI is better than experts at diagnosing eye diseases. Many *Scoreboard* companies are working on one or more of these AI applications.

Some AI applications are beyond the capabilities of conventional computers and this is one of the drivers for work on quantum computers. For example, Google AI Quantum is developing quantum processors and quantum algorithms for the AI of tomorrow. Google's prototype *Sycamore* quantum computer recently achieved 'quantum supremacy' when it solved a test problem in 3 minutes that would take most supercomputers 10,000 years. There is, however, a long way to go before quantum computers can solve real-world problems. But the hope is that quantum computers will revolutionise chemistry, materials science and pharmaceuticals by performing simulations that are too complex for classical computers and hence enabling new drugs and new materials. There will also be applications in encryption, code breaking and financial modelling.

Biotechnology

The rapid development of biotechnology has led to advances in agriculture, animal genetics and a series of new treatments that are saving lives and giving new hope to seriously ill patients. Examples are **immunotherapy**, **gene therapy** and **stem cell therapy**. Cancer immunotherapies remove the cloak of invisibility which cancer cells use to hide from the body's immune system and thus enable the body's immune system to attack the cancer. The first modern cancer Immunotherapy was Bristol-Myers Squibb's Yervoy first approved by the FDA in 2011 to treat metastatic melanoma. Since then a growing range of other immunotherapies have been approved to treat a wide range of cancers. The FDA has granted new approvals for seven cancer immunotherapies in the last year or so. **Gene therapy** is the process of replacing missing, defective or mutated genes and is particularly useful for treating inherited diseases. The EMA (European Medicines Agency) recommended approval of UniQure's Glybera in 2012 for the treatment of the rare disease LPLD (lipoprotein lipase deficiency). Since then interest has intensified with 372 clinical trials of gene therapies ongoing in Q1 2019 and 9% of these in Phase III.

Stem cells are cells that have the ability to develop into most other types of cell in the body and stem cell therapies are another very promising area. The only FDA approved stem cell treatment is the use of cord blood products for patients suffering from blood or immune disorders. Also, bone marrow stem cell transplants are used in the treatment of blood disorders such as lymphoma and leukaemia. Osiris's Prochymal was approved in 2012 to treat graft-vs-host disease, a severe complication of bone marrow transplants. Promising new stem cell clinical trials have been reported for heart tissue regeneration, eye tissue regeneration (e.g. treating macular degeneration and retinitis pigmentosa) and skin tissue regeneration. Imperial college, London reported in June that a 3cmx2cm patch grown in a lab from a rabbit's own stem cells had turned itself into healthy working heart muscle and that it also released chemicals that repair existing heart cells. It is hoped to start patient trials in the next two years.

New Materials

The Nobel Prize for chemistry this year was awarded for work on developing the first lithium ion battery – batteries that now power everything from smartphones to electric cars. New materials R&D includes work on improved lithium batteries, solid state batteries, fuel cells, applications of graphene, nanomaterials, high temperature superconductors, higher efficiency photovoltaics and 4Dprinting (3Dprinting with multi-materials to make objects that can adapt to their environment). The cost/Megawatt of installed solar has fallen by a factor of five over the last 8 years and electric vehicle battery costs are expected to more than halve from 2015 to 2025. An example of a company active in some of these areas is Johnson Matthey which has developed next generation high energy density lithium battery electrodes and is also working on hydrogen-powered fuel cells as well as improved vehicle catalysts. And Versarien PLC is developing graphene materials & applications such as graphene-enhanced composite materials and graphene ultracapacitors.

The role of R&D in achieving the UN's sustainable development goals

The aim of this section is to give examples of technologies and companies in the *Scoreboard* (or those likely to join it as they grow) which contribute to the UN's sustainable development goals. The two key technologies of AI and biotech feature in many of the SDGs. We start with the second UN SDG, zero hunger.

1. **Zero hunger (UN goal 2)**: The key R&D contribution here is the use of biotechnology in animal and plant genetics to improve farming productivity. Examples are genetically improved crops with higher yields that are drought resistant and can be grown on poorer soils. In addition, improved animal genetics can make farm animals resistant to disease and provide higher yields. Examples of companies involved include BASF (which acquired Monsanto's seeds business from Bayer) for crops and Genus for animal genetics. Then there are companies such as Gamaya using AI and remote sensing to increase farming efficiency.

2. **Good health & wellbeing (UN goal 3)**: this area includes biotechnology, health and pharmaceuticals which are together enabling people to live longer, healthier lives. Big advances have been made in treating cancer with immunotherapy drugs and R&D on new antibiotics will be essential in protecting populations against the growing threat of antibiotic-resistant superbugs. Examples of major companies in this area are Medtronic (health devices), Amgen & Gilead Sciences (biotechnology) and AstraZeneca, Bristol-Myers Squibb, Merck and Novartis (biopharmaceuticals). The last four companies (and several others) all have approved cancer immunotherapy drugs for treating a wide range of different cancers. There are 9 Phase III clinical trials in progress for new antibiotics against WHO critical threat pathogens with Merck & Co having applied to the FDA for approval of a tenth.

3. **Quality education (UN goal 4)**: AI enables more personalized education and training, can bring material prepared by the best educators to wide audiences and can lower costs. Companies such as Knewton (adaptive learning technology for higher education), Century Tech (personalized learning plans), Blippar (computer vision & intelligence and augmented reality to enhance the learning experience), Learning Technologies Group (online learning & talent management) and CTI (customisable textbooks) are examples.

4. **Clean water & sanitation (UN goal 6):** Key areas here are water treatment and purification, wastewater and desalination. Given the increasing demand for clean water and the scarcity of water in some areas of the world, desalination is likely to become more and more important. Reverse osmosis is one of the key technologies for desalination and is the subject of much R&D. For example, Lockheed Martin has developed a graphene composite reverse osmosis system which it claims will be 'a game changer' with higher efficiency and lower cost than existing systems.

5. **Affordable & clean energy (UN goal 7):** The major role for R&D here is in reducing the cost of clean renewable energy to enable it to play an increasing role in transport and energy generation and increase

its penetration in poorer countries. R&D is key to the development of larger and more efficient wind turbines that can generate more energy. GE claims the world's largest – a 12MW turbine with a 220m rotor diameter. R&D is also enabling increases in the efficiency of solar panels; this is currently just over 20% for commercial panels from SunPower, LG, REC Solar & Panasonic but concentrator photovoltaics have achieved over 40% with the EU-funded CPV-Match project achieving module efficiencies of 41.4%. There is also promising work using carbon nanotube composites. Many companies are raising the percentage of renewable energy they use – Google, for example, claimed that it had reached its target of using 100% renewable energy by 2017. R&D on better batteries for electric cars will increase range and lower cost to increase clean energy electric cars' market share and make them a more viable option for poorer countries. In the long-term fusion power may provide a massive new source of clean energy.

6. **Decent work & economic growth (UN goal 8):** R&D can assist with this objective by creating new products offering new employment opportunities, by increasing productivity to accelerate economic growth and by providing products to improve safety at work. Mobile/smart phones are an example of a new product area, robotics and IT (companies such as Fanuc, Teradyne, SAP and Microsoft) are technologies that have increased productivity and Halma is just one example of a company involved in process and environmental safety.

7. **Industry, innovation & infrastructure (UN goal 9):** The aim here is to build resilient infrastructure, promote sustainable industrialisation and foster innovation. The R&D *Scoreboard* is a key tool in raising awareness of R&D investment (innovation) and in enabling lagging companies in each sector to see the higher percentages of sales that their more innovative competitors are investing in R&D. Some of them may then increase their own R&D investments with the aim of developing new products and services to become more competitive. With over 80% of world trade volume going by sea, efficient maritime transport is a key enabler of trade & globalisation. In this context, AI is being used to improve logistics and experiments are in progress on autonomous shipping (the first successful autonomous crossing of the English Channel with its busy shipping lanes was reported in May 2019 by the unmanned British ship Sea-Kit Maxlimer).

8. **Sustainable cities & communities (UN goal 11):** R&D can contribute to this goal in two main ways – improving air quality in cities through the development of affordable electric vehicles and less use of fossil fuels for heating buildings aided by designing buildings that are much more energy efficient and, in some cases, of zero net energy. For example, NetZero Buildings Limited uses off-site manufacture to build efficient schools and homes and has to date completed over 100 school projects.

9. **Responsible consumption & production (UN goal 12):** The key actions here are the more efficient use of resources, reduction of waste and more recycling. Good design and process R&D can reduce the amount of material used during production and reduce the associated waste and scrap. Accurate measurement during production plays an important part in this. Companies involved range from Renishaw (precision metrology) to Johnson Matthey (recovery of precious metals from exhaust catalysts). Responsible consumption is reflected in the targets many companies have adopted to increase the percentage of renewable energy they use. Over 90 global companies have committed to the RE100 campaign to reach a 100% renewables target. Vestas reached this target in 2013, SAP in 2014, Google & Wells Fargo in 2017.

10. **Climate action (UN goal 13):** R&D has a major role in reducing greenhouse gas emissions. Examples are the development of cost-effective electric vehicles to reduce transport emissions, more efficient wind and solar energy generation to reduce the need to use fossil fuels for transport and energy generation. R&D is lowering the cost of solar power and is extending the range and lowering the cost of electric cars. Work is well advanced on short-range electric aircraft and electric air taxis (both battery and hydrogen-fuel cell prototypes). In total 150 companies are working on aspects of electric air taxis. And hydrogen fuel cell trains are planned to enable dirty diesels to be phased out. In agriculture, which is estimated to cause around 9% of greenhouse emissions, meat substitutes reduce animal emissions of methane which is 23 times more

polluting than CO2. Examples of companies involved include Vestas Wind systems, Tesla and many major car manufacturers (electric vehicles), Beyond Meat and Impossible Foods (making plant-based 'meat' – and Burger King sells the Impossible Burger). It is estimated that plant-based 'meats' require one-twentieth of the land, one quarter of the water and one-twelfth of the fertilizer needed for animal meat products. R&D to extend product lives also generates considerable savings – for example, extending the life of European smartphones by one year would save 2 million tonnes of carbon emissions. And emissions from homes can be reduced by better insulation, electrification and air & ground force heating.

11. **Life below water (UN goal 14):** Biotechnology is being used in the sustainable development of aquaculture, fisheries and also in the food industry. This contributes to meeting the increasing demand for seafood and to meeting the aims of 1 above (zero hunger). Biotech is helping to improve the quality and quantity of fish reared in aquaculture through induced breeding, genetic modification and enhanced disease resistance. Much of this research is carried out by Institutes such as Nofima AS, the Norwegian institute for fisheries and aquaculture. One of its board members is the MD of Milarex, the seafood company.

12. **Life on land (UN goal 15):** With world consumption of materials expanding it is important not to over-extract resources or damage the environment. Responsible consumption and production (9 above) are important for this as is the reduction of emissions and pollution (5 & 8 above). More efficient farming (see 1 above) and plant-based 'meats' (see 10 above) together mean less land for the same food output and should also help to protect biodiversity by reducing the demand to clear rain forests and other 'wild' areas for farming use. Climate change is leading to more volatile weather patterns and AI is now being used to predict flash flooding years before it occurs so that preventive measures can be taken and building permission refused for land at risk. Responsible production (9 above) and increased recycling both help to reduce resource extraction as does the use of renewable energy to replace fossil fuels.

1.2 | Characterisation of the R&D investment

This section outlines the main characteristics of the 2019 *Scoreboard* dataset and highlights, in particular, the concentration of industrial R&D at company, industry and country levels.

The top 2500 global companies each invested more than €30 million in R&D in 2018, accounting together for a total of €823.4 billion.

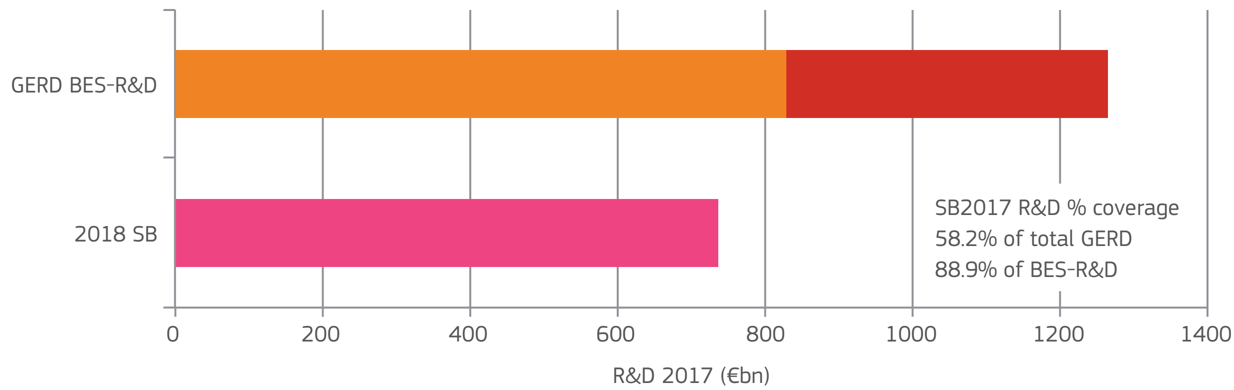

FIGURE 1.1: COMPARISON OF R&D FIGURES OF THE *SCOREBOARD* AND TERRITORIAL STATISTICS.
Note: Total R&D expenditure (GERD) and R&D financed by the business sector (BES-R&D) in 2017 (red dark overlapping bar represent the BES-R&D).
Sources: Latest figures reported by Eurostat including most countries reporting R&D.
The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The amount of R&D investment by these 2500 companies is equivalent to 54% of the total expenditure on R&D worldwide (GERD) and about 90% of the R&D expenditure financed by the business sector worldwide.

This is illustrated in Figure 1.1 where the latest 2017 territorial statistics are compared with the corresponding figures from the previous 2018 *Scoreboard* (GERD €1264.7bn, of which R&D financed by the business enterprise sector "BES-R&D" was €828.8bn and the 2018 *Scoreboard* €736.4bn or 88.9% of global business-financed R&D).

The 2500 company global 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 €8.5 million in R&D in 2018. Of these 1000, 551 appear in the world top 2,500 and another 449 are added with R&D between €8.5m and €30m. The total R&D for the EU1000 is €215.6bn in 2018 which is only €7.2bn larger than the €208.4bn total for the 551 EU companies included in the global 2500.

This additional sample of 1000 companies is analysed separately in chapter 4.

1.2.1 Companies' distribution by country

The 2019 *Scoreboard* comprises companies with headquarters in 44 countries of which 18 are member states of the EU. The sample includes companies based in the EU (551), the US (769), China (507), Japan (318), Taiwan (89), South Korea (70), Switzerland (58), India (32), Canada (28), Israel (22) and a further 17 countries (see Table 1.1 and Figure 1.2a). Note that just 5 EU countries account for 72% of the EU companies and 5 non-EU countries account for 90% of the non-EU companies. If we take into account their subsidiaries, *Scoreboard* companies are present virtually in every country of the world (Figure 1.2b).

Number of companies by country			
EU		non-EU	
Germany	130	US	769
UK	127	China	507
France	68	Japan	318
Netherlands	39	Taiwan	89
Sweden	33	South Korea	70
Denmark	30	Switzerland	58
Ireland	27	India	32
Italy	26	Canada	28
Finland	17	Israel	22
Austria	17	Australia	12
Spain	14	Norway	10
Belgium	12	Brazil	6
Luxembourg	4	Singapore	6
Greece	2	Turkey	5
Portugal	2	New Zealand	3
Hungary	1	Saudi Arabia	3
Slovenia	1	South Africa	2
Poland	1	Further 9 countries	9
Total	551	Total	1949

TABLE 1.1: DISTRIBUTION OF COMPANIES BY COUNTRY.
Note: the 2500 companies all have R&D investment above €30 million.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

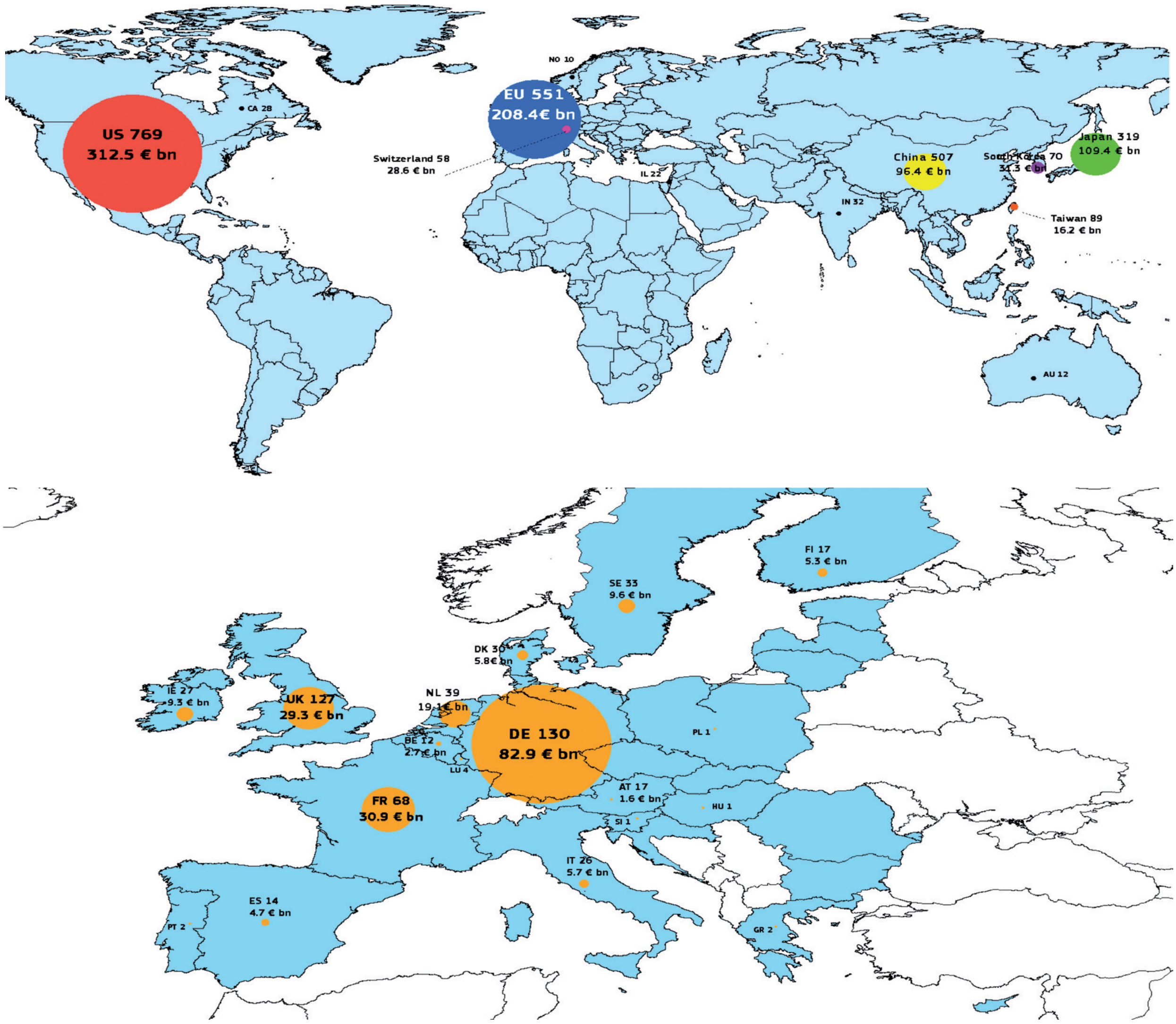

FIGURE 1.2A: DISTRIBUTION OF THE 2500 COMPANIES IN THE 2018 *SCOREBOARD* BY HEADQUARTERS COUNTRY.
Note: Number of companies indicated besides the country code (the world map includes only countries with at least 10 companies). R&D is represented with a bubble whose size is proportional to R&D in 2018 in the country.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

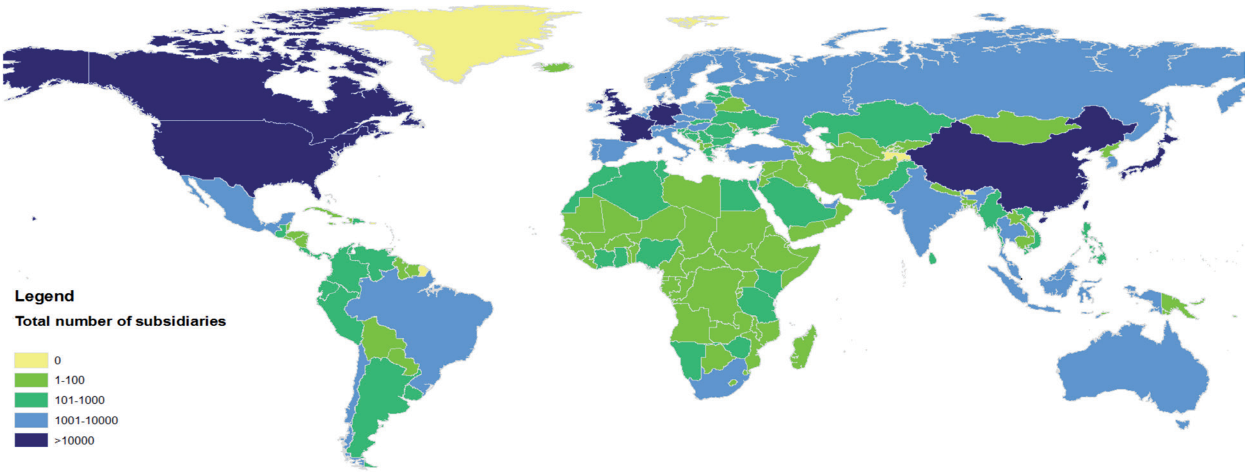

FIGURE 1.2B: DISTRIBUTION OF THE SUBSIDIARIES OF THE 2500 PARENT COMPANIES IN THE 2019 *SCOREBOARD*.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

1.2.2 Companies' aggregation by industrial sector

Assigning companies to industrial sectors according to existing classification systems is not a straightforward task. In fact, sector definitions often 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 taxonomy such as the International Classification Benchmark (ICB)[14].

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 to describe the sectoral distribution of companies' R&D. Tables 1.2 and 1.3 describe two typical classifications of industrial activities applied in the *Scoreboard*. The R&D is highly concentrated by sector, the 76.6% of total R&D is accounted for by just four of the sectors in table 1.2 (automotive, health, ICT producers & ICT services) and in Table 1.3, the high and medium-high R&D-intensity sectors account for 90% of total *Scoreboard* R&D.

Please note that these broad industrial classifications are not sufficient to characterise the technological profile of companies. To analyse the technological development of companies we need additional indicators comprising detailed technological classifications, for example patent or bibliometric analyses. This is shown in this *Scoreboard* edition, in chapters 5, 6 and 7, where the patent portfolios of companies are examined to describe their activities in technological terms. For example, the focus of chapters 6 and 7 on environmental technologies shows how the companies from regulatory-driven sectors such as those related with transport and energy activities are more active in developing such technologies.

Industrial Sector	Sector classification ICB4 digits	N of firms	% of total R&D
Aerospace & Defence	Aerospace; Defence	50	2.5
Automobiles & other transport	Auto Parts; Automobiles; Commercial Vehicles & Trucks; Tires	185	17.2
Chemicals	Commodity Chemicals; Specialty Chemicals	129	2.7
Health industries	Biotechnology; Health Care Providers; Medical Equipment; Pharmaceuticals	515	20.7
ICT producers	Computer Hardware; Electrical Components & Equipment; Electronic Equipment; Electronic Office Equipment; Semiconductors; Telecommunications Equipment	477	23.3
ICT services	Computer Services; Internet; Software	320	15.4
Industrials	Aluminium; Containers & Packaging; Diversified Industrials; Industrial Machinery; Iron & Steel; Nonferrous Metals; Transportation Services	295	5.5
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	529	12.7
Total		2500	100

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 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

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

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	1142	54.9
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	932	35.1
medium-low	Alternative Energy; Beverages; Fixed Line Telecommunications; Food Producers; General Retailers; Media; Oil Equipment, Services & Distribution; Tobacco	152	3.5
low	Aluminium; Banks; Construction & Materials; Electricity; Food & Drug Retailers; Forestry & Paper; Gas, Water & Multi-utilities; Iron & Steel; Life Insurance; Mining; Mobile Telecommunications; Nonferrous Metals; Nonlife Insurance; Oil & Gas Producers; Real Estate Investment & Services; Transportation Services	274	6.5
Total		2500	100

TABLE 1.3: INDUSTRIAL CLASSIFICATIONS APPLIED IN THE *SCOREBOARD* – THE 4 SECTOR GROUPS OF DIFFERENT R&D INTENSITY.
Note: This classification takes into account the average 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 for 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 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

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. The top3 companies are the same as last year in each sector except for Chemicals: BASF was first last year, followed by DOWDUPONT and MONSANTO (acquired by BAYERN in 2018).

Industry	EU	non-EU	Total
Aerospace & Defence	16 (32.0%)	34 (68.0%)	50
Automobiles & other transport	46 (24.9%)	139 (75.1%)	185
Chemicals	21 (16.3%)	108 (83.7%)	129
Health industries	110 (21.4%)	405 (78.6%)	515
ICT producers	63 (13.2%)	414 (86.8%)	477
ICT services	49 (15.3%)	271 (84.7%)	320
Industrials	82 (27.8%)	213 (72.2%)	295
Others	164 (31.0%)	365 (69.0%)	529
Total	551 (22.0%)	1949 (78.0%)	2500

TABLE 1.4: DISTRIBUTION OF GLOBAL 2500 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 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The 551 EU companies comprise 22% of the total of 2500 global companies. The industry groups with higher percentages than this are Aerospace & Defence, Automobiles, Industrials and Others. ICT producers have a much lower percentage while Chemicals and ICT services are lower and Health is similar. The reverse is true for non-EU with ICT producers, ICT services and Chemicals, for example, having much higher percentages than the overall 78% while automotive and industrials are somewhat lower and aerospace & others significantly lower.

Health industries		Automobiles & other transport	
ROCHE	Switzerland	VOLKSWAGEN	Germany
JOHNSON & JOHNSON	US	DAIMLER	Germany
MERCK US	US	TOYOTA MOTOR	Japan
ICT services*		**ICT producers**	
ALPHABET	US	SAMSUNG	South Korea
MICROSOFT	US	HUAWEI	China
FACEBOOK	US	APPLE	US
Aerospace & Defence		**Industrials**	
AIRBUS	Netherlands	GENERAL ELECTRIC	US
BOEING	US	PHILIPS	Netherlands
UNITED TECHNOLOGIES	US	HONEYWELL	US
Chemicals		**Others**	
DOWDUPONT	US	PANASONIC	Japan
BASF	Germany	SONY	Japan
SUMITOMO CHEMICAL	Japan	LG ELECTRONICS	South Korea

TABLE 1.5: TOP 3 COMPANIES BY R&D FOR THE MAIN INDUSTRIES COMPRISED IN THE 2019 *SCOREBOARD*.
*Amazon would be included as #1 in this group if it had reported its technology investment separately rather than combining it with 'content' (see box 3.1 in chapter 3 for more details of this).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

1.2.3 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 all the *Scoreboards* since the first in 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%, 52% and 80%.

There are 7 companies having an R&D investment of more than €10bn, 73 more than €2bn and 159 more than €1bn. The latter group of companies comprises 41 from the EU, 58 from the US, 26 Japanese, 19 Chinese, 5 each from South Korea & Switzerland, 3 from Taiwan and 1 each

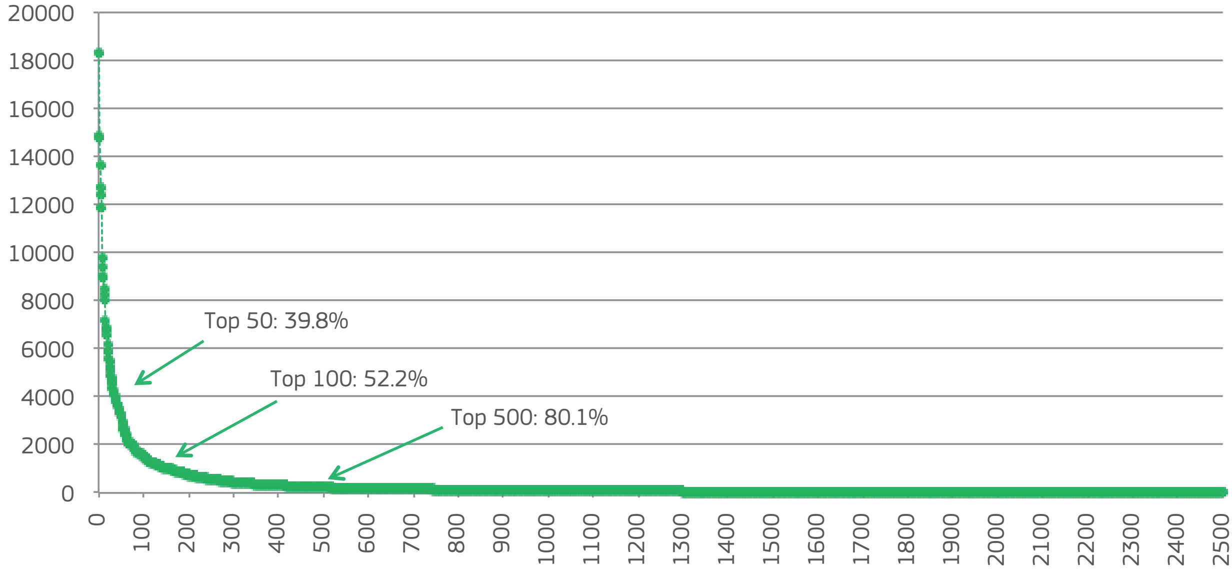

FIGURE 1.3: COMPANIES OF THE 2019 *SCOREBOARD* RANKED BY R&D.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

from India and Israel. The majority of top 100 companies (82) operate in three sectors: 26 in Health industries (EU 9), 22 in Automobiles & other transport (EU 11) and 34 in ICT industries (EU 5).

R&D is very much concentrated by country and world region. This is illustrated by Figure 1.4 which shows the R&D shares of the main countries and regions.

The top 3 (US, China, Japan), top 5 and top 10 countries account respectively for 63%, 77% and 92% of the total R&D investment. Within the EU, the R&D is even more concentrated, the top 3 (Germany, UK, France), top 5 and top 10 countries account respectively for 69%, 82% and 97% of the total R&D invested by the companies based in the 18 EU countries represented in the *Scoreboard*.

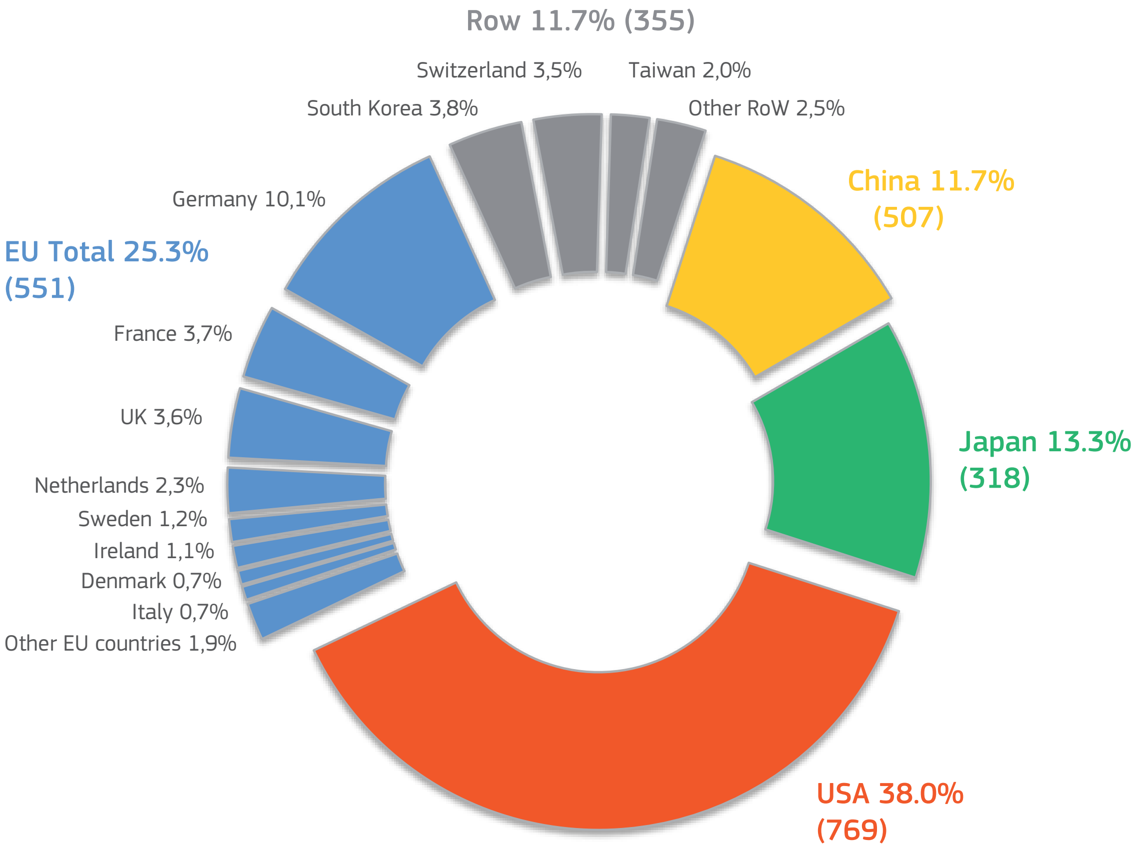

FIGURE 1.4: R&D INVESTMENT BY THE 2500 COMPANIES BY MAIN COUNTRY/REGION (% OF TOTAL €823.4BN).
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

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 77% of the total R&D of the 2500 companies. The main contributions to the total *Scoreboard* R&D are:

- By EU companies: 46% to Automobiles & other transport, 46% to Aerospace & Defence and 27% to Health industries;
- By US companies: 67% to ICT services, 49% to health industries, 41% to ICT producers and 39% to Aerospace & Defence;
- By Japanese companies is 34% to Chemicals, 24% to Automobiles & other transport and 21% to Industrials;
- By Chinese companies is 20% to Industrials, 15% to ICT producers and 23% to other sectors.

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:

- 67% within the EU (Automobiles & other transport 31%; Health industries 22% and ICT producers 14%);

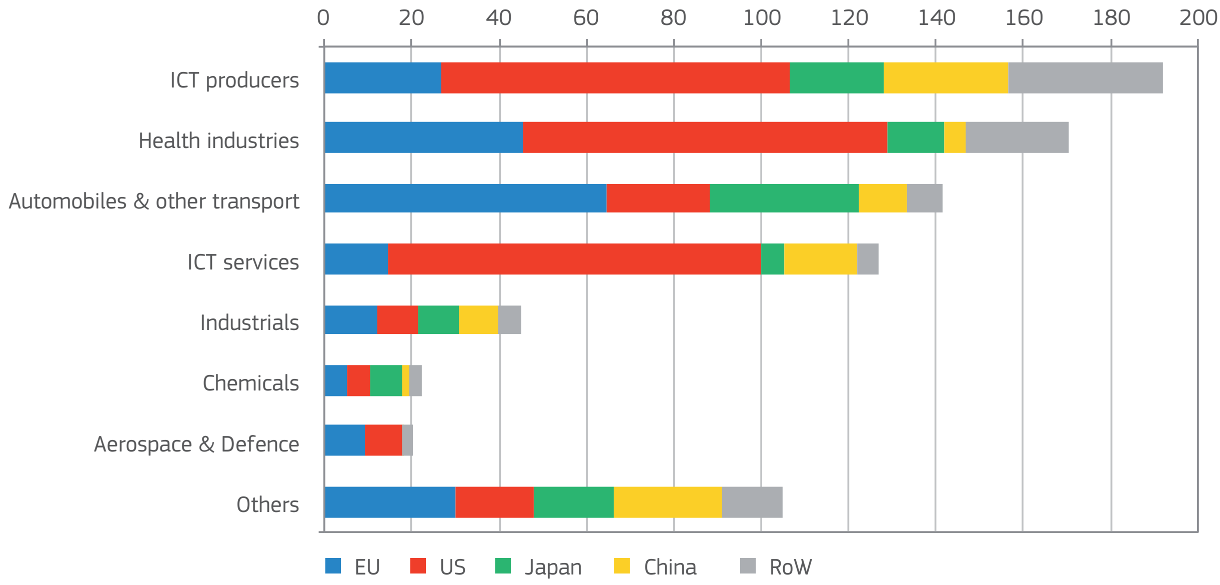

FIGURE 1.5: R&D INVESTMENT BY THE 2500 COMPANIES BY INDUSTRY AND MAIN COUNTRY/REGION (€BN).
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

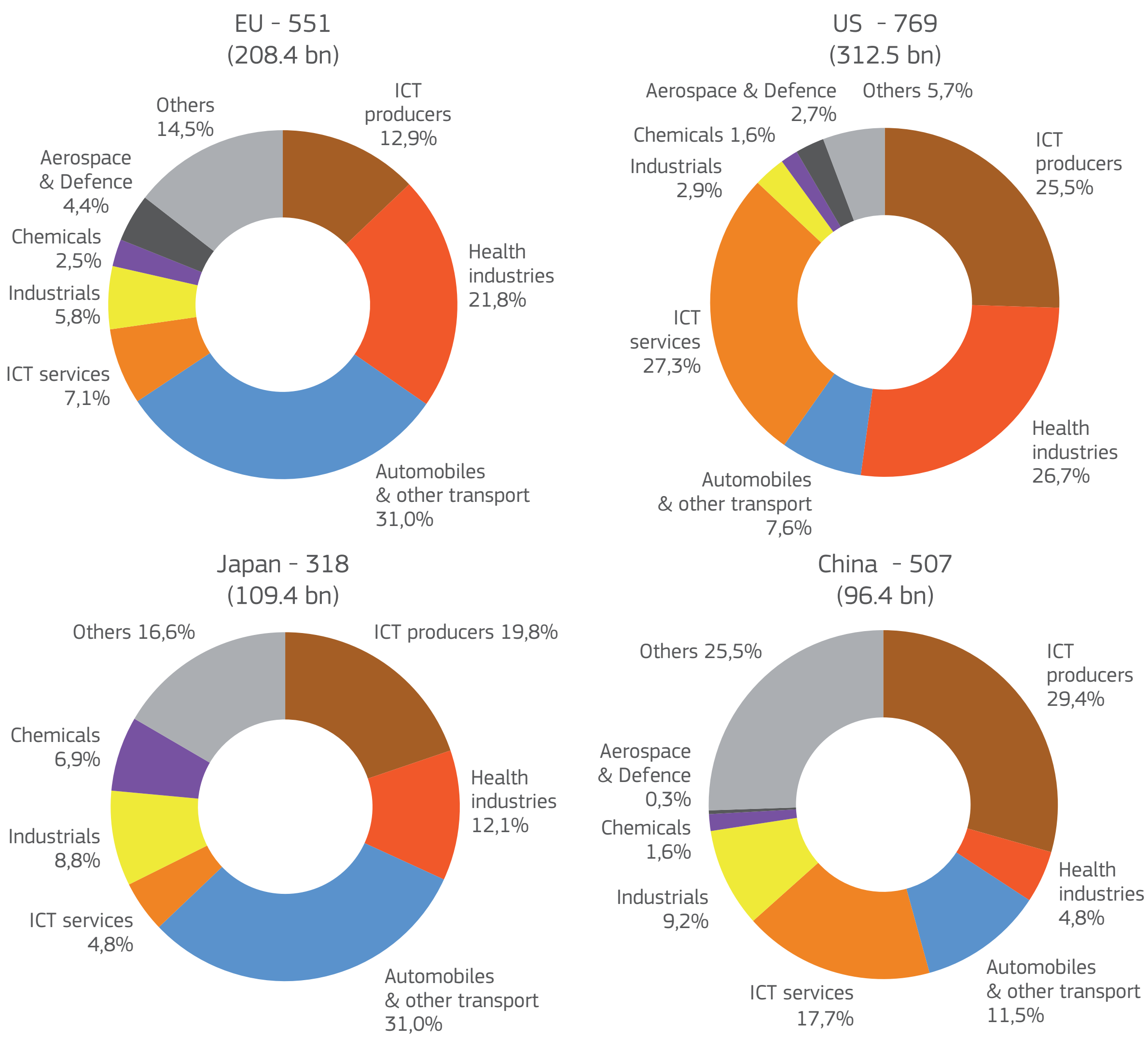

FIGURE 1.6: R&D SHARES OF INDUSTRIAL SECTORS WITHIN MAIN COUNTRIES/REGIONS
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

- 79% within the US (Health industries 27%; ICT services 27% and ICT producers 25%);
- 68% within Japan (Automobiles & other transport 31%; ICT producers 20% and Others 17%);
- 73% within China (ICT producers 29%; Others 26% and ICT services 18%).

Note the similarities in sector structure between the EU and Japan (both have 31% automotive) and between the US and China (both have over 50% in ICT producers & services). The proportion of US R&D in ICT services would be even larger if Amazon could have been included in the *Scoreboard* (see Box 3.1 in chapter 3 for further details of this).

Whereas the top five companies in the EU and the US both account for 20% of the total R&D of those regions, the top five in China and Japan account for 25%. The top five companies in the EU and Japan contain four from the Automobiles sector whereas the top five from the US have four from the ICT sector.

2

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

2 Global R&D trends by industry and world region

The ongoing global technology race intensified in 2018 with US and Chinese companies increasing sharply their R&D investments by 10.3% and 26.7% respectively and EU companies following behind with 4.7%.

Over the past 10 years, the rapid R&D growth in the ICT, health and Automotive industries has reshaped the global industrial structure with EU companies increasing their share in Automobiles and US and Chinese companies' increasing their share in the ICT industries. These changes are magnified by regional differences in R&D intensity where EU companies appear to be lagging compared to the US and are now challenged by their Chinese counterparts.

Two particular challenges are posed for the EU:

- EU's lead in medium-high tech may be eroded as ICT takes a higher proportion of the value added in sectors such as automotive with the advent of new developments such as electric self-driving cars.

- US' increasing leadership in health biotechnology which is the basis of more and more new drugs.

This chapter analyses the main trends in R&D and economic indicators for the world's top 2500 companies that each invested more than €30 million in R&D in 2018. The first part concentrates on the evolution of companies' main performance indicators over the previous year and the second section analyses the long-term performance of companies aggregated by industry and main world regions.

The 2500 companies are grouped into five main sets: the top 551 companies from the EU, 769 companies from the US, 318 from Japan, 507 Chinese companies and 355 companies from the Rest of the World group (RoW). The RoW group includes companies from Taiwan (89), South Korea (70), Switzerland (58), India (32), Canada (28), Israel (22) and companies based in a further 17 countries.

Companies are aggregated into 8 industrial sectors (defined in Chapter 1 – Table 1.2). More disaggregated information (at sector level, ICB 3-digits) is found in Annex A3 – Table A3.1, including the main statistics for the world 2500 sample.

2.1 | Changes in companies' indicators in 2018

In 2018, the 2500 companies as a whole increased significantly their R&D investments and showed good results across most performance indicators, especially in terms of net sales that have increased at a similar rate to the R&D investment. However, as shown in this chapter, companies' results vary greatly across world regions and industries. Tables 2.1 and 2.2 present the one-year change of main indicators for the whole set of companies by main region and country. Figure 2.1 provides an overview of the R&D investment by the main world regions and Figures 2.2 and 2.3 show the one-year change of R&D and net sales for the main world regions and industrial sectors[15].

[15] Data are aggregated into 8 industrial groups (defined in Chapter 1 – Table 1.2). More disaggregated information (at sector level, ICB 3-digits) is found in Annex A3 – Table A3.1, including main statistics for the world 2500 sample.

2.1.1 R&D trends

- Overall R&D investment continued to increase significantly in 2018 for the ninth consecutive year. The 2500 *Scoreboard* companies invested €823.4 billion in R&D, 8.9% more than in 2017, improving slightly on the increase of 8.6 % in the year before.

- Worldwide R&D growth was driven by the ICT services sector (+16.9%), followed by the ICT producers sector (+8.2%) and the Health sector (+7.6%). The lowest R&D growth was shown by Aerospace & Defence (+4.3%).

- The 551 companies based in the EU invested €208.3bn in R&D, an important increase in this period (+4.7%) but at a lower rate than in the previous year (+5.3%). The Japanese companies presented a lower R&D growth rate than their EU counterparts (+3.9%) and, as observed in the previous period, companies based in the US and China showed much higher R&D growth rates (+10.3% and +26.7% respectively).

- For the EU sample, the top 3 sectors in terms of their contribution[16] to R&D growth (weighed by R&D size) were Automobiles (+6.4%), Health industries (+3.8%) and ICT producers (+5.5%) with the lowest contribution was made by Chemicals (-2.6%), mostly due to the performance of the largest R&D investor of the group, BASF (-11.6%).

  Among the largest member states, German and French companies showed the highest R&D growth (3.6% and 10.6% respectively) whereas companies based in the Netherlands increased R&D by 2.7%.

- 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 17%, China 39%), ICT producers (US 9%, China 15%), Health industries (US 9%, China 57%). The poorest performance was shown by the Aerospace & Defence sector across most countries.

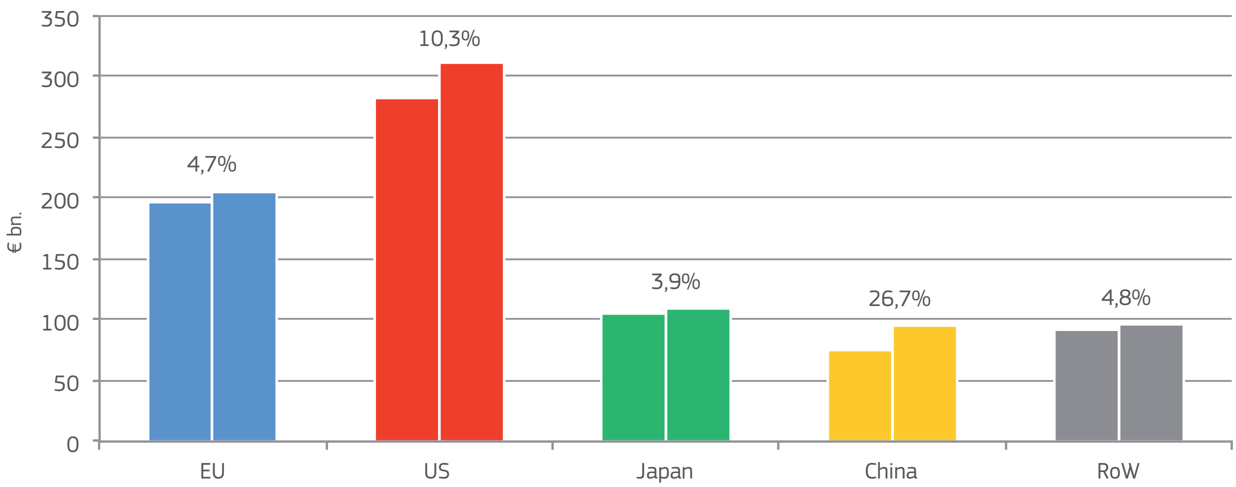

FIGURE 2.1: R&D INVESTMENT BY MAIN WORLD REGION IN THE LATEST TWO YEARS.
Note: Growth rates have been computed for 549 EU, 760 US, 318 Japanese, 487 Chinese and 353 RoW companies for with data are available for both years 2017 and 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.1.2 Trends in key economic indicators

- The overall growth of net sales continued the positive trend shown in the past year, increasing significantly at a similar rate to R&D investment (8.4%). As observed in 2017, *the growth in net sales was led by oil-related companies due to high oil prices, besides significant increases are shown also in ICT and the Industrials sectors.* The overall profits of companies continued to growth at a high rate (9.1%) also due to oil-related

[16] The net 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.

companies and, to a lesser extent, due to the ICT and Chemicals industries. In the same vein, companies' capital investments (Capex) continued the significant recovery seen in the previous year. Capex increases are observed especially in oil-related companies, ICT services and Industrials. The number of employees for the 2500 companies continued to increase at a moderate pace (3.6%).

- The net sales of the 551 companies based in the EU reached €6.0trillion, 4.7% more than in the previous year. Net sales increases were registered in most industries (except in Health). The best sales performance was shown in oil-related sectors but other sectors such as Industrials (5.9%), Aerospace & Defence (6.1%) and Chemicals (3.6%) showed also sales performance above the EU's average.

- The EU companies continued to increase modestly capital expenditures and profits (2.0% and 3.2% respectively). The 551 companies based in the EU employed 19.4 million, 3.9% more than the year before.

- The 769 companies based in the US increased significantly most financial indicators. Net sales increased by 10.4% and capital expenditures increased sharply by 15.8%. US companies showed also a high increase in profits (9.2%) and a fair increase in numbers of employees (4.1%) to reach 11 million.

- The 318 companies based in Japan raised net sales by 3.2% and capital expenditures by 9.0%. They decreased slightly profits (-0.8%) and maintained practically unchanged the number of employees at 9 million.

- The 507 Chinese companies showed a robust growth in net sales (14.5%) driven by PetroChina and China Petroleum and a significant increase in net profits (10.3%). Chinese companies showed better performance than their counterparts in terms of capital expenditure (17.4%) and in terms of growth in the number of employees (5.1%).

- In 2018 sales per employee (a rough measure of productivity) were highest for the US group at €438k followed by the RoW group (€424k), Japan (€352k), the EU (€311k) and China (€282k).

- Values of R&D and Net sales are positively correlated in the sample (54.1%). The value of this correlation for the EU companies is in line with the overall value (54.8%), while is above average for the US and especially Japanese companies (62.1% and 83.6% respectively). For the Chinese and RoW groups R&D and Net sales correlation is still positive but weaker (40.7% and 49.9%). These differences are probably due to the industries in which companies in these regions operate.

Factor	World 2500
R&D in 2018, € bn	823.4
One-year change, %	8.9
Net Sales, € bn	20351.6
One-year change, %	8.4
R&D intensity, %	4.0
Operating profits, € bn	2275.7
One-year change , %	9.1
Profitability, %	11.2
Capex, € bn	1317.3
One-year change , %	7.6
Capex / net sales, %	6.6
Employees, million	55.6
One-year change, %	3.6
Market Cap, € bn	27163.0
One-year change, %	9.2

TABLE 2.1: OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2019 *SCOREBOARD*.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	EU	US	Japan	China	RoW
No. of companies	551	769	318	507	355
R&D in 2018, € bn	208.3	312.5	109.4	96.4	96.7
World R&D share, %	25.3	38.0	13.3	11.7	11.7
One-year change, %	4.7	10.3	3.9	26.7	4.8
Net Sales, € bn	6037.9	4708.9	3151.2	3169.5	3284.1
One-year change, %	4.7	10.4	3.2	14.5	12.3
R&D intensity, %	3.4	6.6	3.5	3.0	2.9
Operating profits, € bn	618.0	640.8	245.2	237.2	534.5
One-year change, %	3.2	9.2	-0.8	10.3	21.8
Profitability, %	10.3	13.7	7.8	7.5	16.3
Capex, € bn	346.5	291.2	208.4	221.7	249.5
One-year change , %	2.0	15.8	9.0	17.4	-1.5
Capex / net sales, %	5.9	6.2	6.7	7.0	7.7
Employees, million	19.4	10.8	9.0	11.2	5.3
One-year change, %	3.9	4.1	1.0	5.1	2.5
Sales/employee, *k€*	311.2	437.8	351.9	282.5	424.2

TABLE 2.2A: OVERALL PERFORMANCE OF THE 2500 COMPANIES IN THE 2019 *SCOREBOARD*.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	Germany	UK	France	Netherlands*
No. of companies	130	127	68	39
R&D in 2018, €bn	82.9	29.3	30.9	19.1
World R&D share, %	10.1	3.6	3.7	2.3
One year change, %	3.6	3.6	10.5	2.7
Net Sales, €bn	1840.4	1265.4	1109.0	465.5
One year change, %	-0.3	12.7	6.6	1.5
R&D intensity, %	4.5	2.3	2.8	4.1

TABLE 2.2B: PERFORMANCE OF COMPANIES BASED IN THE LARGEST R&D COUNTRIES OF THE EU.
*The Netherlands companies include Airbus and Fiat Chrysler whose registered offices are in The Netherlands but whose major business activities are in other countries. These two companies account for 37% of Netherlands R&D in the Scoreboard.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Factor	South Korea	Switzerland*	Taiwan	India
No. of companies	70	58	89	32
R&D in 2018, € bn	31.3	28.6	16.2	4.6
World R&D share, %	3.8	3.5	2.0	0.6
One year change, %	8.0	4.3	5.2	-3.2
Net Sales, € bn	999.3	396.8	551.1	367.6
One year change, %	4.1	6.5	7.1	22.8
R&D intensity, %	3.1	7.2	2.9	1.3

TABLE 2.2C: PERFORMANCE OF COMPANIES BASED IN THE LARGEST COUNTRIES OF THE ROW GROUP.
Note: The RoW group comprises companies based in Taiwan, South Korea, Switzerland, India and a further 19 countries.
*Novartis & Roche account for 62% of Swiss R&D and this explains the high overall R&D intensity
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

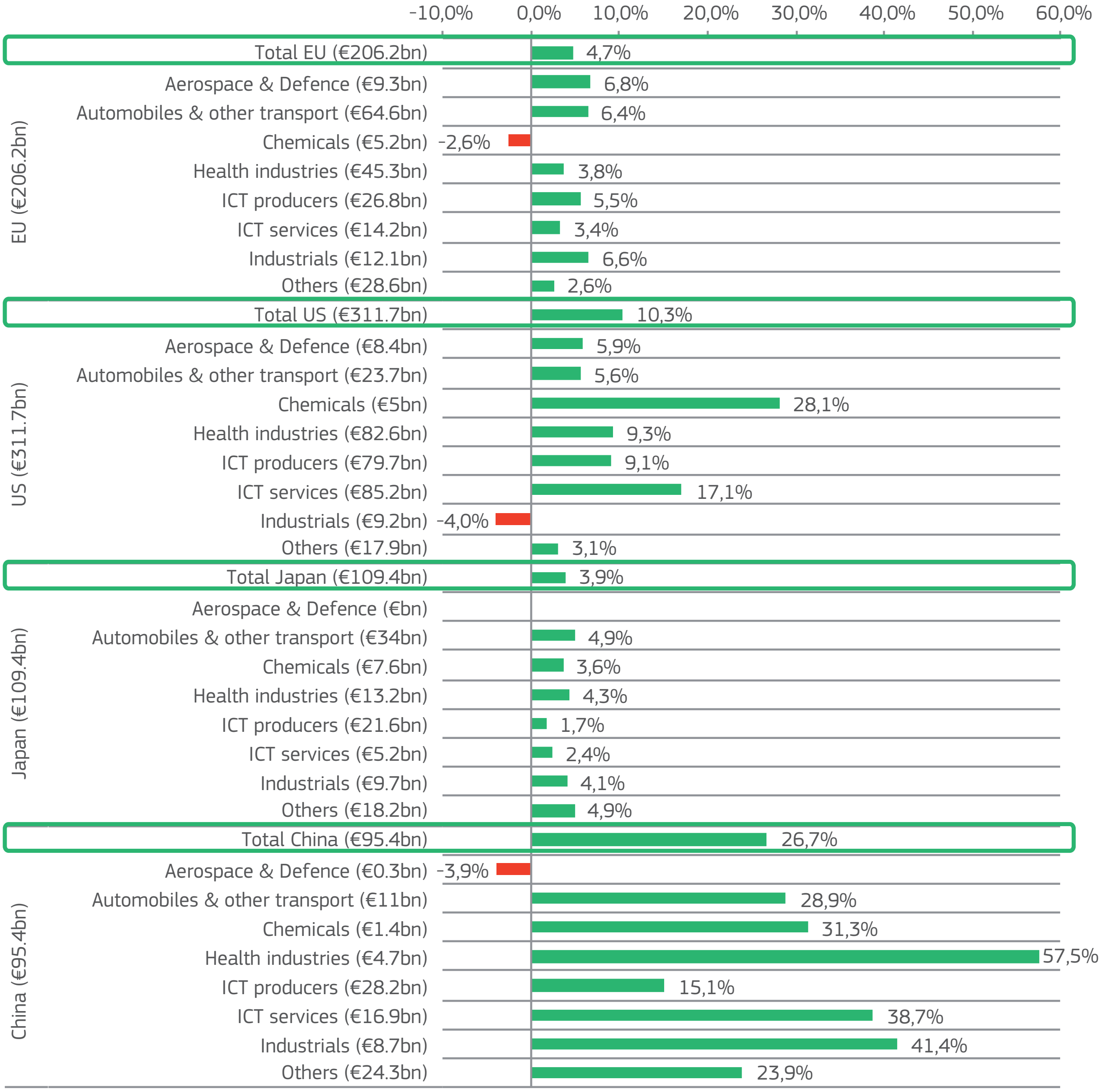

FIGURE 2.2: NOMINAL CHANGE OF R&D OVER THE PAST YEAR FOR MAIN INDUSTRIES AND REGIONS.

Note: growth rates have been computed for 549 EU, 760 US, 318 Japanese, 487 Chinese and 353 RoW companies for which R&D data are available for both years 2017 and 2018.

Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

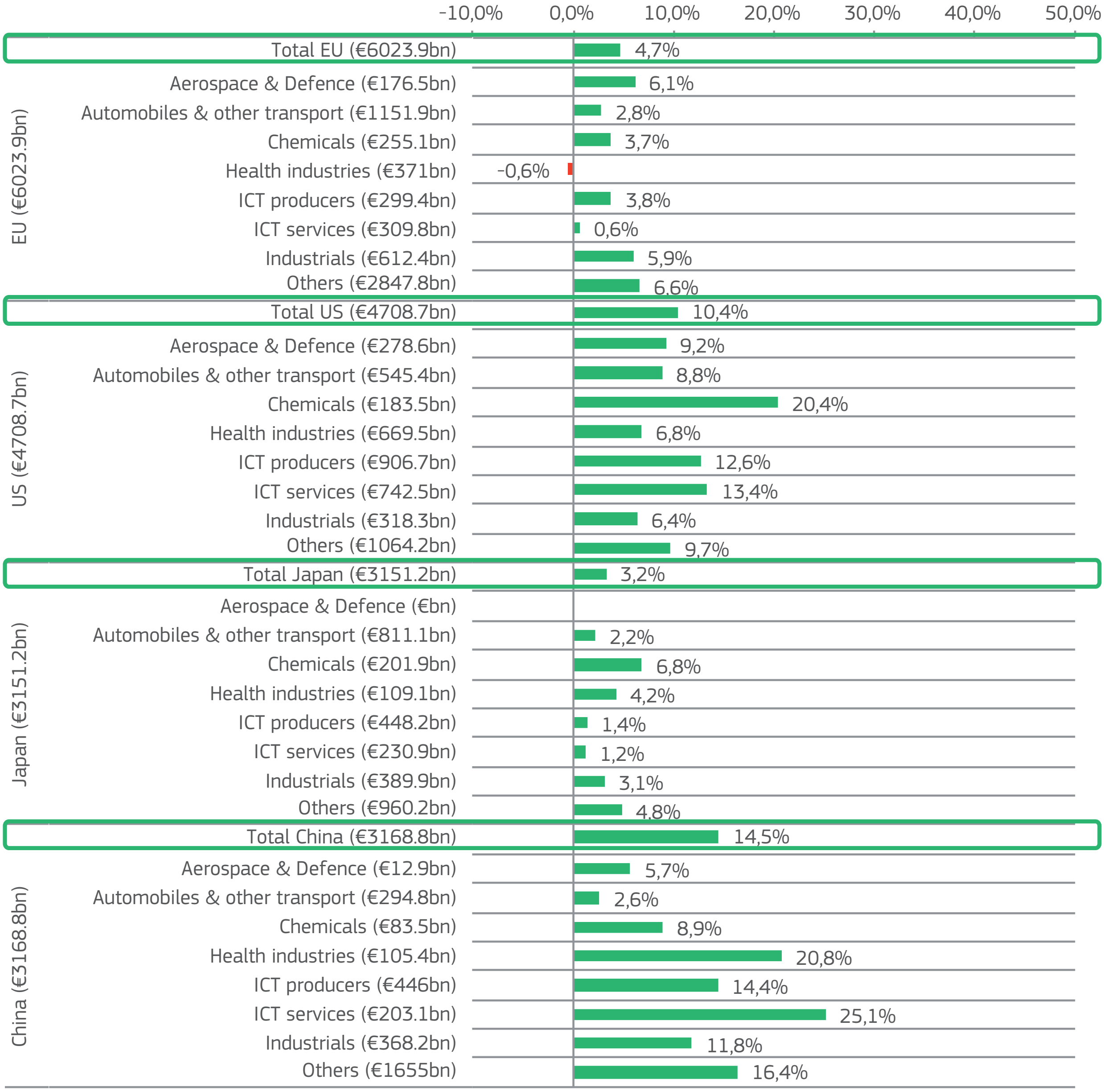

FIGURE 2.3: NOMINAL CHANGE OF NET SALES OVER THE PAST YEAR FOR MAIN INDUSTRIES AND REGIONS.

Note: growth rates have been computed for 540 EU, 703 US, 317 Japanese, 504 Chinese and 349 RoW companies for which Net Sales data are available for both years 2017 and 2018.

Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.2 | Ten-year performance of companies

This section presents the evolution of the main company indicators over the past 10 years for the industrial sectors and major world regions.

2.2.1 R&D trends

The Figures below illustrate the evolution of R&D and the main financial indicators over a 10-year period for companies based in the EU, US, Japan and China. Figure 2.4 shows the world R&D share of each region and Figures 2.5 to 2.8 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 2009-2018 period for 1650 companies (EU 386, US 480, Japan 310, China 199 and RoW 275). Since companies need to have been present for the whole 10-year period, this analysis excludes companies that have failed, been acquired or entered the *Scoreboard* during the 10 years.

Over the past 10 years, the R&D share of EU companies in the total R&D declined slightly (from 27.4% to 25.4%. *This figure directly depends on the exchange rate of the Euro against main currencies. Last year the share was about 26% and the decrease mostly reflects the depreciation of the Euro against the US$ over the last period (see Box A2.1 in the methodological notes).* The main change in this indicator is observed for the Japanese companies whose R&D share fell by ca. 6 percentage points. The loss of R&D share by Japanese companies corresponds to increases in R&D shares for the companies based in China and the US.

Companies based in the EU have shown positive R&D trends for most of the 10-year period. From 2012 to 2016, the growth rate of EU R&D has been positive despite the decline in net sales. For the last two years, net sales in the EU sample have recovered significantly. In the last period, EU companies' capital expenditures continued to improve following several years of negative performance or stagnation. In terms of profitability the EU companies showed a stable behaviour (with a significant increase over the past two years) although the level of profitability remains well below that of US companies (10% vs 15%).

Companies based in the US sustained significant R&D investment growth, especially in the past three years, that showed higher R&D growth than the world's average. The level of capital expenditures of US companies fell significantly over previous years but also recovered significantly in recent years, showing an especially strong increase in 2018. In terms of net sales, US companies continue to recover the negative figures of 2015 recording strong growth in the last two periods, similar to the level of R&D growth. The US-based companies have continued to show a stable high level of profitability since 2010. As said above, the profitability of the US companies is higher than their EU counterparts and especially higher than the Japanese and Chinese ones.

Japanese companies, hit hard by the crisis in 2008-2009 and by the earthquake in 2011, showed a two year positive trend for both R&D investment and net sales. However, in 2015 and 2016 the growth rates of R&D and especially that of net sales decelerated again. Finally, in the last two periods, Japanese companies showed a recovery for R&D, net sales and also capital expenditures. The profitability of Japanese companies continued its 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 year period and their level of capital expenditures that decreased in 2015 recovered robustly in 2017. In terms of net sales, they have had high positive growth rates, except over 2015 where net sales significantly fell but then recovered considerably over the last two years. The China-based companies have decreased profitability slightly at the beginning of the ten-year period but remained stable over the last 5 years at the low level of 6%.

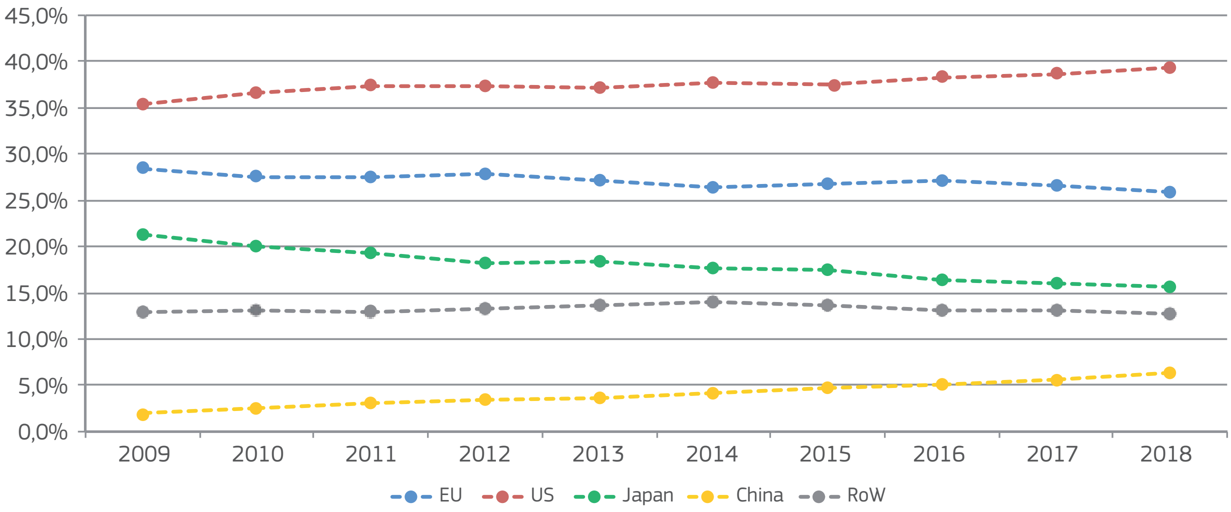

FIGURE 2.4: EVOLUTION OF R&D SHARES OF MAIN REGIONS.
Note: Figures displayed refer only to the 1650 companies (386 EU; 480 US; 310 Japan; 199 China; 275 RoW) for which data on R&D, Net Sales and Operating Profits are available for the entire period 2009-2018. These companies represent 84.6% of R&D, 84.1% of Net Sales and 79.8% of Operating Profits of the whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

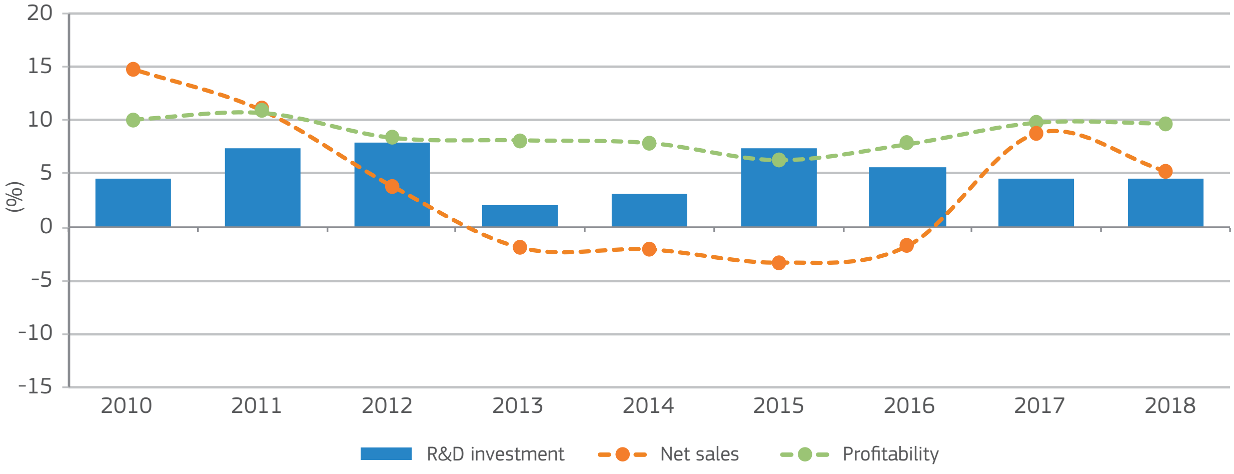

FIGURE 2.5: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY FOR THE EU COMPANIES.
Note: Growth rates for the three variables have been computed on 386 out of the 551 EU companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2009-2018. These companies represent 86.6% of R&D, 86.4% of Net Sales and 82.0% of Operating Profits of the EU companies in the whole sample in 2018.
Source: The 2019EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

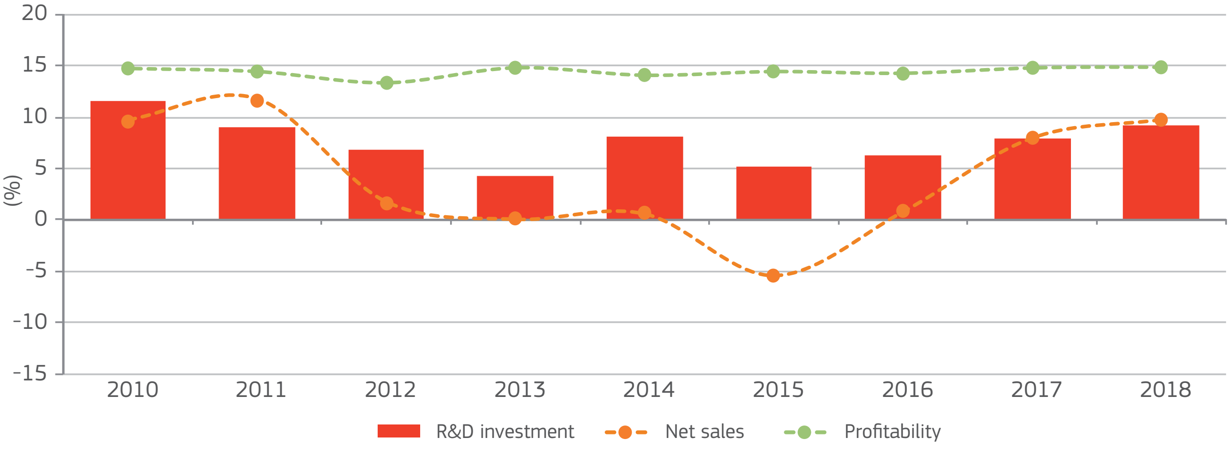

FIGURE 2.6: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY FOR THE US COMPANIES.
Note: Growth rates for the three variables have been computed on 480 out of the 769 US companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2009-2018. These companies represent 87.9% of R&D, 92.4% of Net Sales and 101.2% of Operating Profits of the US companies in the whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

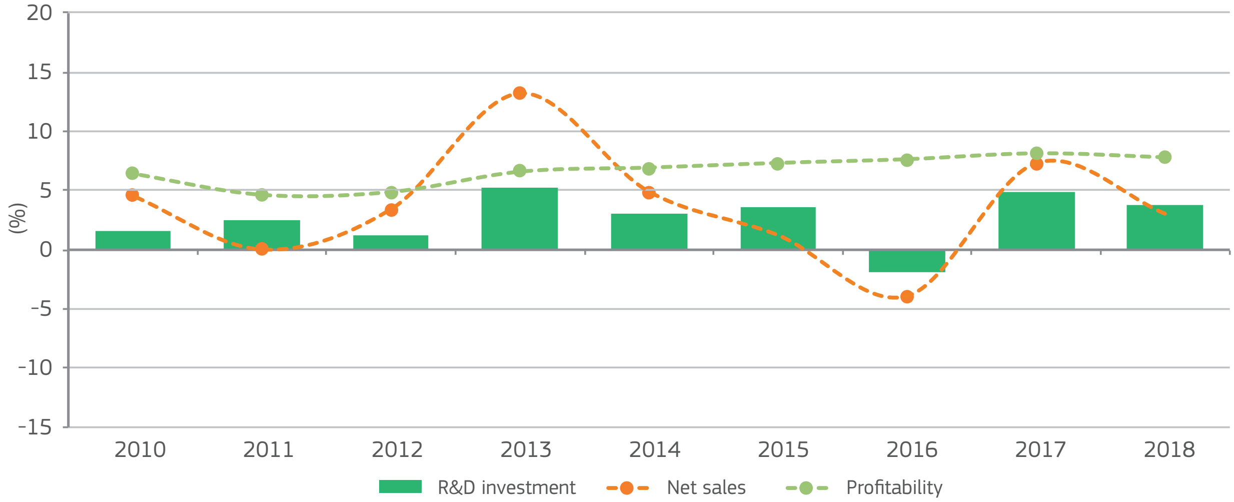

FIGURE 2.7: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY FOR THE JAPANESE COMPANIES.
Note: Growth rates for the three variables have been computed on 310 out of the 318 Japanese companies for which data are available for the entire period 2009-2018. These companies represent 99.2% of R&D, 96.7% of Net Sales and 97.5% of Operating Profits of the Japaniese companies in the whole sample in 2018.
Source: The 2019EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

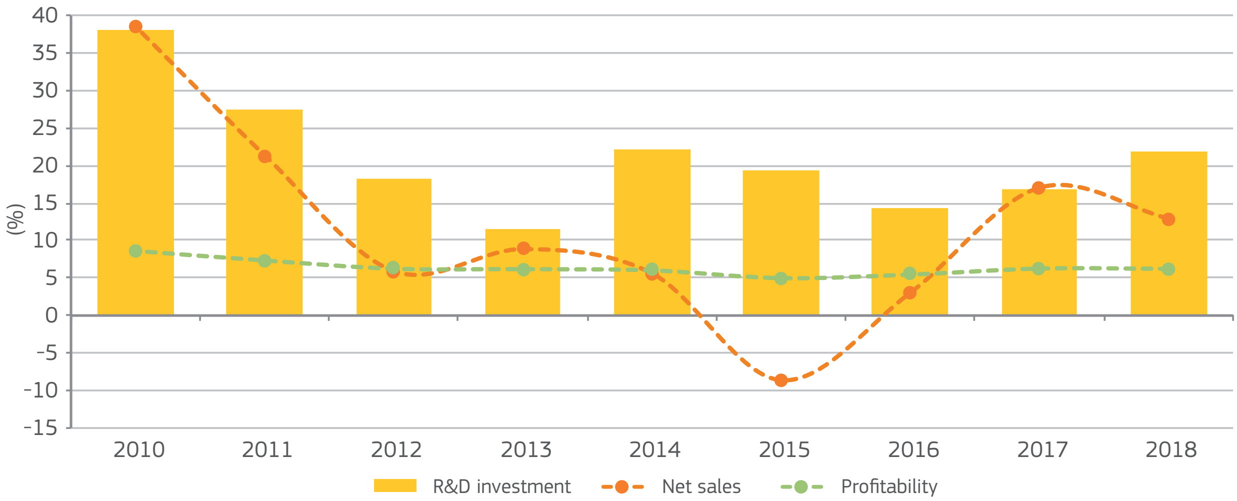

FIGURE 2.8: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE CHINESE COMPANIES.
Note: Growth rates for the three variables have been computed on 199 out of the 507 Chinese companies for which data are available for the entire period 2009-2018. These companies represent 46.3% of R&D, 60.0% of Net Sales and 50.1% of Operating Profits of the Chinese companies in the whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

2.3 | Change in R&D, net sales and employees over 2009-2018

The changes in R&D, net sales and number of employees over the past 10 years are presented respectively in Figures 2.9, 2.10 and 2.11. Companies are aggregated by main region and by the four main groups of industrial sectors with characteristic R&D intensities[17] (see definition in Chapter 1 – Table 1.3).

These Figures refer to a set of 1460 companies that reported R&D, net sales and employees in the first and last year of the period 2009-2018 (EU-389, US-453, Japan-310, China-181 and RoW group-127). The analysis necessarily excludes companies for which data are missing for one of these variables in one of the two years considered.

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

2.3.1 Ten-year changes in R&D

- Worldwide companies increased R&D by 67%:
  - By sector, high tech 73%, medium-high tech 69%, medium-low tech 14% and low tech 65%;
  - By region, EU 59%, US 83%, Japan 27% and China 439%.
- For EU companies, R&D increased in medium-high tech sectors (84%), high tech (48%) and low tech (28%).
- The US companies increased significantly R&D in high tech (97%) and medium-low tech (48%) and decreased R&D in low tech sectors by 1%.
- The Japanese companies increased R&D in medium-high tech (39%) and high tech sectors (12%) and decreased it in medium-low tech sectors (-2%).
- For the companies based in China, all sectors showed 3-digit increases in R&D, mainly in high tech (621%) and medium-high tech (509%).

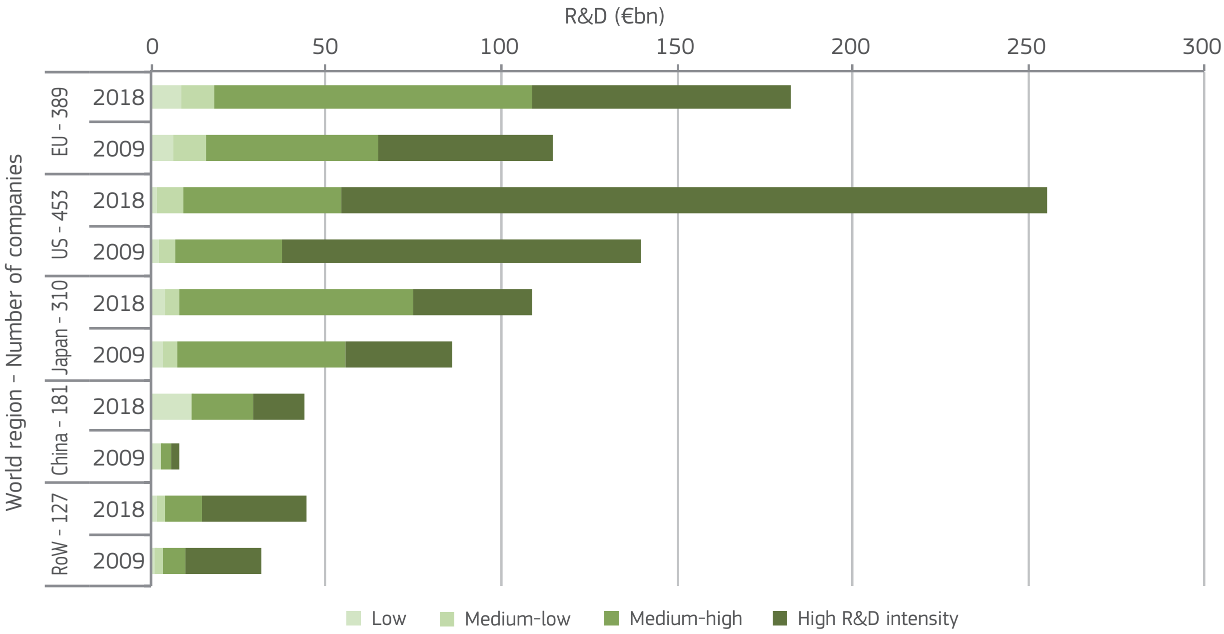

FIGURE 2.9: R&D INVESTMENT IN 2009 AND 2018 BY MAIN REGION AND SECTOR GROUPS.
Note: Figures displayed refer only to the 1460 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 77.0% of R&D of the whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.3.2 Ten-year changes in net sales

- Worldwide companies increased net sales by 47%:
  - By sector, high tech 62%, medium-high tech 59%, medium-low tech 16% and low tech 36%;
  - By region, EU 38%, US 38%, Japan 38% and China 154%.
- For the EU companies, net sales increased in medium-high tech (69%), high tech (42%) and low tech (26%).
- For the US companies, net sales increased in high tech (74%) and medium-high tech (34%) and decreased in low tech (-21%).
- For the Japanese companies, net sales increased in medium-high tech (50%) and low tech sectors (35%).
- The companies based in China showed 3-digits rise in net sales for most sectors. Net sales went up in medium-low tech sectors (309%), high tech (208%), medium-high (201%) and low tech (127%).

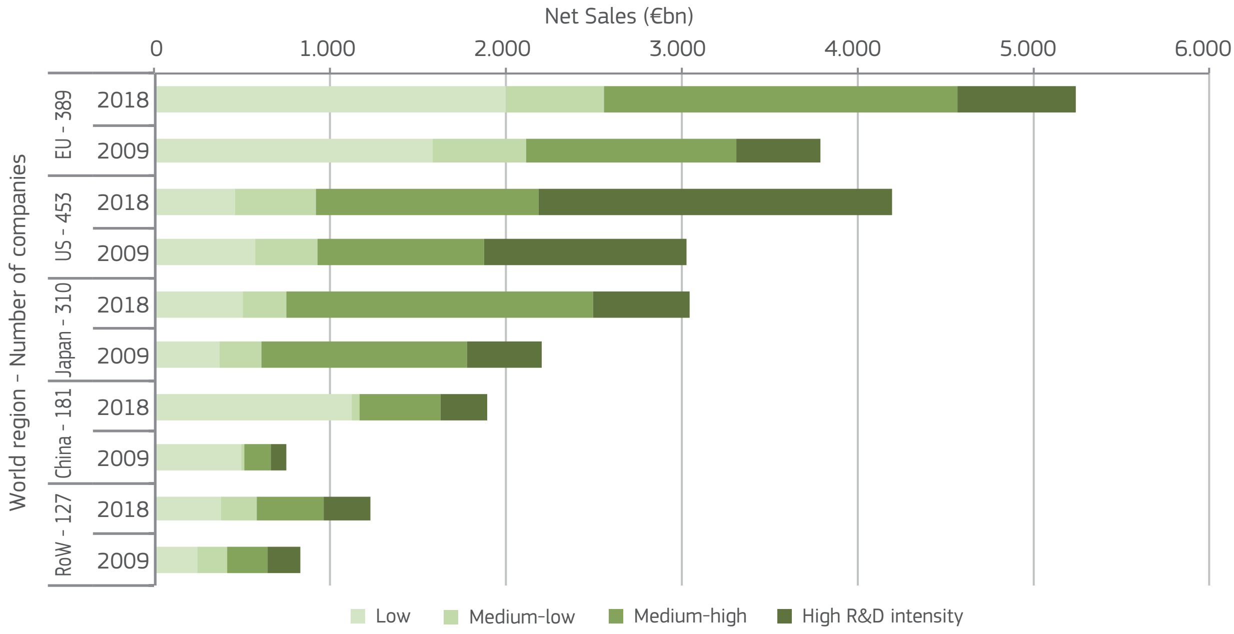

FIGURE 2.10: NET SALES IN 2009 AND 2018 BY MAIN REGION AND SECTOR GROUPS.
Note: Figures displayed refer only to the 1460 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 76.7% of Net Sales of the whole sample in 2018.The large proportion of sales in the low-tech sector group for the EU and China reflect the large sales of major oil companies in these two regions (4 companies for the EU and 3 for China.)
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

2.3.3 Ten-year changes in employment

- Worldwide companies increased employment by 21%:
  - By sector, high tech 28%, medium-high tech 31%, medium-low tech -1% and low tech 6%;
  - By region, EU 17%, US 18%, Japan 16% and China 52%.
- The EU companies increased employment in high tech (36%), medium-high tech (35%), low tech

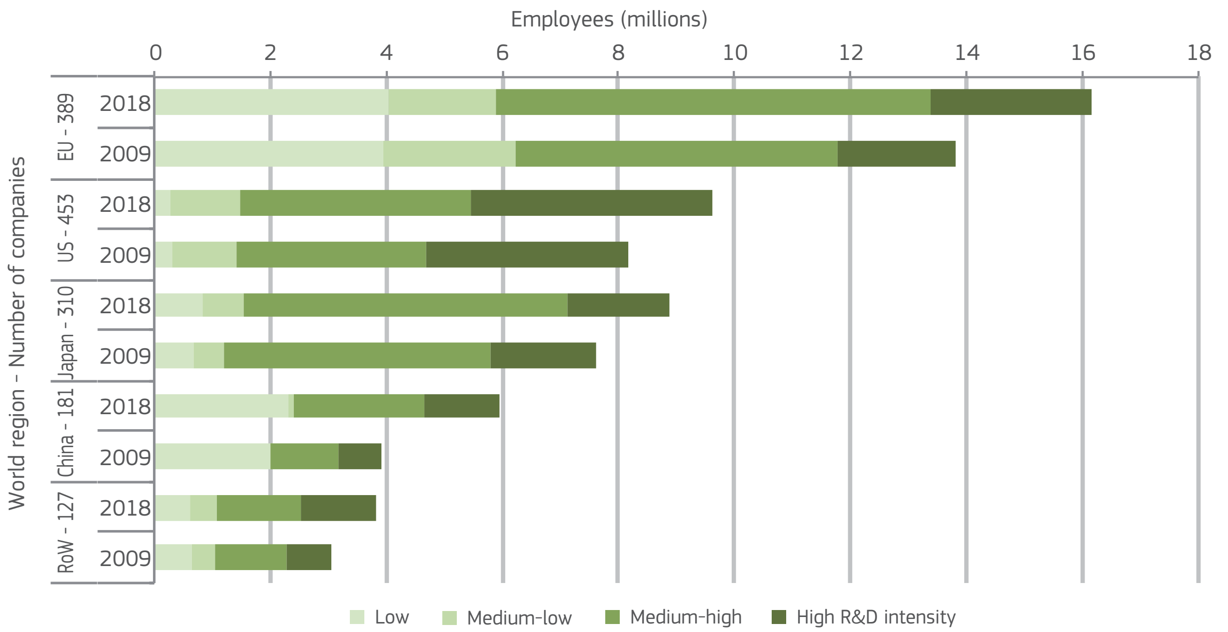

FIGURE 2.11: EMPLOYMENT IN 2009 AND 2018 BY MAIN REGION AND SECTOR GROUPS.
Note: Figures displayed refer only to the 1460 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 79.8% of Employment of the whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

sectors (3%) and drop it considerably in medium-low tech (-20%).

- For the US companies, employment increased in medium-high tech (21%), high tech (20%) and decreased significantly in low tech (-14%).

- For the Japanese companies, employment increased in medium-low tech (39%), medium-high tech (21%) and decreased in high tech (-4%).

- For the companies based in China, main employment increases were in medium-low tech (277%), medium-high tech (94%) and high tech (75%).

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).

2.4 | Change in sector composition over 2009-2018

This section examines the changes in 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 global R&D shares, reflecting the R&D specialities of regions and structural changes occurring over 2009-2018. The Figures 2.12 shows the evolution of the R&D shares for the main industries and Figures 2.13 and 2.14 show the R&D weight of the EU and US companies in the global composition of each industry.

On the whole, the main sector shift in the past 10 years is observed in ICT industries. In ICT services the R&D share increased from 10.7% to 15.0% and for ICT producers from 22.9% to 23.6%. On the other hand, sectors that underwent decreases in R&D shares were mainly low-tech sectors and also, to a lesser extent, Industrials, Aerospace & Defence and Chemicals.

EU companies reinforced their specialisation in medium-high tech sectors, increasing significantly their R&D

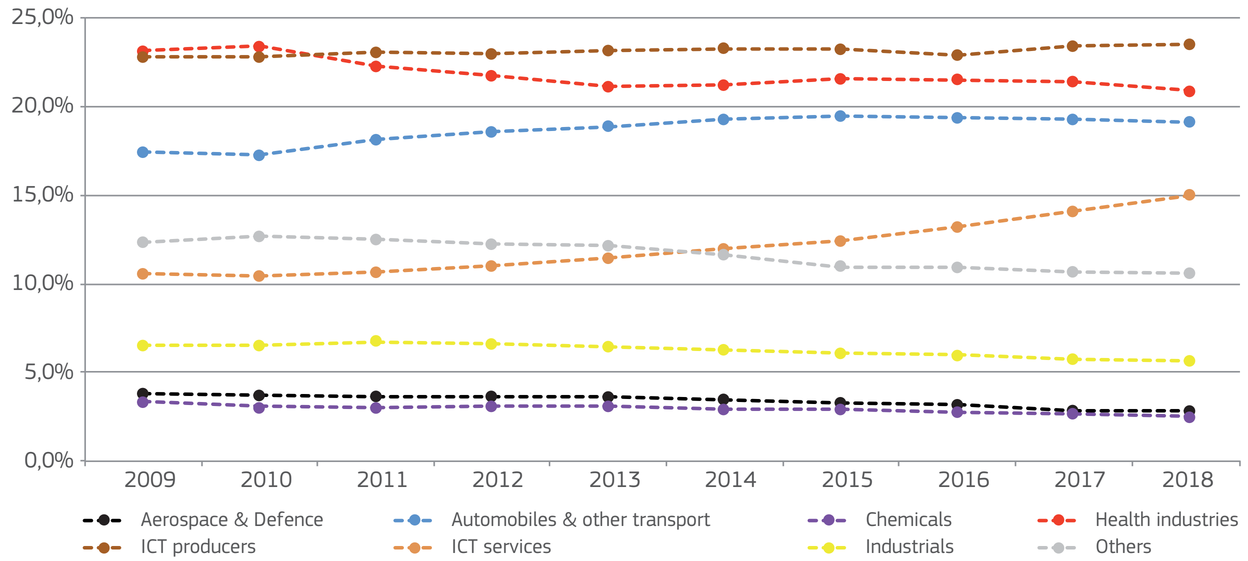

FIGURE 2.12: EVOLUTION OF GLOBAL R&D SHARES FOR INDUSTRIAL SECTORS.
Note: Calculated for a sample of 1650 companies for which data on R&D, Net Sales and Operating Profits are available for the entire period 2009-2018. These companies represent 84.6% of R&D of the whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

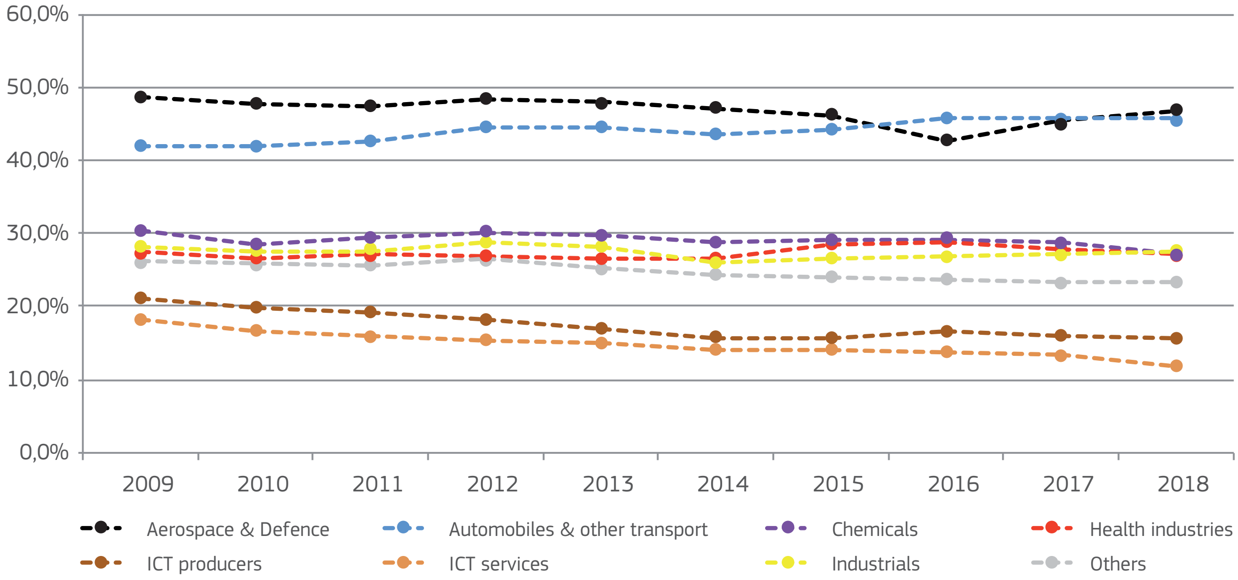

FIGURE 2.13: EVOLUTION OF THE GLOBAL R&D SHARE OF EU COMPANIES FOR THE MAIN INDUSTRIAL SECTORS.
Note: Figures displayed refer only to the 386 out of the 551 EU companies with R&D data available for the all period 2009-2018. These companies represent 86.6% of R&D whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

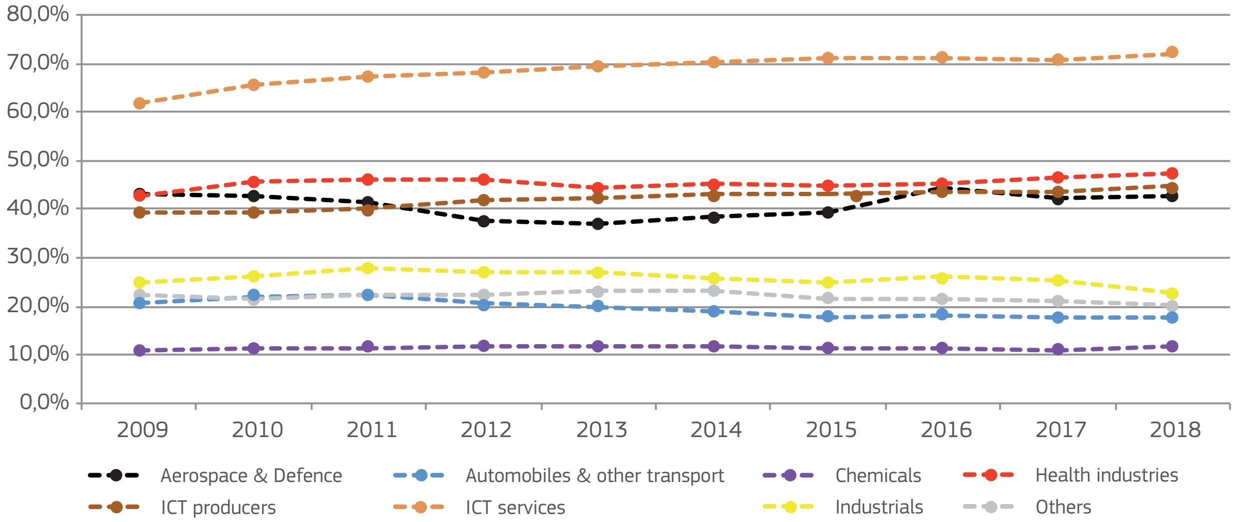

FIGURE 2.14: EVOLUTION OF THE GLOBAL R&D SHARE OF THE US COMPANIES FOR THE MAIN INDUSTRIAL SECTORS.
Note: Figures displayed refer only to the 480 US companies with R&D data available for the all period 2009-2018. These companies represent 87.2% of R&D whole sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

contribution to the global R&D of Automobiles by more than 6 percentage points (from 41.6% to 45.3%). On the other side, EU companies reduced significantly their global R&D share in ICT industries, in ICT services from 18.2% to 11.8% and ICT producers from 21.2% to 15.8%. EU companies also decreased slightly their weight in low tech and Chemicals sectors.

US companies strengthened their position in high tech sectors, increasing substantially their global R&D weight in ICT services and Health (respectively by 10 and 5 percentage points). At the other extreme, US companies reduced their R&D share in Automobiles by 3 percentage points and by 2% in Industrials and 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 global R&D shares for all sectors (mostly in low tech, ICT services and Industrials) whereas Japanese companies' global R&D shares fell across the board (mostly in ICT industries, low tech sectors and Automobiles).

2.5 | Concluding remarks

1. EU companies have strengthened their position in medium-high tech sectors such as automotive and industrials, they have maintained their position in health but have lost ground in ICT (almost doubling the medium-high tech sector while growing more slowly the high tech sector). There is a danger that the EU's lead in medium-high tech may be eroded as ICT takes a higher proportion of the value added in sectors such as automotive with the advent of new developments such as electric self-driving cars. The EU's overall profitability is bolstered by the high profitability of many of its banks and chemical companies in the *Scoreboard*, but remains well below that of US companies (10.3% vs 13.7% respectively).

2. US companies have been steadily increasing their share of global R&D to reach 38% in 2018 (doubling their high tech R&D from 2009 to 2018). The big driver for the US has been growth in its ICT sectors (particularly ICT services) and, to a lesser extent, in health. The US is well placed for the future in health as it is the clear world leader in biotechnology which is the basis of more and more new drugs. The ICT and health sectors have high profitability and, since these sectors now account for around 80% of US R&D, the overall profitability of US *Scoreboard* companies is also very high.

3. Japanese companies have an even larger proportion of its R&D in medium-high tech sectors and less in high-tech than the EU companies (growing significantly their medium-high tech group but barely changing the size of their high tech group). Japanese companies have an overall profitability lower than that of the EU companies (7.8%) because of a long tail of low profitability companies and the absence of a boost from the profitability of large banks and oil companies.

4. Chinese companies have been increasing their global R&D share at a fast rate but from a very low base to reach an 11.7% world share in 2018. China has grown its low, medium and high tech groups (especially the ICT sector supported by the state). The Chinese group of companies have low profitability levels (7.4%), mostly due to the losses or small profits of large companies such as China Petroleum, China Railway Construction and China Shipbuilding that offset the large profitability of ICT companies (e.g. Tencent, Baidu and Netease).

3

PERFORMANCE OF TOP **GLOBAL R&D INVESTORS**

3 Performance of top global R&D investors

ALPHABET is the top R&D investor worldwide, followed by SAMSUNG and MICROSOFT. In the fourth position is VOLKSWAGEN, top R&D investor in the EU. The other companies in the top-ten are, HUAWEI, APPLE, INTEL, ROCHE, JOHNSON & JOHNSON and DAIMLER.

Within the top 50 R&D investors there are 17 based in the EU, 22 US companies, 6 from Japan, and 2 each from Switzerland and China and one from South Korea.

Over the last 15 years:

- The 3 largest R&D sectors (ICT, health and automotive) continue to concentrate R&D players in the top 100 group but most new comers in this group are companies based in Asia.

- Eight companies have moved up in the global ranking by 70 or more places. These are Alphabet, Huawei, Apple, Facebook, Alibaba, Celgene, Gilead Sciences and Continental indicating the rising importance of ICT and biotechnology.

The ranking of the top 50 large global companies by R&D intensity (all with intensity of 13.3% or more) also highlights the importance of these two technologies with 23 companies from biopharmaceuticals and 24 from ICT.

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. The most extreme example of this is Amazon which would be positioned at #1 in the world R&D ranking if it had separated its R&D and content investments in its annual report (see explanation in Box 3.1).*

3.1 | Main company changes at the top of the global R&D ranking

In this *Scoreboard* edition, the top R&D investor is the US company ALPHABET (€18.3bn) although it would have been Amazon if it had separated its technology (R&D) and content investments so it could be included in the *Scoreboard*. The 2nd position is taken by SAMSUNG (€14.8bn) from South Korea, MICROSOFT (€14.7bn) from the US takes the 3rd position and the 4th one is for the German company VOLKSWAGEN (€13.6bn). The other companies in the top-ten are HUAWEI from China, APPLE, INTEL and JOHNSON & JOHNSON from the US, ROCHE from Switzerland and DAIMLER from Germany.

In the EU sample, R&D growth was led by automotive companies such as BMW (13%), PEUGEOT (25%), RENAULT (19%) and VALEO 37%) and from other sectors SANOFI (8%), ERICSSON (11%) and SIEMENS (7%). The poorest R&D performance was shown by TELECOM ITALIA (-39%), FIAT CHRYSLER (-14%), BARCLAYS (-58%) and NOKIA (-6%). See Table 3.1.

In the non-EU group, top R&D companies showing high R&D growth were ICT companies from the US, ALPHABET (30%), APPLE (23%), FACEBOOK (32%), MICROSOFT (15%), and from China, ALIBABA (64%) and HUAWEI (13%). The poorest performance was shown by SNAP (-51%), GENERAL ELECTRIC (-14%) and TEVA PHARMACEUTICAL (-34%). See Table 3.2.

Box 3.1
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 can lead to understating or omitting the actual R&D effort of some companies.

An extreme example of a possible understatement/omission of R&D figures is the US company Amazon. This company only quotes a figure for 'technology & content' investment in its annual report and nowhere does it indicate how much of this is technology (R&D). However, from Amazon's annual report for 2012-15 it is estimated that approximately $10.3bn of the $12.5bn technology & content costs (T&C) in the 2015 income statement are technology (R&D). Further, Amazon states in its 2018 annual report that the increases in T&C costs in 2017 and 2018 are primarily due to an increase in spending on technology infrastructure and the technical teams expanding existing products & services and introducing new ones. If we conservatively assign two-thirds of the $16.3bn increase in T&C costs from 2015 to 2018 as R&D – i.e. £10.9bn – then we arrive at a best estimate of Amazon's 2018 R&D of $21.2bn or €18.4bn. This would put Amazon in the #1 position in the *Scoreboard*, just ahead of Alphabet at #2 with R&D of €18.3bn.

The data collection methodology used for the *Scoreboard* subtracts any R&D tax credit disclosed in annual reports from the quoted R&D investment. This reduces the *Scoreboard* R&D for companies from countries with an R&D tax credit (such as Belgium, France, Japan, The Netherlands and the UK) compared to countries that do not have a credit such as Germany and Switzerland or those like the US which have a less generous credit. In addition, many countries have a patent box innovation incentive and this is not deducted from their R&D.

company	One-year R&D growth (%)	company	One-year R&D growth (%)
BMW	12.8	TELECOM ITALIA	-39.2
PEUGEOT (PSA)	24.7	FIAT CHRYSLER	-14.0
RENAULT	18.9	BARCLAYS	-57.7
VALEO	36.5	NOKIA	-5.6
VOLKSWAGEN	3.8	BASF	-11.6
SANOFI	8.1	SEAGATE TECHNOLOGY	-16.7
DAIMLER	4.4	OM RESIDUAL UK	-74.8
SIEMENS	6.7	GLAXOSMITHKLINE	-3.3
ERICSSON	11.3	ELECTRICITE DE FRANCE	-19.6
ASML HOLDING	27.1	ASTRAZENECA	-2.7
AIRBUS	9.3	DEUTSCHE BANK	-8.7
SAP	8.4	COMMERZBANK	-23.4

TABLE 3.1: LARGEST R&D INCREASES AND DECREASES AMONG THE EU COMPANIES IN 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

company	One-year R&D growth (%)	company	One-year R&D growth (%)
ALPHABET	30.3	SNAP**	-51.0
APPLE	22.9	GENERAL ELECTRIC	-13.9
FACEBOOK	32.5	TEVA PHARMACEUTICAL	-34.4
MICROSOFT	14.6	TATA MOTORS	-18.0
ALIBABA	64.5	ELI LILLY	-11.6
HUAWEI	12.9	MERCK US	-4.7
SAMSUNG	9.8	ZTE	-18.4
DOWDUPONT*	45.0	IBM	-7.1
HONDA MOTOR	12.2	AT&T	-20.6
SAIC MOTOR	52.9	DAIICHI SANKYO	-13.7
TENCENT	31.4	FUJITSU	-15.0
GILEAD SCIENCES	19.5	SUBARU	-15.2

TABLE 3.2: LARGEST R&D INCREASES AND DECREASES AMONG THE NON-EU COMPANIES IN 2018.
*Dow and DuPont completed their merger in September 2017 and the large increase reflects that.
**SNAP increased its R&D by over 8 times from 2016 to 2017 and then decreased it in 2018 to over 4 times the 2016 level.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

3.1.1 Top 50 R&D investors

Among the group of top 50 R&D investors, there are 17 companies based in the EU (one less company than last year) and 33 non-EU companies. See the R&D ranking of the top 50 companies in Figure 3.1.

The table 3.3 shows changes in the R&D ranking of the top 50 companies since the first *Scoreboard* in 2004. It is important to note, as stated in the previous reports, that the growth of companies is often accompanied by mergers and acquisitions.

In the EU group, four companies left the top 50 (ALCATEL, ISTITUTO FINANZIARIO INDUSTRIALE, PHILIPS, BAE SYSTEMS) and three companies joined the top 50 (FIAT CHRYSLER, SAP and CONTINENTAL). ALCATEL first merged with LUCENT and the combined entity was later acquired by NOKIA.

In the non-EU group, fourteen companies left the top 50 (FUJITSU, CANON, DELPHI, ELI LILLY, HITACHI, HEWLETT-PACKARD, MATSUSHITA ELECTRIC, NEC, MOTOROLA, NORTEL NETWORKS (acquired), WYETH (acquired), SUN MICROSYSTEMS (acquired), NTT and TOSHIBA) and fifteen companies joined the top 50 (Alphabet, Alibaba, Amgen, Apple, Broadcom, Dell, Denso, Celgene, Facebook, Gilead Sciences, Huawei, Oracle, Panasonic, Qualcomm, and Abbvie-demerged from ABBOTT). Celgene is in the process of being acquired by Bristol-Myers Squibb.

The distribution of the top 50 companies by main industrial sector and region changed from 2004 to 2018 as follows:

- Automobiles & Parts, from 13 (EU 7) to 14 (EU 8);
- Health industries, from 11 (EU 3) to 14 (EU 4);
- ICT industries, from 13 (EU 3) to 16 (EU 3).

Three EU companies improved in the R&D ranking by at least 20 places – these are BAYER (NOW RANKED 26TH), SAP (now 43th) and CONTINENTAL (47th). Two companies dropped twenty or more places but remained within the top 50: Ericsson (now 46th) and GlaxoSmithKline (now 34th). Bayer completed its acquisition of Monsanto in June 2018 and Continental has made a total of 14 acquisitions.

There are 10 non-EU companies that gained more than 20 places, Samsung (now 2nd), ALPHABET (1st), HUAWEI (now 5th), APPLE (now 6th), ORACLE (now 25th), QUALCOMM (now 27th), GILEAD SCIENCES which acquired Pharmasset in 2011 and Kite pharma in 2017 (now 41st), BRISTOL-MYERS SQUIBB (now 24th), CELGENE (now 37th) and FACEBOOK (11th). Three companies dropped twenty or more places but remained within the top 50: IBM (now 33th), SONY (now 39th) and PANASONIC (now 32nd).

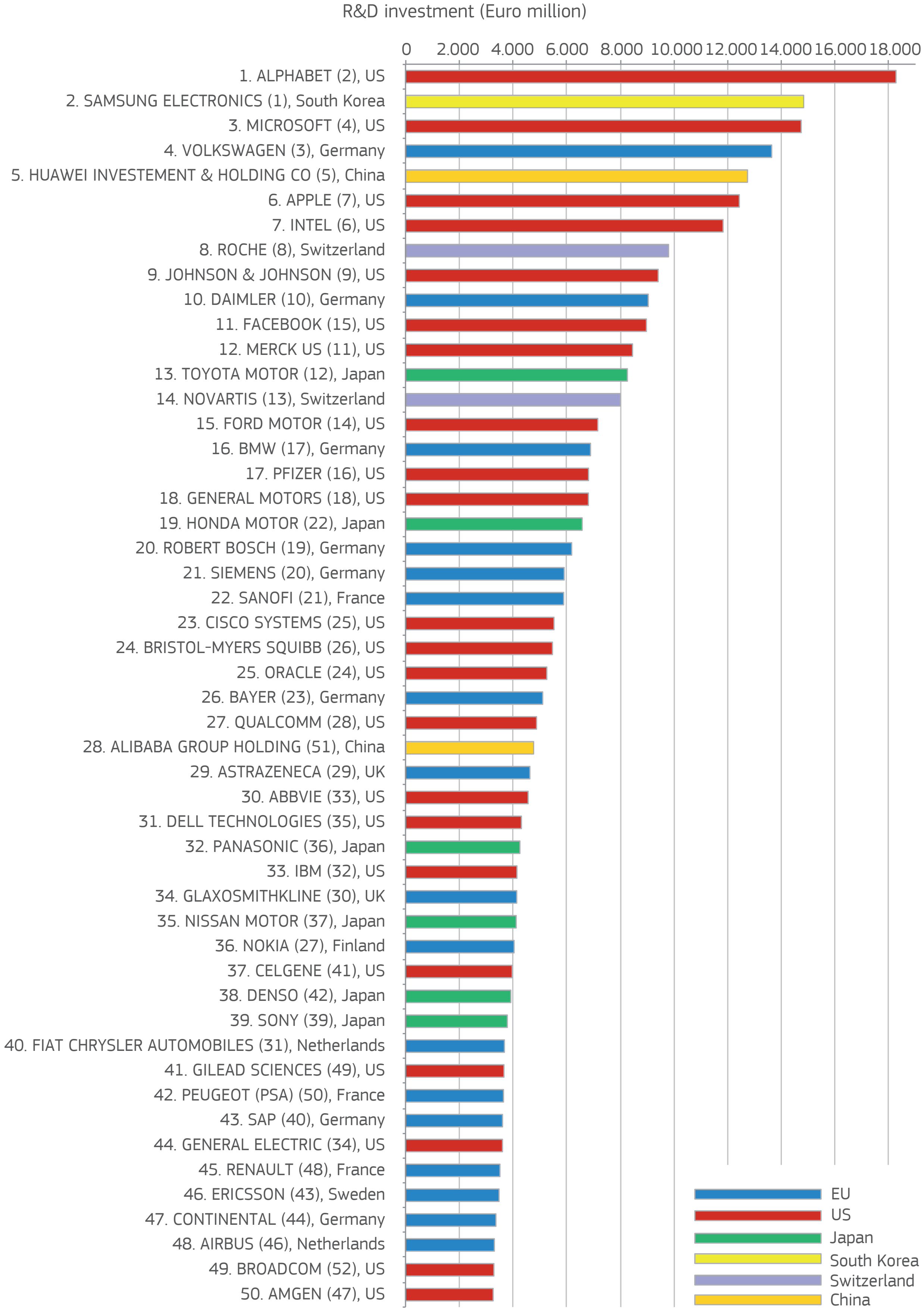

FIGURE 3.1: THE WORLD'S TOP 50 COMPANIES BY THEIR TOTAL R&D INVESTMENT IN THE 2019 *SCOREBOARD*.
Note: between brackets the ranking the company had in the 2018 EU R&D Scoreboard.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Rank 2019	Company	Country	R&D in 2018 (€bn)	R&D intensity (%)	Rank change 2004-2019
1	ALPHABET	US	18.3	15.3	up > 200
2	SAMSUNG	South Korea	14.8	7.8	up 31
3	MICROSOFT	US	14.7	13.4	up 10
4	VOLKSWAGEN	Germany	13.6	5.8	up 4
5	HUAWEI	China	12.7	13.9	up > 200
6	APPLE	US	12.4	5.4	up 98
7	INTEL	US	11.8	19.1	up 7
8	ROCHE	Switzerland	9.8	19.4	up 10
9	JOHNSON & JOHNSON	US	9.4	13.2	up 3
10	DAIMLER	Germany	9.0	5.4	down 7
11	FACEBOOK	US	9.0	18.4	up > 200
12	MERCK US	US	8.5	22.9	up 17
13	TOYOTA MOTOR	Japan	8.3	3.5	down 8
14	NOVARTIS	Switzerland	8.0	17.2	up 6
15	FORD MOTOR	US	7.2	5.1	down 14
16	BMW	Germany	6.9	7.1	up 12
17	PFIZER	US	6.8	14.5	down 15
18	GENERAL MOTORS	US	6.8	5.3	down 12
19	HONDA MOTOR	Japan	6.6	5.3	up 12
20	ROBERT BOSCH	Germany	6.2	7.9	up 8
21	SIEMENS	Germany	5.9	7.1	down 16
22	SANOFI	France	5.9	17.1	down 6
23	CISCO SYSTEMS	US	5.5	12.8	up 7
24	BRISTOL-MYERS SQUIBB	US	5.5	27.8	up 18
25	ORACLE	US	5.3	15.3	up 21
26	BAYER	Germany	5.1	12.9	up 34
27	QUALCOMM	US	4.9	24.6	up 65
28	ALIBABA	China	4.8	9.9	up > 200
29	ASTRAZENECA	UK	4.6	24.0	down 4
30	ABBVIE	US	4.6	16.0	New*
31	DELL TECHNOLOGIES	US	4.3	5.5	New*
32	PANASONIC	Japan	4.3	6.8	down 25
33	IBM	US	4.2	6.0	down 23
34	GLAXOSMITHKLINE	UK	4.1	12.1	down 23
35	NISSAN MOTOR	Japan	4.1	4.5	down 1
36	NOKIA	Finland	4.0	17.9	down 26
37	CELGENE	US	4.0	29.8	up > 200
38	DENSO	Japan	3.9	9.3	down 3
39	SONY	Japan	3.8	5.6	down 24
40	FIAT CHRYSLER	Netherlands	3.7	3.3	up 4
41	GILEAD SCIENCES	US	3.7	19.0	up > 200
42	PEUGEOT (PSA)	France	3.6	4.9	down 4
43	SAP	Germany	3.6	14.6	up 27
44	GENERAL ELECTRIC	US	3.6	3.4	down 7
45	RENAULT	France	3.5	6.1	same
46	ERICSSON	Sweden	3.5	16.9	down 29
47	CONTINENTAL	Germany	3.4	7.6	up 70
48	AIRBUS	Netherlands	3.3	5.2	down 13
49	BROADCOM	US	3.3	18.1	up 67
50	AMGEN	US	3.3	15.7	down 13

TABLE 3.3: THE TOP 50 COMPANIES IN THE 2019 *SCOREBOARD*: RANK CHANGE 2004-2019.
Note: companies in "blue" went up more than 20 ranks and in "red" lost more than 20 ranks.
*Dell Technologies was formed after Dell's $67bn acquisition of EMC in 2015. AbbVie was formed when Abbott Laboratories spun off its pharmaceutical division as a separate listed company in 2013.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

3.1.2 Top 100 R&D investors

The profile of the group of top 100 *Scoreboard* companies reflects the concentration of global industrial R&D in a few companies, industries and countries. In the 2019 *Scoreboard*, this group accounts for 52% of the total R&D, 82 companies from the 3 major sectors (ICT 34, Health 26 and Automotive 22) and 80 companies from 3 regions (EU 29, US 36 and Japan 15). In 2018, the top 100 companies showed growth of R&D (8.2%) somewhat below the world average (8.9%) and also lower growth of net sales (6.7% vs 8.4%).

Seventy-three companies in the top 100 have shown positive R&D investment growth. Among them, 34 companies had double-digit R&D growth, and of these, 20 companies also showed double-digit growth in net sales.

Most of the top 100 companies showing double-digit R&D increases are in Automobiles (9), ICT producers (8), ICT services (7) and Health industries (5). The 5 companies showing the largest increase in R&D are ALIBABA, SAIC MOTOR, DOWDUPONT, VALEO and FACEBOOK. Several of these large increases such as that for DowDuPont are due to acquisitions or mergers.

Among the companies that had double-digit growth in R&D and net sales, the top 5 companies are ALIBABA, MICRON TECHNOLOGY, DOWDUPONT, FACEBOOK and SK HYNIX.

Twenty-seven companies in the top 100 have experienced a decrease in R&D investment. The companies with the largest decrease in R&D are TATA MOTORS, FIAT CHRYSLER AUTOMOBILES, GENERAL ELECTRIC, DAIICHI SANKYO and BASF. GENERAL ELECTRIC has been divesting companies at part of its strategic recovery plan and this is the cause of its decrease in R&D.

The R&D intensity of companies in the top 100 (7.0%) remained practically the same of the previous year.

Among the top 100 companies, only 3 made losses (ALLERGAN, GENERAL ELECTRIC and BAYER) with 24 showing profitability of only 5% or less but 31 showing profitability over 20%. All but one of the 31 operates in high R&D-intensive sectors (HSBC). ALLERGAN is in the process of being acquired by AbbVie for $63bn.

There have been six new entries in the top100 compared to last year's edition top 100. Of these six companies, five were already in the *Scoreboard*: SAIC MOTOR CORPORATION (China, 71, last year 104); OTSUKA HOLDINGS CO (Japan, 85, last year 108); SALESFORCE.COM (US, 90, last year 107); AISIN SEIKI (Japan, 96, last year 101); NXP SEMICONDUCTORS (Netherlands, 99, last year 109); and CHINA RAILWAY CONSTRUCTION CORPORATION (China, 100, last year 105). HSBC (UK, 99) was not in the *Scoreboard* last year given to missing recent R&D figures published at the time.

Five of the six companies exiting the top 100 are still in the *Scoreboard*: TELECOM ITALIA (Italy, 127, last year 65); ZTE CORPORATION (China, 103, last year 76); TEVA PHARMACEUTICAL (Israel, 145, last year 90); LEONARDO (Italy, 107, last year 93); BANCO SANTANDER (Spain, 102, last year 96); and DEUTSCHE BANK (Germany, 122, last year 100). SHIRE (UK, last year 98) is not in the *Scoreboard* anymore because have been acquired by TAKEDA PHARMACEUTICAL.

In the first *Scoreboard* edition in 2004, the top 100 sample comprised 8 less companies from the 3 largest sectors (ICT 34, Health 21 and Automotive 19) however 14 more companies from the main regions (EU 35, US 37, Japan 22). Most changes from 2004 to 2019 in the top 100 group are due to companies from Japan and the EU (7 and 6 leavers respectively) and new comers from companies based in Asia (China 9, Taiwan 3 and S. Korea 2).

3.1.3 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 3.4 (ordered by level of R&D growth).

The high growth companies, at the top of the table, showed more than 3-fold increase of R&D and employees and more than 5-fold increase of net sales.

On the other extreme, the firms at the bottom of the table underwent a simultaneous drop of R&D, net sales and employees over the past ten years. Some of these large changes are due to acquisitions and divestments. Examples are: ALLERGAN has a long record of acquisitions and doubled its sales and quadrupled its R&D just from 2013 to 2016. ALLERGAN was acquired by Activis in early 2015 and Activis then changed its name (and that of the combined entity) back to ALLERGAN and now it is being acquired by AbbVie. CELGENE is being acquired by Bristol-Myers Squibb. Amongst the big decreases is PROCTER & GAMBLE which decided to divest 100 brands in 2014 and sold 43 of these to Coty for $12.5bn. Another big decrease was recorded by NOKIA which had a 49% share of the smartphone market in 2007 but this had dropped to 3% by 2013 when it sold the business to MICROSOFT (which itself exited that business in 2016).

	Firm	R&D investment 2018 (€bn)	Change in R&D 2009-2018 (%)	Change in net sales 2009-2018 (%)	Change in employees 2009-2018 (%)
High growth firms	BAIDU	2	3524	2199.5	474.8
	TENCENT	2.9	2250.1	2413.6	622.7
	BROADCOM	3.3	1438	1304.9	368.8
	SALESFORCE.COM	1.6	1183	917.3	781.8
	ALLERGAN	2	1047.1	465.2	189.9
	APPLE	12.4	968	519	258.7
	SAIC MOTOR	2	715.9	539.4	4874
	ALPHABET	18.3	635.8	478.5	398
	CELGENE	4	482.3	468.1	214.7
Low growth firms	NOKIA	4	-19.1	-44.9	-16.6
	PHILIPS	1.7	-3.3	-21.9	-33.2
	IBM	4.2	-3.9	-16.9	-12.2
	PROCTER & GAMBLE	1.6	-4.6	-12.7	-23.6

TABLE 3.4: COMPANIES AMONG THE TOP 100 R&D INVESTORS SHOWING THE LARGEST CHANGES IN R&D, NET SALES AND EMPLOYEES.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

3.2 | Ranking of large companies by R&D intensity

The previous section discussed the largest companies by R&D investment. However, some of these companies may also have very large sales so that their R&D, while large, may not be a substantial percentage of sales and may not be a key success factor for the company. Oil, telecoms and construction companies provide examples of this with China Petroleum & Chemicals (#156 in the *Scoreboard*) with an R&D intensity (R&D as % sales) of 0.3%, Petrochina (#81) with 0.6% intensity, AT&T (#149) with an intensity of 0.7% and China State Construction (#72) with intensity of 1.3%. In contrast, companies in the biotechnology & pharmaceuticals, software and technology hardware sectors have R&D intensities well into double figures and R&D is a key success factor for them.

The table 3.5 lists the top 50 large companies (those drawn from the 159 in the global *Scoreboard* having R&D over €1bn) ordered by R&D intensity. An R&D intensity of at least 13.3% is needed to enter the top 50 compared with 12.6% in the 2018 *Scoreboard*. The top 10 companies have intensities ranging from 24% to 63%. The main features of the table are:

- Three sectors dominate the table with 23 biopharma companies, 13 from technology hardware, 11 from software and three others. The latter three are retail (eBay – essentially software), travel & leisure (CTrip.com – mainly software) and electronics (Renesas);
- The distribution of the 50 companies between world regions is US (27), Europe (13 of which 11 are EU) and 10 from Asia (of which 6 are Japan);
- There are 9 new entries into the table which are companies whose R&D has risen above €1bn since last year and which are therefore now eligible for the

table. The 9 companies that have left were those near the bottom of the 2018 table. Seven companies have fallen in the ranking by more than 10 places from last year while just one company (Gilead Sciences) has risen by more than 10 places – 20 places up because of Gilead's acquisition of Kite Pharma, a cancer immunotherapy biotech.

There are some clear regional specialisations in the table with 9 of the 11 software companies in the table from the US, 7 of the 13 companies from Europe from biopharma and 5 of the 10 Asian companies from biopharma (all from Japan). Of the 50 companies in the table just 15 have R&D intensity, sales growth and profitability all of at least 10%. Six of the 15 are software companies, six are technology hardware and three are from pharmaceuticals. Twelve of the 15 companies are from the US, two from the EU and one from China.

Rank by Intensity ()=2018	Company (All have R&D>€1bn)	Industrial sector	R&D 2018 €bn	R&D intensity (R&D/sales) 2018 %	Rank change from 2018 & reason for any new entry
1 (new)	Incyte	Biopharma	€1.03bn	62.6%	New (R&D>€1bn)
2 (new)	Vertex Pharma	Biopharma	€1.23bn	46.2%	New (R&D>€1bn)
3 (new)	Workday	Software	€1.06bn	42.9%	New (R&D>€1bn)
4 (2)	CTrip.com Int	Travel/leisure	€1.23bn	31.1%	-2
5 (5)	Electronic Arts	Software	€1.25bn	29.9%	=
6 (3)	Celgene	Biopharma	€3.97bn	28.8%	-3
7 (4)	Bristol-Myers Squibb	Biopharma	€5.47bn	27.8%	-3
8 (new)	UCB	Biopharma	€1.13bn	25.5%	New (R&D>€1bn)
9 (7)	Qualcomm	Tech. Hardware	€4.88bn	24.9%	-2
10 (10)	Mediatek	Tech. Hardware	€1.64bn	24.2%	=
11 (9)	AstraZeneca	Biopharma	€4.63bn	24.0%	-2
12 (6)	Merck (US)	Biopharma	€8.46bn	22.9%	-6
13 (new)	Advanced Micro Devices	Tech. hardware	€1.25bn	22.1%	New (R&D>€1bn)
14 (8)	Daiichi Sankyo	Biopharma	€1.61bn	21.9%	-6
15 (new)	Intuit	Software	€1.11bn	21.1%	New (R&D>€1bn)
16 (16)	Nvidia	Tech Hardware	€2.08bn	20.3%	=
17 (new)	Eisai	Biopharma	€1.01bn	20.0%	New (R&D>€1bn)
18 (13)	Roche	Biopharma	€9.80bn	19.4%	-5
19 (17)	Biogen	Biopharma	€2.27bn	19.3%	-2
20 (12)	Intel	Tech. Hardware	€11.83bn	19.1%	-8
21 (41)	Gilead Sciences	Biopharma	€3.67bn	19.0%	+20
22 (new)	Analog devices	Tech. Hardware	€1.02bn	18.8%	New (R&D>€1bn)
23 (14)	Facebook	Software	€8.97bn	18.4%	-9
24= (15)	Broadcom	Tech. Hardware	€3.29bn	18.1%	-9
24= (24)	NXP Semiconductors	Tech. Hardware	€1.48bn	18.1%	=
26 (11)	Nokia	Tech. Hardware	€4.04bn	17.9%	-15
27 (18)	Takeda	Biopharma	€2.90bn	17.6%	-9
28 (21)	Novartis	Biopharma	€8.00bn	17.2%	-7
29 (28)	Sanofi	Biopharma	€5.89bn	17.1%	-1
30 (24)	Adobe	Software	€1.34bn	17.0%	-6
31= (26)	Ericsson	Tech. Hardware	€3.48bn	16.9%	+5
31= (new)	Renesas	Electronics	€1.01bn	16.9%	New (R&D>€1bn)
33 (36)	Otsuka	Biopharma	€1.70bn	16.7%	+3
34= (20)	Abbvie	Biopharma	€4.57bn	16.0%	-14
34= (22)	Astellas Pharma	Biopharma	€1.64bn	16.0%	-12
36 (27)	Amgen	Biopharma	€3.26bn	15.7%	-9
37 (30)	Baidu	Software	€2.01bn	15.4%	-7
38= (34)	Alphabet	Software	€18.27bn	15.3%	-4
38= (30)	Oracle	Software	€5.26bn	15.3%	-8
40= (19)	Eli Lilly	Biopharma	€3.21bn	15.0%	-21
40= (39)	Merck (DE)	Biopharma	€2.23bn	15.0%	-1
42 (35)	SAP	Software	€3.61bn	14.6%	-7
43 (38)	Pfizer	Biopharma	€6.82bn	14.5%	-5
44 (44)	Allergan	Biopharma	€1.98bn	14.3%	=
45 (32)	Salesforce.com	Software	€1.65bn	14.2%	-13
46 (29)	ST Microelectronics	Tech. Hardware	€1.18bn	14.1%	-17
47= (47)	ASML	Tech. Hardware	€1.47bn	13.4%	=
47= (42)	Microsoft	Software	€14.74bn	13.4%	-5
47= (44)	ZTE	Tech. Hardware	€1.46bn	13.4%	-3
50 (35)	eBay	Gen Retail	€1.25bn	13.3%	-15

TABLE 3.5: TOP 50 GLOBAL COMPANIES BY R&D INTENSITY.

Note: The colours indicate world region (red for US, blue for Europe, including two from Switzerland and green for Asia).

Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

4

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

4 Analysis of the top EU 1000 R&D investors

Companies from the three largest countries (Germany, France and the UK) contribute two thirds of both total R&D and total sales of the EU 1000 sample. Most German R&D is in the automotive and industrial engineering sectors, the UK's in pharmaceuticals and software while France has a more diversified R&D sector composition with a much smaller total number of companies than either Germany or the UK.

In 2018 R&D growth in the EU was driven first and foremost by the automotive sector, namely by French and German companies, and to a lesser extent by companies from the Health and ICT industries. Companies from Sweden and Denmark showed R&D growth well above the EU's average rate. Companies showing the highest R&D growth were BMW (13%), PEUGEOT (25%), RENAULT (19%), VALEO 37%), SANOFI (8%), ERICSSON (11%) and SIEMENS (7%). The poorest R&D performance was shown by TELECOM ITALIA (-39%), FIAT CHRYSLER (-14%), BARCLAYS (-58%) and NOKIA (-6%).

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 551 EU companies included in the world top 2500 sample and 449 additional companies based in the EU. The EU1000 have a total R&D of €215.8bn but the top 551 companies alone account for €208.3bn or 97% of this. The distribution of the EU 1000 companies across industrial sectors and countries can be found in Annex 3.

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

4.1 | Changes in the main indicators in 2018

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 903 companies based in the top 10 Member States accounting for 96.9 % of the total R&D. Just three broad sectors (automotive, health and ICT) account for 72% of the EU1000's 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 (see Tables 4.1 and 4.2). These three countries account for 60.3% of the companies, 68.4% of the total R&D and 67.9% of total net sales.

The top 1000 R&D companies in the EU invested €215.8bn, 4.7% more than the previous year.

The French companies made the largest contribution to the growth of the EU 1000 sample. They increased R&D by 10.5% and net sales by 6.5%. These results reflect to a large extent the performance of the French companies in the Automobiles sector (22.7% in R&D and 7.0% in net sales) and also good performance in other sectors such as Aerospace & Defence and ICT industries. The companies showing the highest contribution to the R&D growth of the French sample were PEUGEOT (which acquired Opel in late 2017), RENAULT, VALEO, SANOFI, SAFRAN, UBISOFT and SCHNEIDER (which acquired the IGE+XAO Group in late 2017).

The German companies showed an overall R&D growth below the EU's average (3.6%), showing good performance in ICT and Automobiles but penalised by R&D decreases in Aerospace & Defence and Chemicals. The companies showing the highest contribution to the R&D growth of the German sample were BMW, VOLKSWAGEN, DAIMLER, SIEMENS, SAP, ROBERT BOSCH and CONTINENTAL.

The companies based in the UK increased R&D by 3.2% but showed a large increase in net sales (12.0%) due mainly to the impact of the oil price in companies such as SHELL and BP. The largest contributions to R&D growth were made by companies from several different sectors, e.g. APTIV, MELROSE INDUSTRIES (which acquired GKN in early 2018), LLOYDS BANKING, ROLLS-ROYCE, MYOVANT SCIENCES, ATLASSIAN CORPORATION and ARRIS.

Apart from the three top Member States, among the group of largest EU countries, companies from Denmark and Sweden increased considerably their R&D investments (13.6% and 11.9% respectively). Companies that contributed most to the R&D growth of Denmark were LEO PHARMA, DANSKE BANK, VESTAS WIND SYSTEMS and H LUNDBECK and those from Sweden were ERICSSON, VOLVO, SVENSKA HANDELSBANKEN and ELECTROLUX.

Apart from the aforementioned, other companies that showed high R&D growth were ASML HOLDING and AIRBUS based in the Netherlands; ALLERGAN from Ireland which is being acquired by AbbVie; UCB from Belgium and AMADEUS from Spain.

Country	No. of companies	R&D in 2018 (€bn)	R&D Share within EU (%)	R&D one year growth (%)	Net Sales one year growth (%)
Germany	218	84.3	39.1	3.6	-0.6
France	112	31.6	14.7	10.5	6.5
UK	273	31.6	14.6	3.2	12.0
Netherlands	53	19.4	9.0	2.7	1.2
Sweden	78	10.4	4.8	11.9	8.8
Ireland	30	9.4	4.4	3.9	4.3
Denmark	44	6.1	2.8	13.6	0.6
Italy	39	5.9	2.7	-10.0	4.5
Finland	35	5.7	2.6	-1.9	6.0
Spain	21	4.8	2.2	5.3	2.1
Top 10 countries	**903**	**209.2**	**96.9**	**4.6**	**4.4**
Other EU	97	6.6	3.1	9.8	4.7
Total EU	**1000**	**215.8**	**100**	**4.7**	**4.4**

TABLE 4.1: R&D TRENDS FOR COMPANIES BASED IN THE TOP 10 EU MEMBER STATES.
Note: For the sample of 1000 EU companies.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Sector	EU1000 R&D in 2018 (€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	9.4	-15.1	-5.1	16.0	11.2	7.2	0.9
Automobiles & other transport	64.9	4.6	1.6	22.7	7.0	20.8	-10.6
Chemicals	5.5	-5.8	3.1	1.4	3.3	1.1	12.9
Health industries	46.9	2.2	-4.5	6.4	2.7	1.4	2.0
ICT producers	27.6	7.7	2.3	9.4	3.9	5.9	0.5
ICT services	15.9	9.3	1.6	6.2	2.8	0.6	2.6
Industrials	13.0	4.2	1.3	-2.4	9.5	42.2	60.2
Others	32.6	-3.7	-4.9	1.5	6.8	0.0	13.0
Total	**215.8**	**3.6**	**-0.6**	**10.5**	**6.5**	**3.2**	**12.0**

TABLE 4.2: 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 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Among the large countries, two groups of companies decreased R&D, are Italy (-10.0%) and Finland (-1.9%). In Italy, the good performance of companies such as COFIDE, ENEL, PRYSMIAN, SALVATORE FERRAGAMO and KEDRION has been offset by the reduction of R&D by TELECOM ITALIA and to a lesser extent also by LEONARDO and RECORDATI. In Finland, the R&D decline of the sample was mostly due to the reduction of NOKIA's R&D growth and its high weight in Finland's sample of companies.

In 2018, the average R&D intensity of the EU-1000 companies increased slightly because of the higher increase of R&D investments compared to that of net sales, 4.7% vs 4.4%.

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. The three largest companies in Ireland (Medtronic, Allergan & Seagate) are US companies with registered offices in Ireland to take advantage of low Irish corporate tax rates.

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

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

4.2.1 Ten-year trends

The annual growth rates of R&D and net sales and profitability for companies based in Germany, France, the UK and the Netherlands over the past 10 years is provided respectively in Figures 4.1, 4.2, 4.3 and 4.4. These Figures are based on our history database comprising these indicators over the whole 2009-2018 period for EU companies based in Germany (159), France (87), UK (128) and NL (30)[18].

Companies based in Germany showed a strong performance in terms of R&D from 2010 to 2017, recovering to and then improving on levels of R&D growth prior to the financial crisis, however, over the last period, the R&D growth of German companies was below the EU's average. The growth of net sales has not followed the same path: a slowdown from 2010 to 2013 has been followed by a hesitant recovery from 2013 to 2014/15, then again sales decreased from 2015 to 2016 and recovered significantly in 2017 but then declined again in 2018. On the other hand, German companies have maintained a stable level of profitability over the past 10 years in the 6-8% range with a stable trend over the past two years.

Companies based in France showed a low but positive trend in R&D growth after the decrease from 2013 to 2014, but at much lower levels than their EU or non-EU counterparts although growth recovered significantly from 2016 to 2017 and rose substantially in 2018. The growth of net sales reversed the negative trend showed over 2010-2014 increasing significantly from 2016 to 2017 and remaining stable over 2018. The average profitability of the French companies showed a negative trend from 2011 to 2015 but it then increased from 2015 to 2016 and remained stable in 2017 and 2018 at 9%.

Companies based in the UK showed a strong recovery of R&D and net sales from 2009 to 2010 that then reversed in 2010 to 2012. In 2012-2013 their R&D investment resumed growth at a significant pace but with a level of net sales practically unchanged. In 2014-2015 the R&D level remained practically unchanged although with a

[18] The requirement for a company to be present in the Scoreboard over the whole 10-year period excludes companies that have grown quickly and entered the *Scoreboard* during this period and also companies which have failed or been acquired during that time (Alcatel-Lucent being just one example). Some of the growth may not be organic but due to acquisitions (e.g. Peugeot acquiring Opel in 2017 and Allergan's many acquisitions). These exclusions and factors may affect the growth rates quoted below.

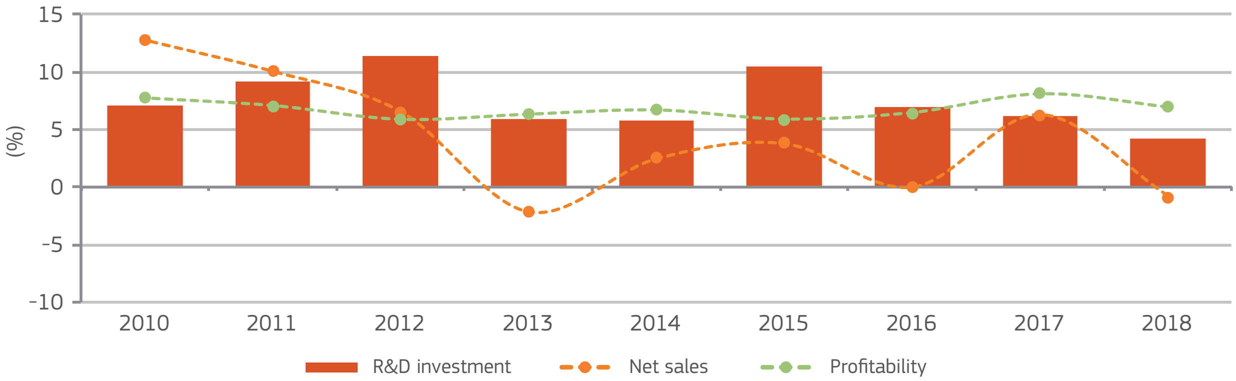

FIGURE 4.1: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE GERMAN COMPANIES.
Note: Growth rates for the three variables have been computed on 159 out of the 218 German companies for which data are available for the entire period 2009-2018. These companies represent 91.5% of R&D, 89.8% of Net Sales and 92.5% of Operating Profits of the German companies in the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

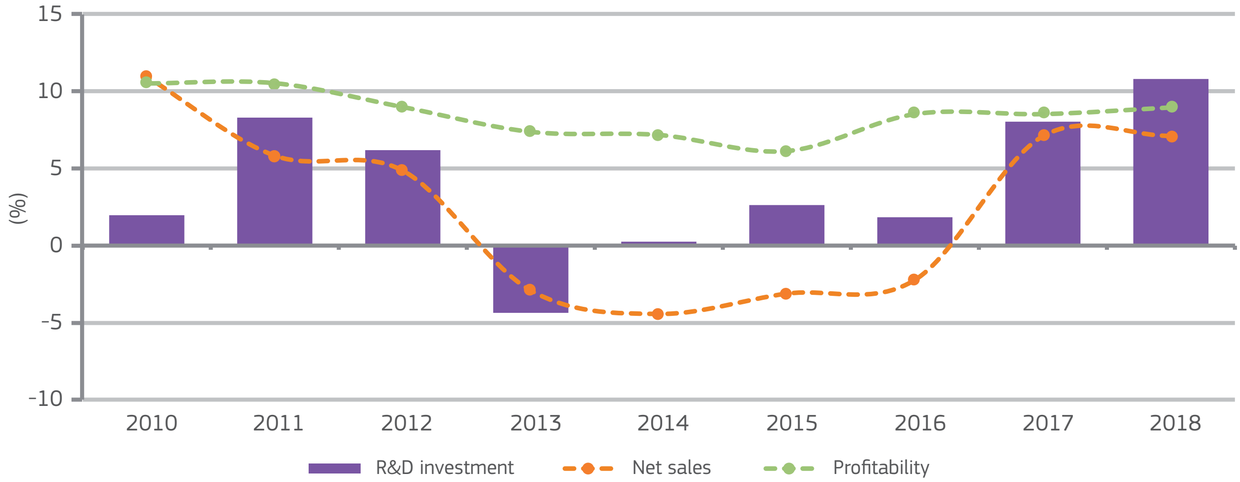

FIGURE 4.2: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE FRENCH COMPANIES.
Note: Growth rates for the three variables have been computed on 87 out of the 112 French companies for which data are available for the entire period 2009-2018. These companies represent 94.6% of R&D, 89.7% of Net Sales and 89.0% of Operating Profits of the French companies in the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

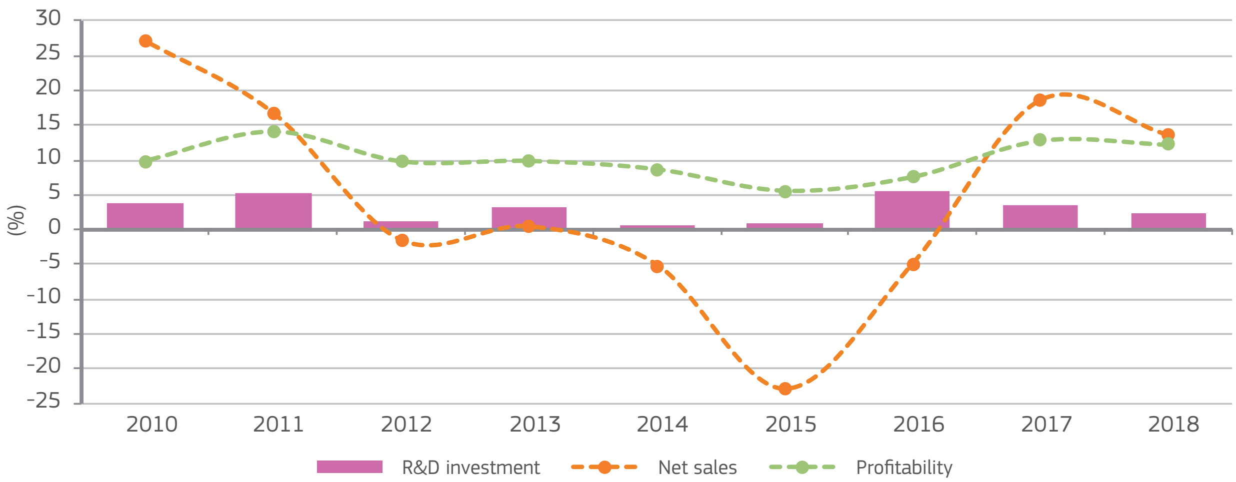

FIGURE 4.3: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE UK COMPANIES.
Note: Growth rates for the three variables have been computed on 128 out of the 273 UK companies for which data are available for the entire period 2009-2018. These companies represent 68.4% of R&D, 83.5% of Net Sales and 78.6% of Operating Profits of the UK companies in the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

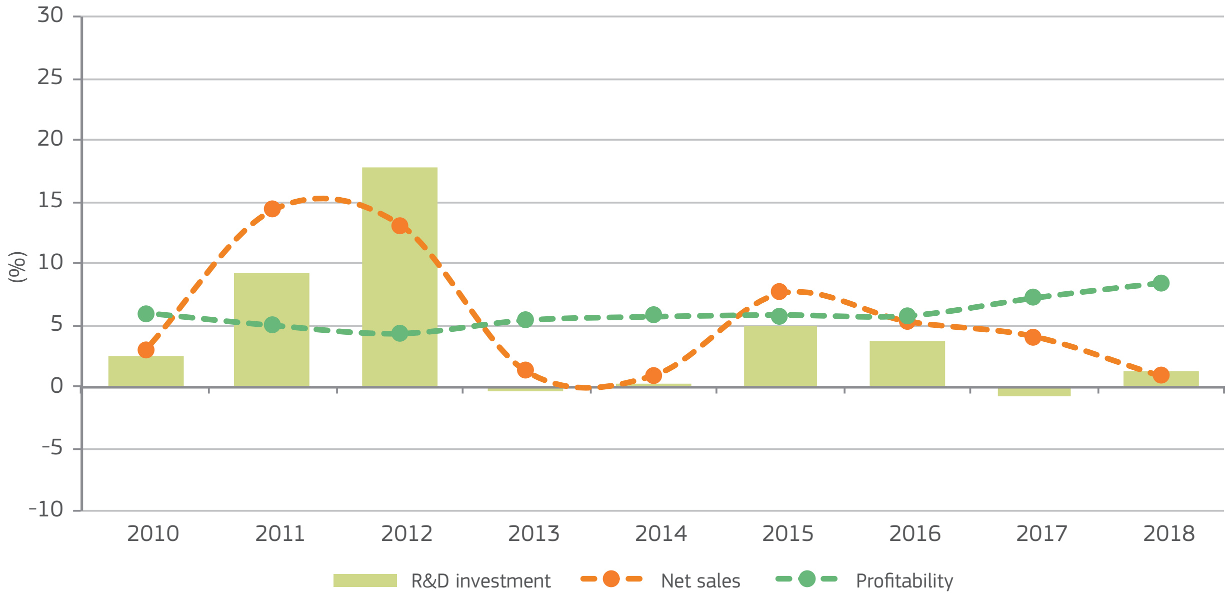

FIGURE 4.4: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH AND PROFITABILITY BY THE DUTCH COMPANIES.
Note: Growth rates for the three variables have been computed on 30 out of the 53 Dutch companies for which data are available for the entire period 2009-2018. These companies represent 85.8% of R&D, 77.3% of Net Sales and 64.0% of Operating Profits of the Dutch companies in the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

significant decrease of net sales and then both R&D and sales increased significantly from 2015-2017. In 2018, R&D rose below the EU's average but net sales increased strongly (mostly due to the impact of high oil prices). The average profitability of the UK companies was the highest of the three countries throughout the period although, like their French counterparts, showed a decreasing trend from 2011-2015 but a strong increase in 2016 remaining stable at 10-11% over the last three years.

Companies based in the Netherlands registered an increase in R&D and sales over 2009-2012 and then a slowdown over 2012 to 2014. From 2015 to 2016, R&D and sales grew moderately and over 2017 R&D stagnated while sales grew at a significant pace. Over 2018, companies based in the Netherlands showed a positive growth of R&D and net sales, but well below the average growth of their EU counterparts. The profitability of companies based in the Netherlands remained stable at 5-6% from 2010 to 2016, showing a slight upward trend to 7% in 2017 and 9% in 2018. Two companies - Fiat Chrysler and Airbus account for 40% of Netherlands R&D in the *Scoreboard*, their headquarters are in the Netherlands but their main operations are located elsewhere.

4.2.2 Change in R&D, net sales and employment over 2009-2018 for groups of sectors and top EU company aggregates

The levels of R&D, net sales and employment in 2009 and 2018 are presented in Figures 4.5, 4.6 and 4.7 for groups of industrial sectors with characteristic R&D intensities[19] (see definition in Chapter 1 – Table 1.3).

These Figures refer to a set of 637 companies that reported R&D, net sales and number of employees in the first and the last year of the period 2009-2018 (DE-164, FR-82, UK-130, NL-30 and Other EU-231).

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

The overall changes for each indicator are:

- R&D increased by 58% (high tech 48%, medium-high tech 83%, medium-low tech 3% and low tech 22%);

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

- Net sales increased by 35% (high tech 43%, medium-high tech 67%, medium-low tech 5% and low tech 21%);

- Employment increased by 17% (high tech 41%, medium-high tech 35%, medium-low tech -18% and low tech 2%).

These three indicators changed in very different proportions across member states and sector groups. By sector groups the highest increases were:

- In high tech (R&D - DE 81%; Net sales - DE 71%; Employment, FR 78%);

- In medium-high tech (R&D - DE 100%; Net sales - DE 79%; Employment – UK 43%);

- In medium-low tech (R&D - Netherlands 41%; Net sales - UK 55%; Employment - UK -2%);

- In low tech sectors (R&D - NL 597%; Net sales - NL 120%; Employment - NL 77%)[20].

The above results analysed by member state show distinct characteristics of the R&D investing companies in each country. Germany has the largest proportion of its R&D in medium-high tech, with the UK having the largest proportion in high tech while France has almost equal proportions in high tech and medium-high tech.

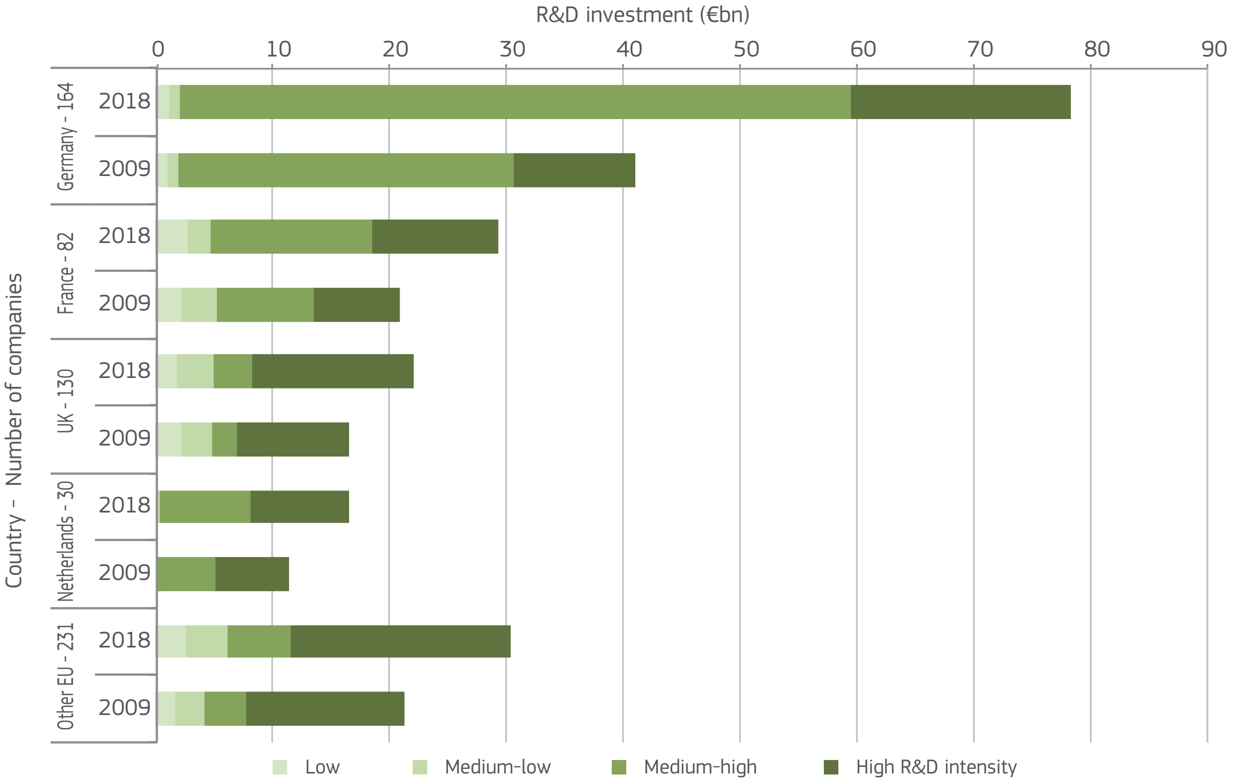

FIGURE 4.5: R&D INVESTMENT IN 2009 AND 2018 BY SECTOR AND MAIN EU GROUPS.
Note: Figures displayed refer only to the 637 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 86.4% of R&D, 85.8% of Net Sales and 83.3% of Employment of the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[20] There are only two Dutch companies in the low-tech group. One of them, AHOLD, showed tenfold increase in R&D, Net sales and Employees mostly through acquisitions.

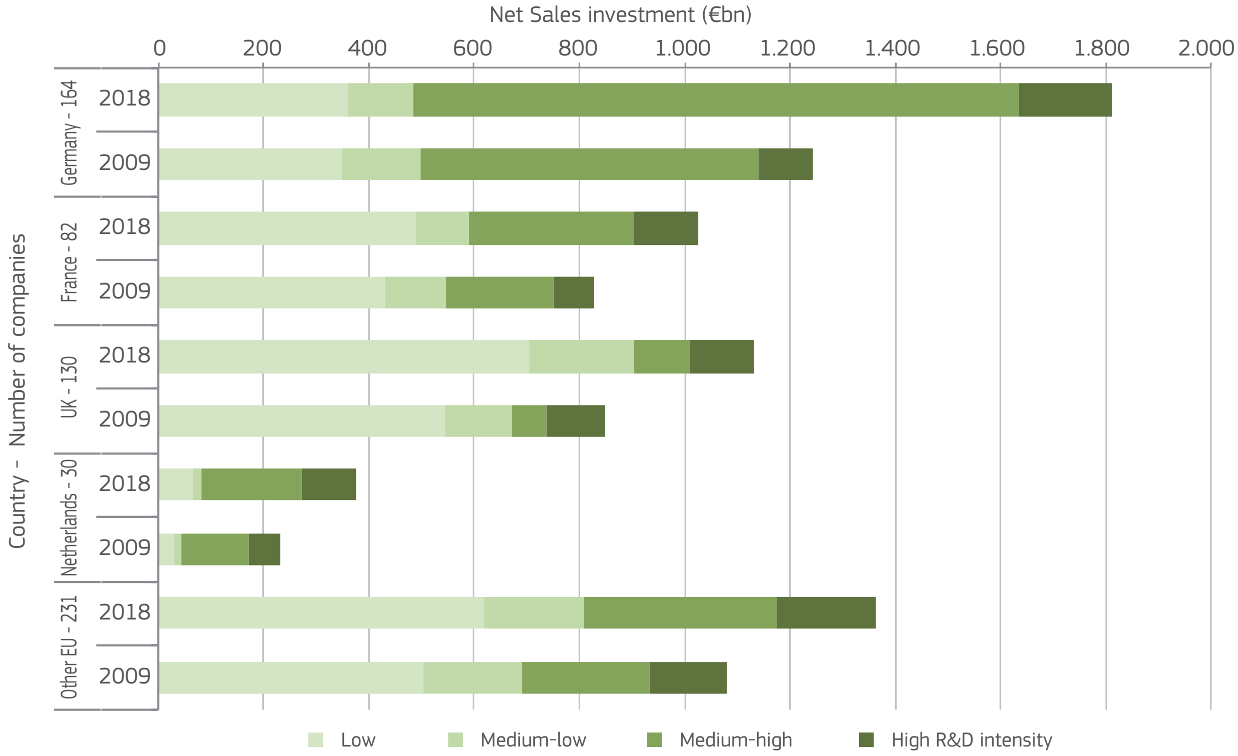

FIGURE 4.6: NET SALES IN 2009 AND 2018 BY SECTOR AND MAIN EU GROUPS.
Note: Figures displayed refer only to the 637 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 86.4% of R&D, 85.8% of Net Sales and 83.3% of Employment of the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

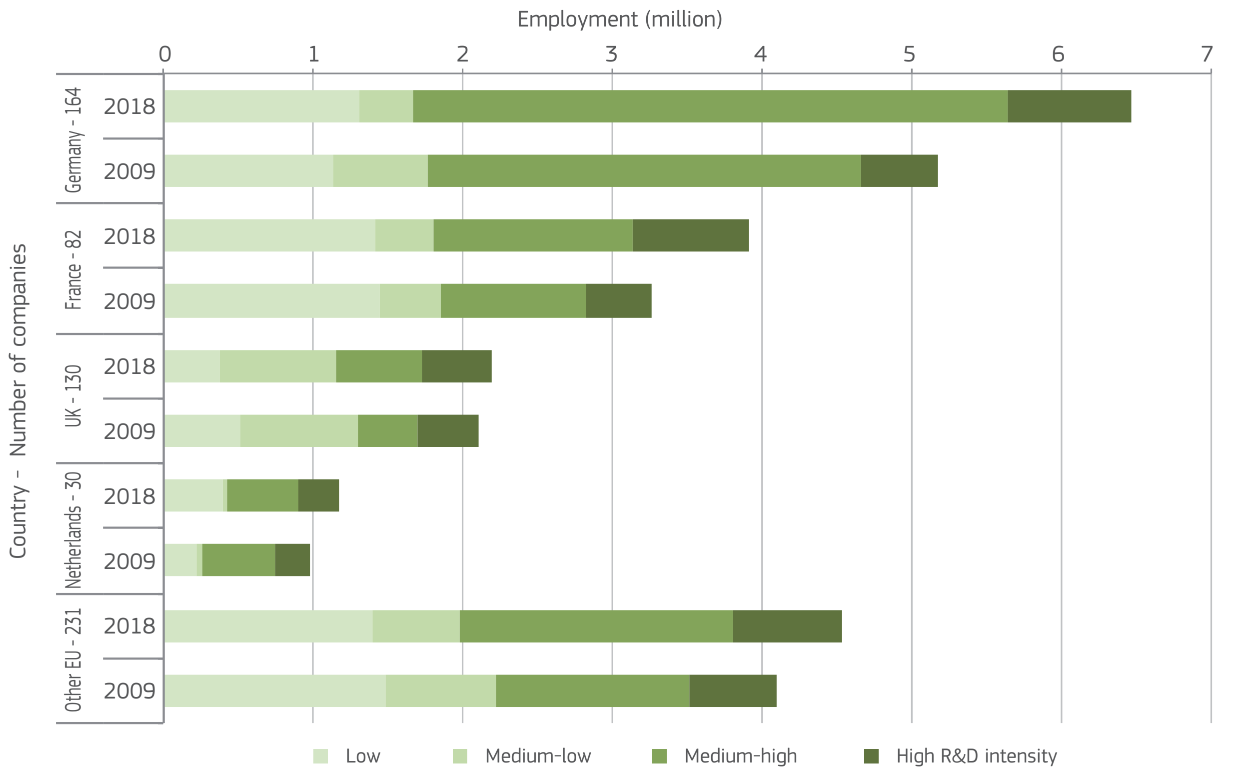

FIGURE 4.7: EMPLOYMENT IN 2009 AND 2018 BY SECTOR AND MAIN EU GROUPS.
Note: Figures displayed refer only to the 637 companies for which data are available for all variables (R&D, Net Sales and Employment) both years (2018 and 2009). These companies represent 86.4% of R&D, 85.8% of Net Sales and 83.3% of Employment of the EU1000 sample in 2018.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

5

TEN-YEAR PERFORMANCE OF PHARMA AND BIOTECH COMPANIES: DECREASING **R&D EFFICIENCY?**

5 Ten-year performance of pharma and biotech companies: decreasing R&D efficiency?

Top R&D investors in the pharma and biotech sector have registered significant performances in all financial indicators in the past 10 years.

Despite an increasing investment in R&D in the past 10 years, the number of patents filed at EPO and USPTO in the same period by pharma and biotech companies has decreased.

There is a difference in the Pharma and Biotech sector between EU and US in terms of their technological profile and is mainly driven by the low number of Biotech companies in the EU compared to the US.

As observed in past *Scoreboard* editions, the top R&D companies in the pharma and biotech sector have shown a robust performance in most indicators over the past ten years. For example, the whole sample of companies increased R&D by around 60% and sales by around 50% and showed also significant increases in capital expenditures, number of employees, profits, and market capitalisation.

Nevertheless, these industries, and in particular the drug development, are facing serious challenges that seem to result in a decreasing efficiency of the R&D investments[21], i.e. significantly higher investments per each new medicine approved. Indeed, the development of new medicines are facing ever higher effectiveness requirements, stricter approval regulations, complex market issues and high uncertainties involved in the R&D&I processes.

In this context, the objective of this chapter is to analyse further the economic and innovation performance of these industries over the past ten years and to analyse how the investments (input) compare to the company results (output) developed. The analysis is based on company indicators of the top industrial players including R&D investment, patent portfolios and main financial data.

5.1 | Sluggish growth rates of R&D investments and net sales in pharma and biotech sector, but EU companies slowly catching-up

Looking at the period between 2008 and 2016 in the pharma and biotech sector both of the R&D investment and the net sales growth rates are successively slowing down (fig 5.1), although beyond this trend the year-by-year figures have been strongly influenced by the global economic environment (e.g. the global financial crisis between 2009 and 2012). Another factor is the very large number of mergers and acquisitions in the biopharmaceutical sector that have occurred in the last decade. This increase in M&A appears to be the companies' response to two technology trends. The first is the greater difficulty of developing biologic drugs compared to the small molecule drugs of

[21] See: a) Cséfalvay, Zoltán (2017), *TECHtonic Shifts*, Chapter 11 – "Efficiency of R&D investments on pharma steadily dropping since the 1950 - Eroom law". Kairosz Kiadó, Budapest.; b) Deloitte Centre for Health Solutions (2018), *Unlocking R&D productivity, measuring the return from the pharmaceutical innovation*, UK.

previous decades. This demands more R&D per successful drug and has also increased the regulatory requirements for new drug approval and larger companies are therefore more able to do this. The second trend is the emergence of smaller biotech companies, particularly in the US, which are able to raise funding to develop innovative new drugs. When such drugs are successful in later stage clinical trials, these biotech (or their lead drug candidates) are usually acquired by large pharmaceutical companies who complete Phase III clinical trials, obtain regulatory approval and use their extensive sales & marketing teams to achieve the new drug's full potential in the market[22].

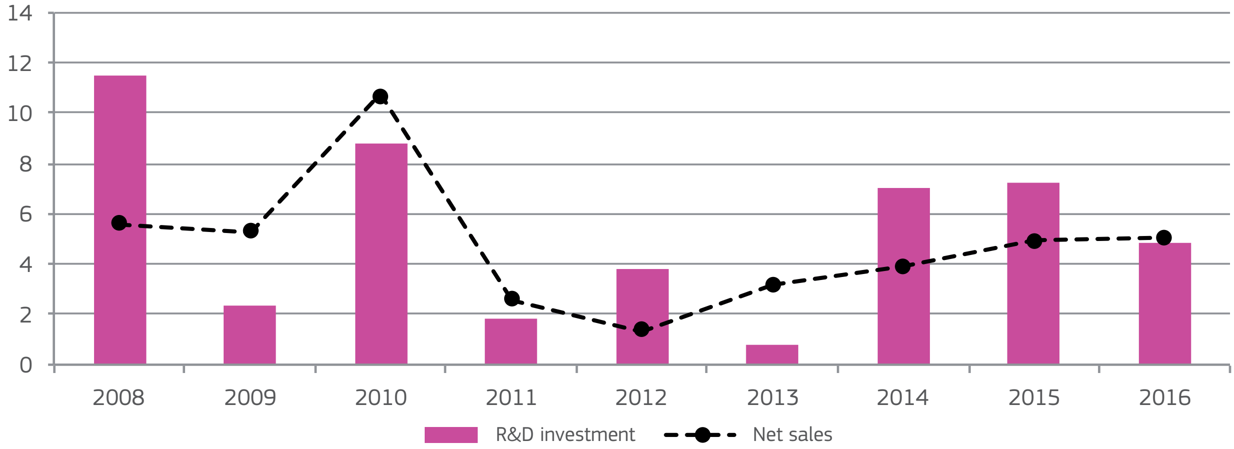

FIGURE 5.1: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH FOR THE PHARMA AND BIOTECH SECTOR.
Note: growth rates (in percentage) of R&D and Net sales have been computed on 148 out of the 304 pharma and biotech companies in the top 2000 for which data are available for the entire period 2007-2016. These companies represent 87.3% of R&D,87.9% of Net Sales and 97.8% of Operating Profits of the Pharma and Biotech companies in the whole sample in 2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Nevertheless, despite the trend of sluggish growth rates in the past few years R&D investment and net sales in pharma and biotech sector were growing faster in the EU than in the US (fig 5.2). In addition, it seems that while US pharma and biotech companies spend in R&D around 1.5 times more than their European counterparts, the EU companies might have started a catching-up process in this respect.

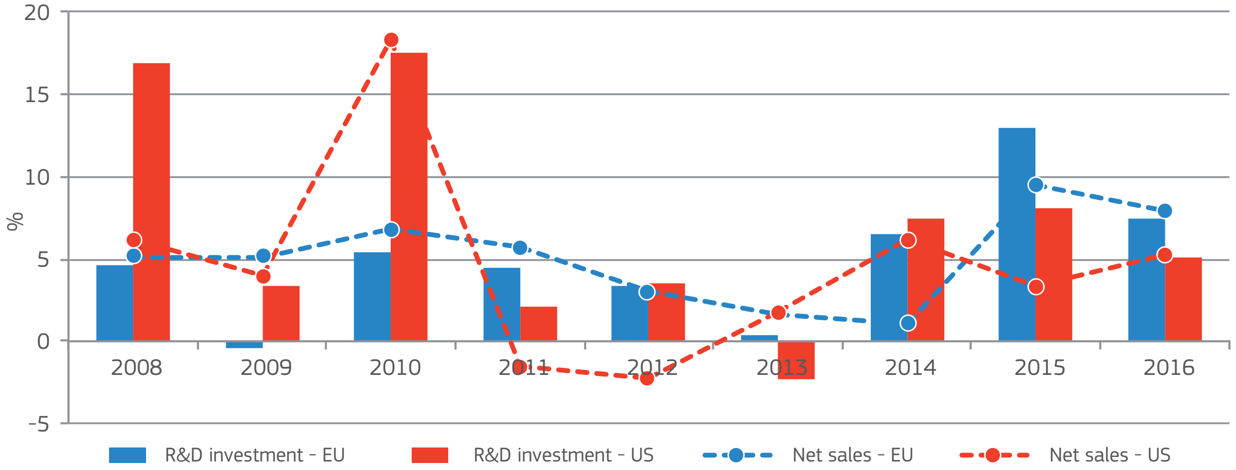

FIGURE 5.2: ONE-YEAR R&D INVESTMENT AND NET SALES GROWTH FOR THE PHARMA AND BIOTECH SECTOR COMPANIES – EU VS US.
Note: growth rates (in percentage) of R&D and Net sales have been computed on 41 out of the 73 EU (representing 93.5% of the R&D of these companies in 2016) and 52 out of the 152 US (representing 81.0% of the R&D of these companies in 2016) pharma and biotech companies in the top 2000 for which data are available for the entire period 2007-2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

[22] Examples of large M&A deals in the last 10 years are: Pfizer acquiring Wyeth (2009) and Hospira (2015); Takeda acquiring Shire (2018, Shire having acquired Baxalta in 2016); Merck US acquiring Schering-Plough (2009); Abbvie acquiring Pharmacyclics (2015) and Allergan (2019); Gilead acquiring Pharmasset (2011) and Kite Pharma (2017); Johnson and Johnson acquiring Actelion (2017); Amgen acquiring Onyx (2013) and Otezla (2019); Sanofi acquiring Bioverativ (2018); Roche acquiring Genentech (2009); Novartis acqurìng Alcon (2010).

5.2 | Why the catching-up of EU companies in Health sector is important?

This catching-up process is paramount in light of the fact that there are two sectors – Pharma and Biotech and ICT services– which have significantly higher profitability level compared to the other industries. Moreover, the profitability gap between the Pharma and Biotech and ICT sectors and the others industries seems to be a long-term tendency throughout the period between 2007 and 2016. This development is in line with the overall shift of the value creation to intangible assets and services (information, data, intellectual properties, algorithms, software, and applications)[23] which is more prominent in case of R&D intensive industries, such as the Health sector and ICT (fig 5.3).

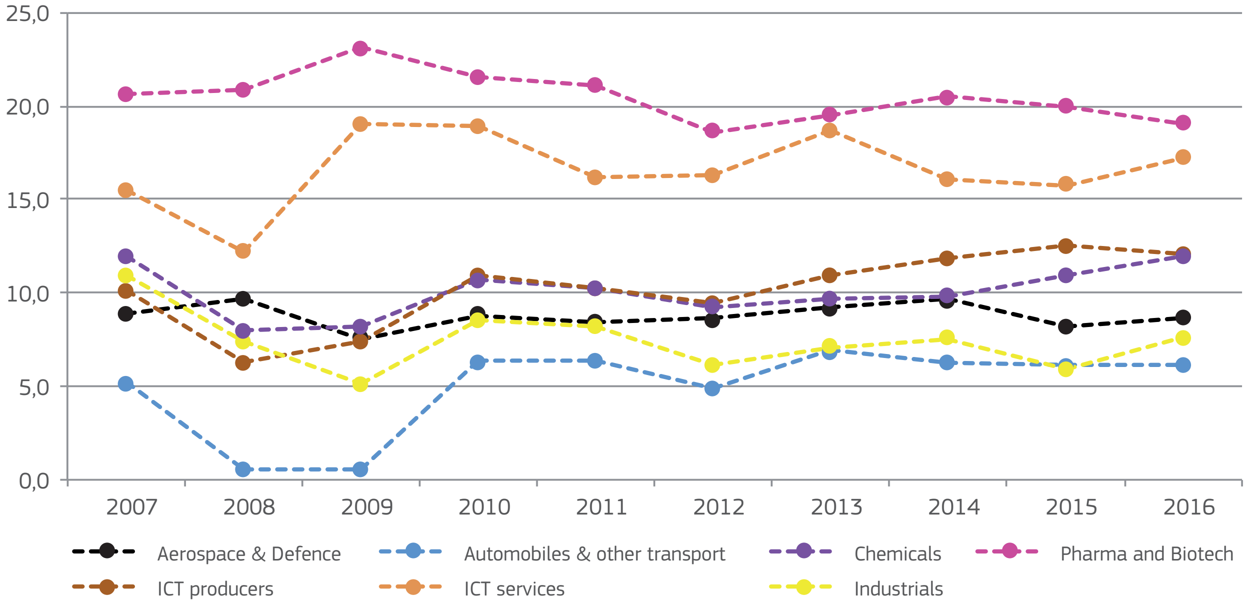

FIGURE 5.3: PROFITABILITY TRENDS (ALL SECTORS).
Note: Profitability (sales as percentage of profits) has been computed on 1434 out of the top 2000 for which data are available for the entire period 2007-2016. Data on the "Others" sector not shown. These companies represent 86.9% of R&D, 84.6% of Net Sales and 85.5% of Operating Profits of the companies in the whole sample in 2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

The sectoral difference is particularly relevant to the EU, since in the US also the ICT producer companies are very profitable and the profitability gaps among the different industries are smaller too. Furthermore, the US companies on average have higher profitability in almost all sectors with the exception of "Automobiles & other transport", where the EU companies have higher profitability levels (see Figures 5.4 and 5.5), but which is forming an ever smaller proportion of total US R&D.

[23] See: Haskel, Jonathan and Westlake, Stian 2017. *Capitalism without Capital: The Rise of the Intangible Economy*. Princeton University Press, Princeton, N. J.

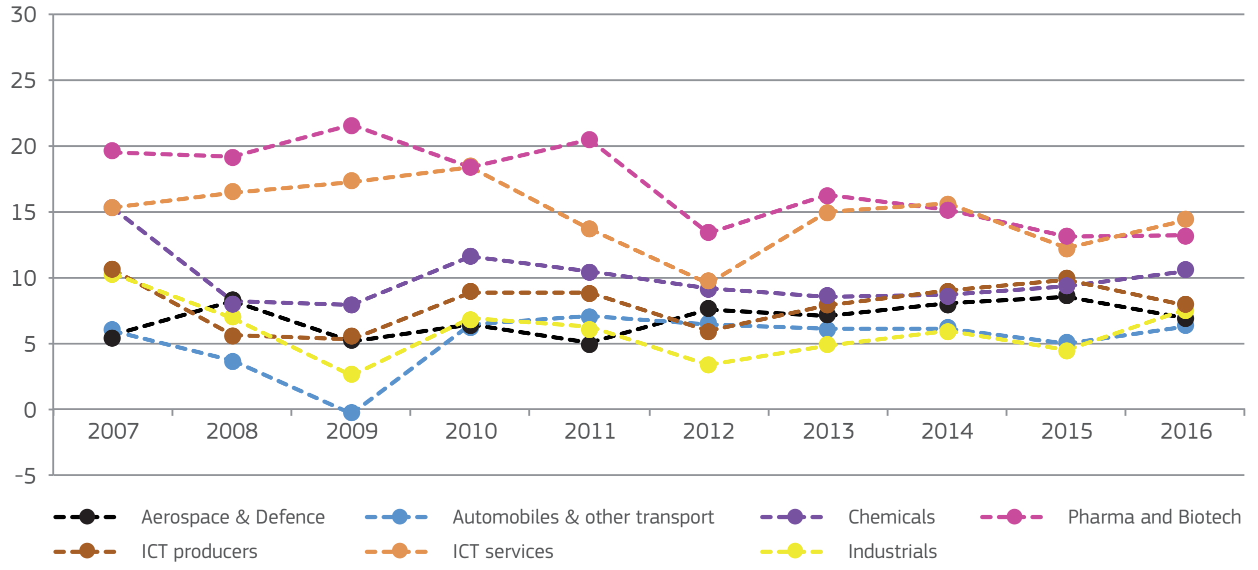

FIGURE 5.4: PROFITABILITY TRENDS (ALL SECTORS) - EU COMPANIES

Note: Profitability (sales as percentage of profits) has been computed on 344 out of the 474 EU companies in the top 2000 for which data are available for the entire period 2007-2016.

Data on the "Others" sector not shown. These companies represent 88.2% of R&D, 85.1% of Net Sales and 84.5% of Operating Profits of the EU companies in the whole sample in 2016.

Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

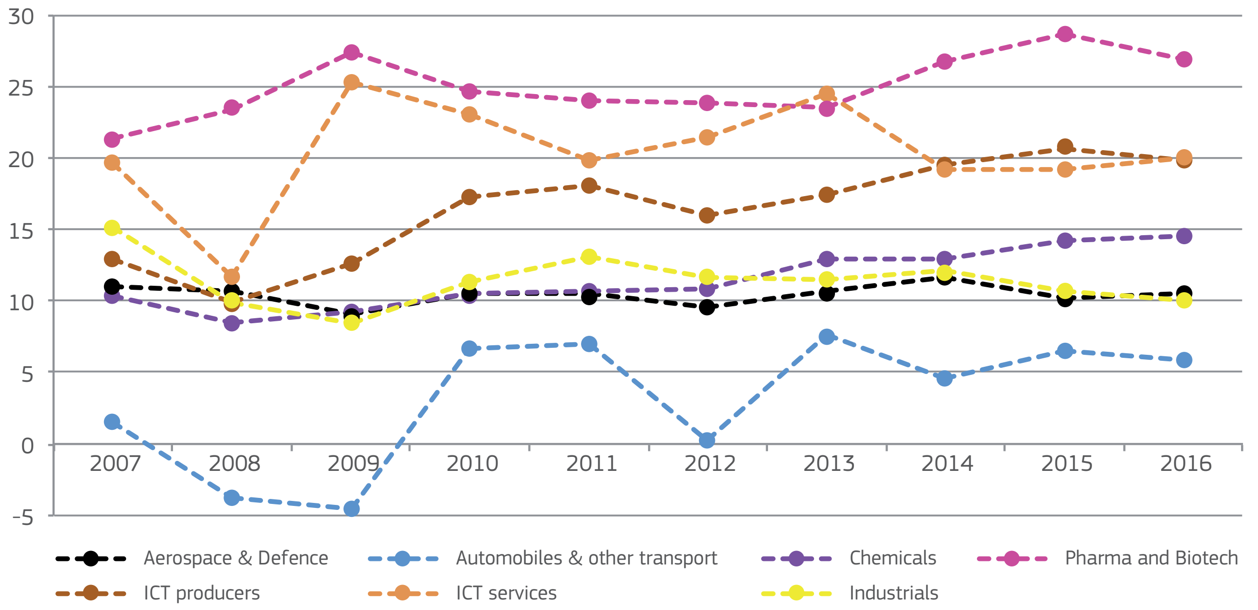

FIGURE 5.5: PROFITABILITY TRENDS (ALL SECTORS) - US COMPANIES

Note: Profitability (sales as percentage of profits) has been computed on 472 out of the 661 US companies in the top 2000 for which data are available for the entire period 2007-2016.

Data on the "Others" sector not shown. These companies represent 90.0% of R&D, 86.4% of Net Sales and 93.2% of Operating Profits of the US companies in the whole sample in 2016.

Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

5.3 | Declining efficiency of R&D investment in Pharmaceuticals and Biotechnology?

Since Pharmaceuticals and Biotechnology belong to the most R&D intensive sectors (see previous EU R&D *Scoreboard* editions), the long-term development of the R&D investment, and particularly the question, how efficient are these investments, is becoming of crucial importance. Taking, however, a simple input-output model, where R&D

investments are regarded as input and patents as output, the long-term development in Pharmaceuticals and Biotechnology industries shows a widening gap between investment and patent activities (fig 5.6). Moreover, this gap is much wider in case of Pharmaceuticals and Biotechnology than in all other sectors (fig 5.7), which are showing also declining paten activity despite increasing R&D investment, but the gap in case of Pharmaceuticals and Biotechnology is significantly deeper.

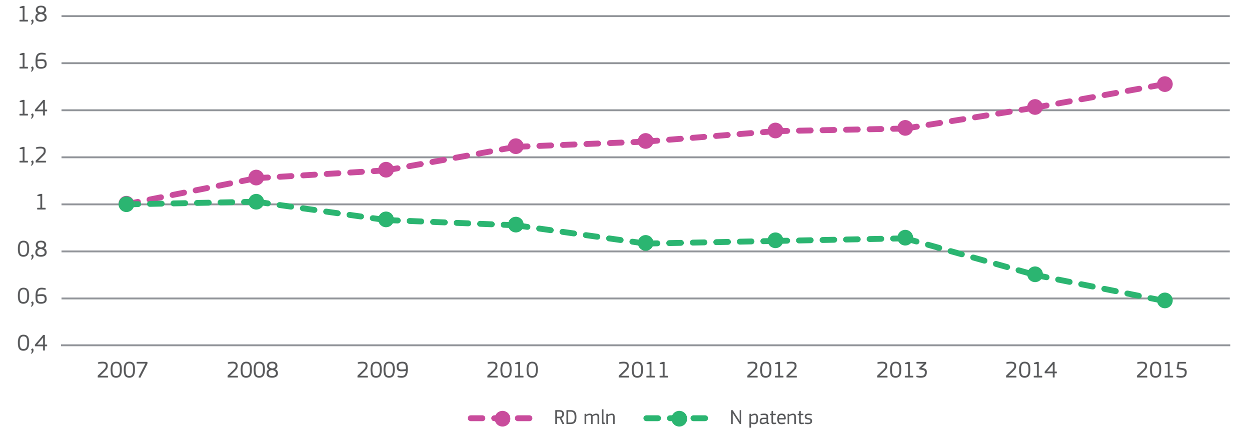

FIGURE 5.6: R&D INVESTMENT AND PATENTS TRENDS FOR THE PHARMA AND BIOTECH SECTOR COMPANIES.

Note: data computed on 148 out of the 304 Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016. Values in 2007 used as base year for both R&D and patents. These companies represent 87.3% of R&D,87.9% of Net Sales and 97.8% of Operating Profits of the Pharma and Biotech companies in the whole sample in 2016.

Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

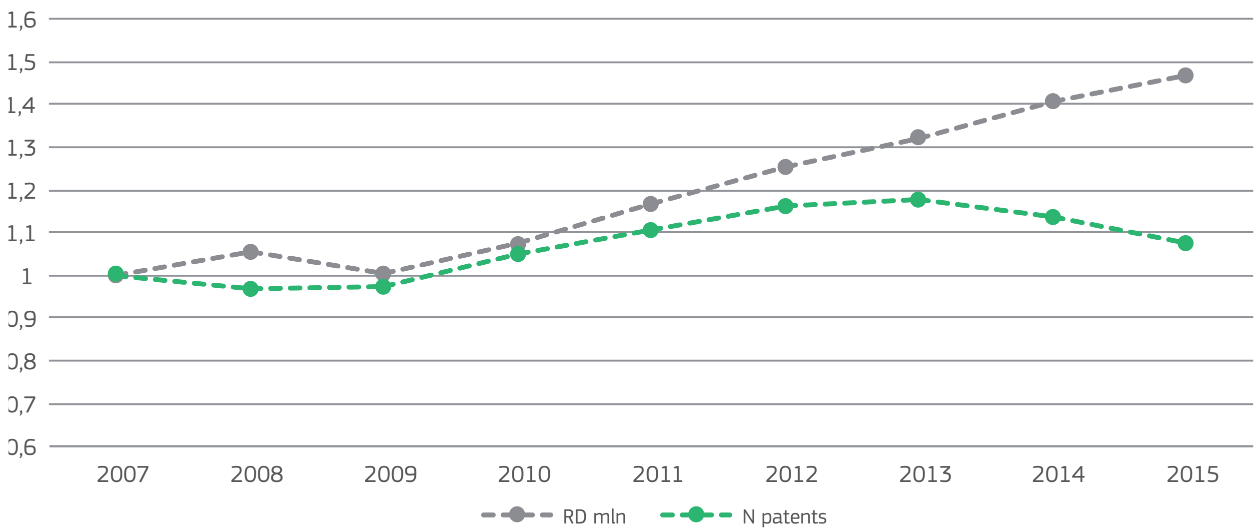

FIGURE 5.7: R&D INVESTMENT AND PATENTS TRENDS (ALL OTHER SECTORS).

Note: data computed on 1286 out of the 1696 non Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016. These companies represent 86.9% of R&D of the non Pharma and Biotech companies in the whole sample in 2016.Values in 2007 used as base year for both R&D and patents.

Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Additionally, in Pharmaceuticals and Biotechnology the observed development of declining patent activity despite increasing R&D investment seems to be a general trend, since in this regard there are now significant differences between the US and EU companies. Nevertheless, this gap is currently wider in the US than in the EU, see Figures 5.8 and 5.9. This is not surprising since the US is leading the world in biotechnology and hence in the development of more complex biologic drugs. For example, the recent breakthroughs in cancer immunotherapy, gene therapy and stem cell therapy are all being led by US companies. There are European companies active in cancer immunotherapy such as AstraZeneca, Novartis and Roche but there are many more US companies in this field.

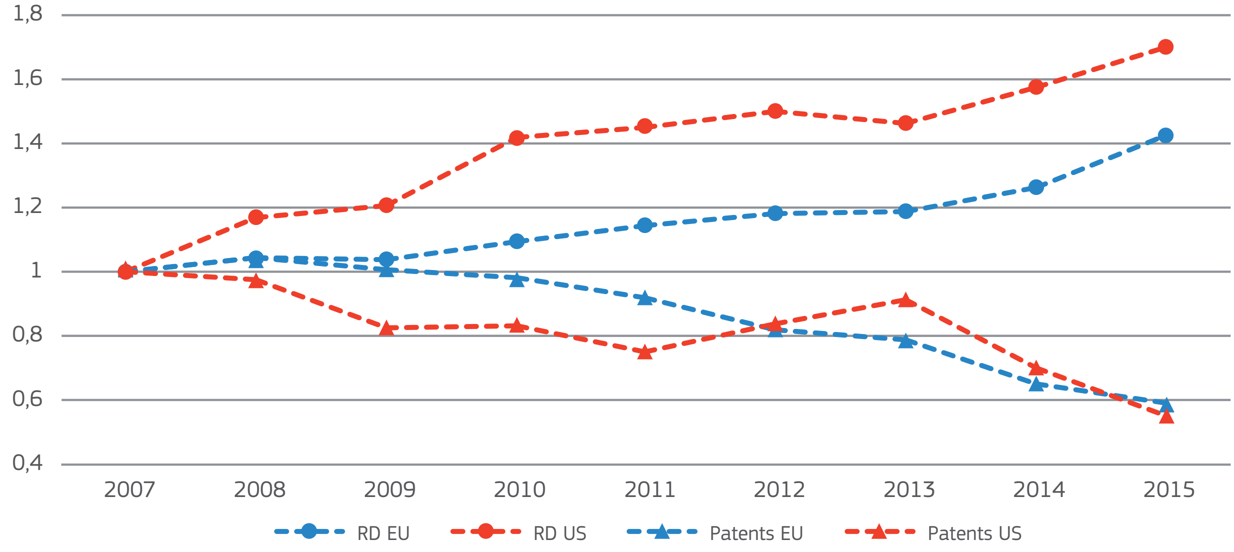

FIGURE 5.8: R&D INVESTMENT AND PATENTS TRENDS FOR THE PHARMA AND BIOTECH SECTOR COMPANIES –EU VS US.
Note: data computed on 41 out of the 73 EU (representing 93.5% of the R&D of these companies) and 52 out of the 152 US (representing 81.0% of the R&D of these companies) pharma and biotech companies in the top 2000 for which data are available for the entire period 2007-2016. Values in 2007 used as base year for both R&D and patents.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

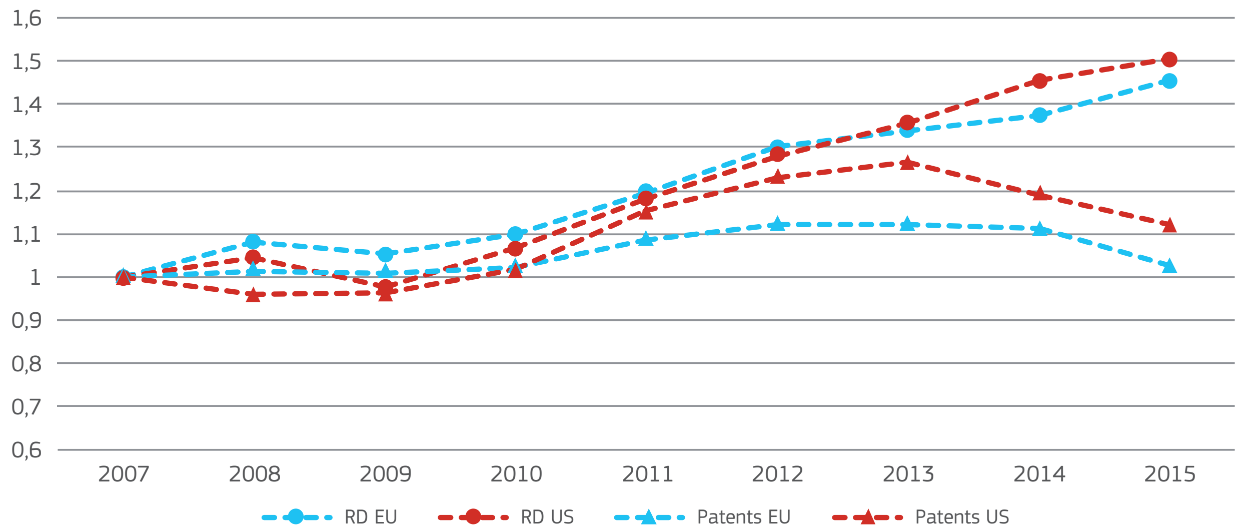

FIGURE 5.9: R&D INVESTMENT AND PATENTS TRENDS (ALL OTHER SECTORS) –EU VS US.
Note: data computed 303 out of the 401 EU (representing and 420 out of the 509 US non Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016. Values in 2007 used as base year for both R&D and patents.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

All in all, Pharma and Biotech companies are responsible for 20% of the total cumulative investment in R&D by the top 2000 R&D investors worldwide in the period 2007-2015. In the same period, they filed only 5% of the total patents filed by the companies in our sample. This is to be expected because of the low ratio of patents to R&D characteristic in the biopharma sector.

Declining efficiency of R&D investment in Pharmaceuticals and Biotechnology has long been discussed and the phenomenon is popularly known as „Eroom law" (Moore's law spelled backwards). This "law" intends to make the difference between the ICT sector, where as a sing for efficiency of R&D investments the performance of microprocessors at the heart of all ICT devices has increased dramatically through the past five decades, while in Pharmaceuticals a completely opposite process seems to take place, and the R&D efficiency measured as number of new marketable medicines per billion US$ of R&D investment has declined over time[24].

[24] See: Scannell, Jack W.–Blanckley, Alex–Boldon, Helen–Warrington, Brian (2012): Diagnosing the decline in pharmaceutical R&D efficiency. *Nature Reviews Drug Discovery* 11, March, 191–200.

Nevertheless, there might be many reasons for the declining efficiency of R&D investments in Pharmaceuticals and Biotechnology sectors, and the majority of these are rooted in the specific nature of the sector. For instance, in Pharmaceuticals and Biotechnology incremental innovation is rarely a viable solutions in the consumer market; e.g. the patients expect from the new medicine to be significantly more effective than the previously one. In Pharmaceuticals and Biotechnology the regulatory environment is more cautious than in other sectors in order to reduce the safety risks to a minimum when a new pharmaceutical product is introduced to the market. Furthermore, Pharmaceuticals and Biotechnology are typically industries where, due to the advanced technology and the high costs for R&D, the manufacturer can determine the products with which it enters the market. Among other factors exactly the high R&D intensity and high cost involved is one the reasons for the high concentration of the producer market. Finally, it is also a specific feature of these sectors that the way from invention and scientific discovery to the marketable products is much longer than in other sectors (because of long and extensive clinical trial procedures), in other words, the rate of return of investment is longer, than in many other industries.

Definitely, further research is needed to analyse in every aspects the role of the different factors, - such as industry specific factors, the role of the regulatory environment, the market structures – in order to get the whole picture.

5.4 | The technological profile of the Pharma and Biotech companies

Looking at the technological profile of companies in the pharma and biotech sector (fig 5.10) – i.e. the technological fields in which they patent – it does not surprise the bulk of their patents is concentrated in few technological fields.

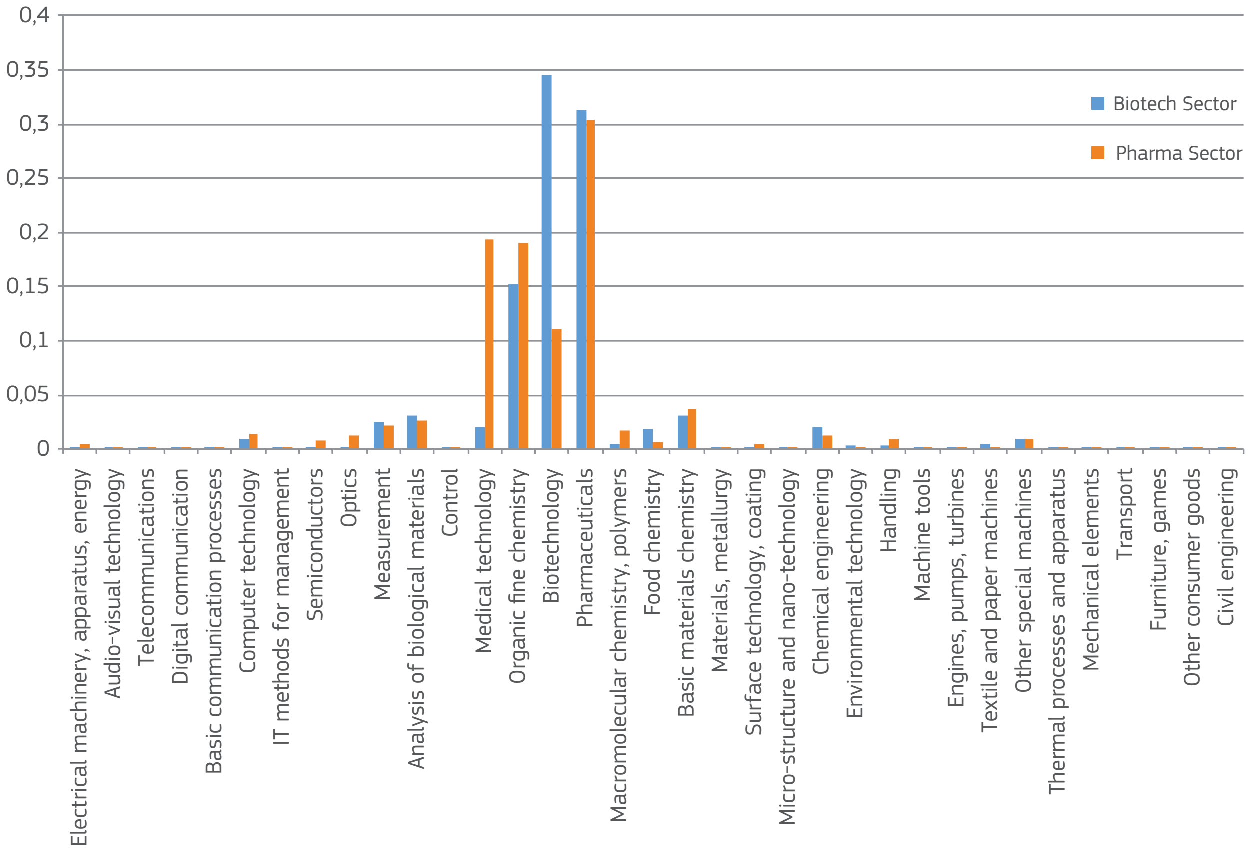

FIGURE 5.10: TECHNOLOGICAL PROFILE OF PHARMA AND BIOTECH COMPANIES.
Note: percentage of patents in each technological filed over the total number of patents of each sector.
Data computed on 148 out of the 304 Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016. These companies represent 87.3% of R&D,87.9% of Net Sales and 97.8% of Operating Profits of the Pharma and Biotech companies in the whole sample in 2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

For the Pharma companies, almost 80% of their patents are in 'Pharmaceuticals' (30.4%), 'Medical technology' (19.4%), 'Organic fine chemistry' (19.1) % and 'Biotechnology' (11.1%).

For the Biotech companies, almost 85% of their patents are in 'Biotechnology' (34.6%). 'Pharmaceuticals' (31.4%), 'Organic fine chemistry' (15.2%), and 'Basic materials chemistry' (3.1%). Although the patents of both subsectors are quite contracted in few technologies, levels of concentration are slightly higher in the biotechnology sector.

If we disaggregate the data and compare the EU vs the US pharma and biotech sectors (Figures 5.11 and 5.12), some difference emerges. Before looking at these differences, we need to keep in mind that the two sectors are quite different in the two regions. While the Pharma component is comparable among the EU and US groups of companies, the Biotech one is very different, with EU companies investing in R&D around 4.5% of what the US biotech companies do, and filing far less patents (around a third of those filed by their US counterparts). The EU has very few of the larger biotech companies and none to compare with the large US biotechs such as Amgen, Biogen, Celgene, Gilead.

Having said that, what emerges comparing the technological profiles of EU and US pharma and biotech companies is a higher concentration of EU companies' patents in few technologies. However, in both regions the sector is dominated by few big firms, responsible for the majority of both patents and R&D.

Top 3 patenting technologies for the EU Pharma companies are 'Pharmaceuticals' (30.7%), 'Organic fine chemistry' (20.0%), and 'Medical technology' (13.9%), while for US Pharma companies are 'Medical technology' (36.2%), 'Pharmaceuticals' (23.9%) and 'Organic fine chemistry' (16.1%). This highlights an interesting difference: while EU pharma companies are more concentrated in traditional pharma technologies, their US counterparts are patenting in medical technologies, suggesting a different development strategy.

Top 3 patenting technologies for the EU Biotech companies are 'Biotechnology' (60.5%), 'Basic materials chemistry' (10.8%), and 'Food chemistry' (7.7%), while those for US Biotech companies are 'Pharmaceuticals' (39.9%), 'Biotechnology' (26.5%) and 'Organic fine chemistry' (20.0%). In this case, it seems EU Biotech

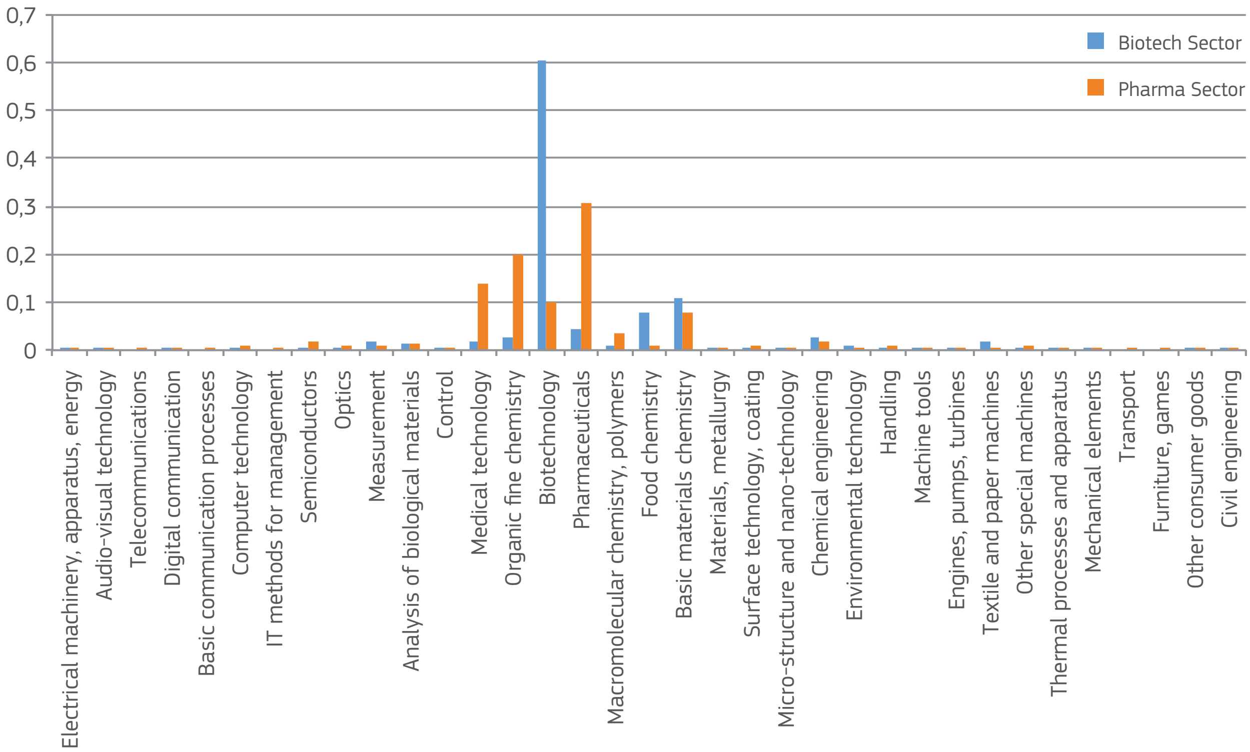

FIGURE 5.11: TECHNOLOGICAL PROFILE OF EU PHARMA AND BIOTECH COMPANIES.
Note: percentage of patents in each technological filed over the total number of patents of each sector.
Data computed on 41 out of the 73 EU (representing 93.5% of the R&D of these companies in 2016) Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

companies mainly develop biotech technologies, while in the US there is much more variety. This is due probably to the structural difference already mentioned between EU and US in the biotech sectors, where the US if by far the world leader.

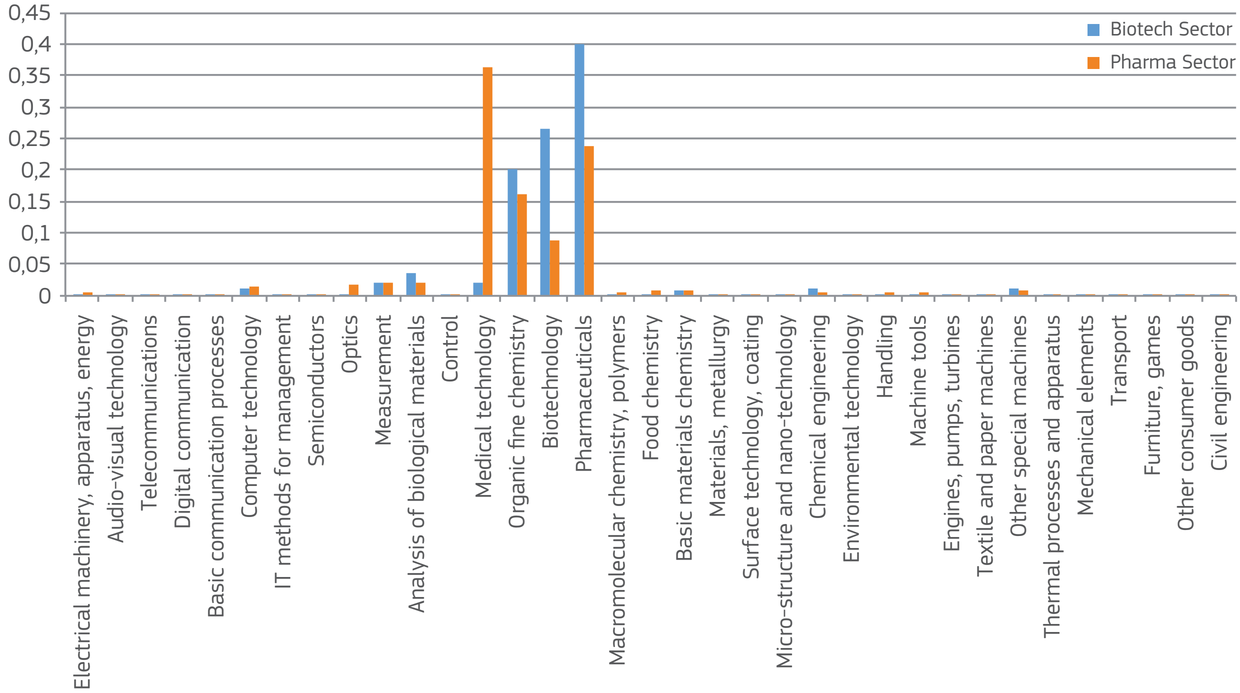

FIGURE 5.12: TECHNOLOGICAL PROFILE OF US PHARMA AND BIOTECH COMPANIES.
Note: percentage of patents in each technological filed over the total number of patents of each sector.
Data computed on 52 out of the 152 US (representing 81.0% of the R&D of these companies in 2016) Pharma and Biotech companies in the top 2000 for which data are available for the entire period 2007-2016.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

5.5 | Concluding remarks

- Albeit the good performance in financial indicators in the past decade, top R&D investing companies in the pharma and biotech sector are experiencing a decrease of patents filed at EPO and USPTO.

- This decline in R&D efficiency can be explained by multiple reasons, mainly connected to the specific nature of the sector, characterised by heavy regulation, long terms of return of investment and incremental innovation.

- Also the industry has undergone a change from chemicals to biological drugs. The move from the earlier small molecule drugs to the modern biologicals means that more R&D is now needed to achieve a granted patent in biopharma since a much smaller proportion of drugs are now based on small molecules.

- There is a clear difference between EU and US in the Pharma and Biotech sector in terms of their technological profile. This is mainly driven by the low number of Biotech companies in the EU compared to the US.

6

THE GREEN TECHNOLOGIES **OF TOP R&D INVESTORS**

6 The green technologies of top R&D investors

The top R&D investors own 50% of patents filed in the EPO and USPTO offices from 2012 to 2015. The share of green patents in the total is 9% of which 53% belong to the top R&D companies.

The highest shares of green patents are held by companies from regulatory driven sectors, like transport-related industries, industrials, and chemicals, but ICT producers follow at short distance.

EU companies show comparative advantages in most green technologies, with the exception of ICT for energy applications.

The objective of this chapter is to analyse the technological profile of the *Scoreboard* companies from an environmental technology viewpoint. The technological perspective allows an assessment of how the innovation activity of different industrial players may contribute to the reduction of the human footprint.

The chapter is based on patent analysis, focusing on assessing the capacity of EU companies to develop environmental technologies, analyse their strengths and weaknesses in specific sub-fields and compare this with other economic areas.

Accounting for 90% of the world's business-funded R&D, the companies of the present *Scoreboard* (SB) have a great potential for using their resources and competencies to develop new technologies in the environmental domain. Important insights about the actual exploitation of this potential can be obtained by inspecting their portfolio of "green patents" over the period 2012-2015 (see Box 6.1 for the methodology). The main areas defined as 'green' for this purpose are transportation (e.g. plug-in or hybrid vehicles), energy production and distribution (e.g. wind and solar electricity generation), production of goods (e.g. fuels from renewable energy sources), Information and Communication Technologies (ICT) related to energy use (e.g. power management systems), buildings (e.g. roof systems for photovoltaic cells), adaptation to climate change (e.g. floating houses), waste (e.g. landfill gas capture) and capture, storage, sequestration or disposal of greenhouse gases (e.g. subterranean or submarine CO_2 storage).

Green patents still represent a limited share (8.6%) of all the kinds of patents filed at the EPO and USPTO over the period 2012-2015 (Figure 6.1a). The same incidence is detectable for SB companies: the share of green over the entire spectrum of patents that SB companies have filed across the board is about 9%. On the other hand, the share of this small part of green technologies invented by SB companies is appreciable and larger than 52% (Figure 6.1b). This mimics the remarkable share (50.4%) of total patents (green and non-green) that SB companies filed at the same patent offices.

6.1 | The green-patent breakdown of top R&D investors: technologies, industries and geographical areas

More than half (58%) of the green patents filed by SB companies refer to transportation (38.1%) and energy (20.6%) technologies (Figure 6.2a), while about 35% of them are distributed over the production of environmental goods (14.2%), ICTs for energy (12.3%) and buildings (8.1%). Climate Change Adaptation Technologies (CCAT) attract only 4% of the green inventive efforts of SB companies, while their involvement in water and waste (1.2%) and in Carbon Capture and Storage (CCS) (1.1%) is negligible.

The bulk of SB green patents (about 80%) is concentrated in companies headquartered in Japan (30.9%), the US (26.8%), Germany (11,8%) and South Korea (10.5%), showing an interesting "triangle" among East Asia, North-America, and Central Europe in the introduction of environmental technologies (Figure 6.2b). On the other hand, European countries other than Germany – France, the UK, the Netherlands, and Sweden, among the first – as well as China and Taiwan, host companies contributing to the total of the SB green patents to a limited extent (5% or even less).

Box 6.1
Methodology for the identification of green patents

Following the extant research on the topic (Hascic and Migotto, 2015)[25], green patents are hereby considered as a reliable proxy of the development/adoption of green technologies at the company level.

Green patents are identified by using the Cooperative Patent Classification (CPC) codes assigned to patents by the European Patent Office (EPO). In particular, the "Y02" class included in the CPC enables us to identify inventions related to technologies for mitigation or adaptation against climate change. Therein, the classification is articulated into eight subclasses at 4-digit level, encompassing a broad spectrum of environmental-related technologies, which will be used in the present analysis: transportation, energy production and distribution, production of goods, Information and Communication Technologies (ICT) related to energy use, buildings, adaptation to climate change, waste and capture, storage, sequestration or disposal of greenhouse gases. This classification of green technologies mirrors the one proposed by the OECD (Hascic and Migotto, 2015), whose adoption yields similar results to those reported in this chapter. The approach proposed here instead differs from the one adopted by Fiorini et al. (2017)[26], which includes other codes (e.g. Y04) in order to embrace patent activity in smart grids.

The analysis refers to patent families - collections of patent applications for the same green invention, filed at different patent offices - and uses priority date as temporal reference for them. Taking stock of their cooperative efforts in classifying patents, and following recent analyses of the geography of green technologies, the analysis is performed on inventions for which intellectual property right protection has been sought at the European Patent Office (EPO) and/or United States Patent and Trademark Office (USPTO). Crossing the need of reducing changes in the sample of the 2000 observed *Scoreboard* companies with that of avoiding truncation in patent data, the analysis is performed over the period 2012-2015. With the exception of the number green patents, patent families referring to multiple technological fields are assigned to each of them, and the same is done with respect to countries (Nesta et al., 2014)[27].

[25] Haščič, I.,&Migotto, M. (2015). Measuring environmental innovation using patent data (OECD Environment Working Papers No. 89).

[26] Fiorini, A., Georgakaki, A., Pasimeni, F., and Tzimas, E. (2017). Monitoring R&I in Low-Carbon Energy Technologies. Methodology for the R&I indicators in the State of the Energy Union Report -2016 edition. JRC Science for Policy Report.

[27] Nesta, L., Vona, F., & Nicolli, F. (2014). Environmental policies, competition and innovation in renewable energy. *Journal of Environmental Economics and Management*, 67(3), 396-411.

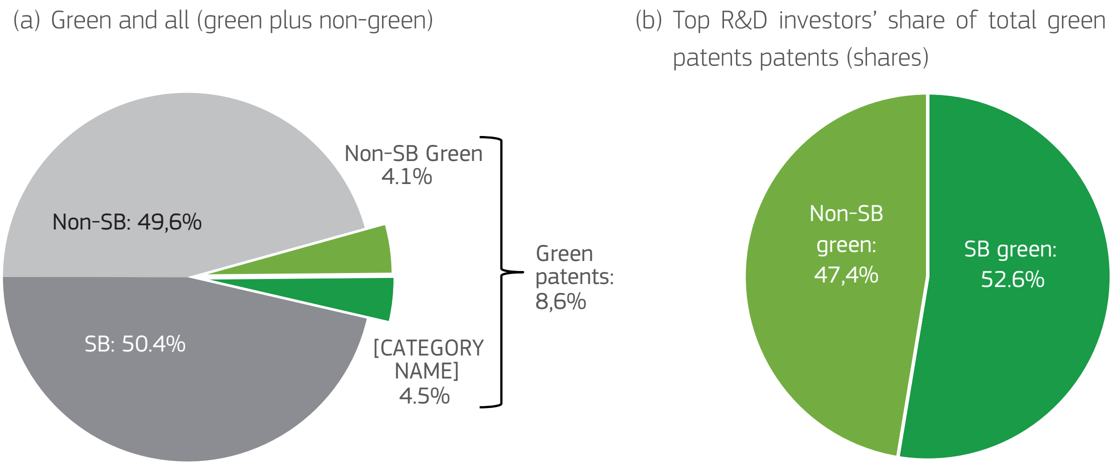

FIGURE 6.1: THE GREEN PATENTS OF TOP R&D INVESTORS, 2012-2015.
Note: (a) Patents filed by Scoreboard (SB) and non-Scoreboard (Non-SB) companies and share of green patents (according to CPC classification)[28]; (b) Green patents filed by Scoreboard and non-Scoreboard companies.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

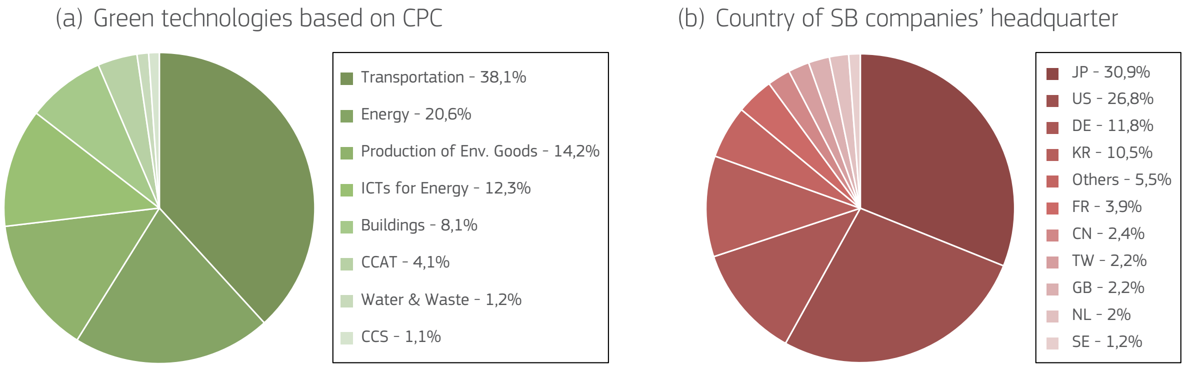

FIGURE 6.2: TOP R&D INVESTORS' GREEN PATENTS BY TECHNOLOGY (A) AND COUNTRY (B), 2012-2015.
Note: (a) Caption: CCS = "Carbon Capture and Storage", ICT = "Information and Communication Technologies", CCAT = "Climate Change Adaptation Technologies", ICB = "Industry Classification Benchmark".
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

The geographical distribution of the most green-patenting SB companies reveals interesting insights when their industry breakdown is considered (Figure 6.3). ICT producers reveal a dominant share of green patents (83%) of those filed by Chinese SB companies, with the other industries lagging substantially behind. It is instead automobile and other transport SB companies that show the highest share of green patents filed by the European, the US and the Japanese ones, while ICT producers follow a short distance behind. Finally, US and Europe are the only areas of the four where SB companies in aerospace and defence concentrate an appreciable share of green patents (about 17% and 14%, respectively).

[28] The Cooperative Patent Classification (CPC) is an extension of the IPC and is jointly managed by the EPO and the US Patent and Trademark Office. https://www.epo.org/searching-for-patents/helpful-resources/first-time-here/classification/cpc.html.

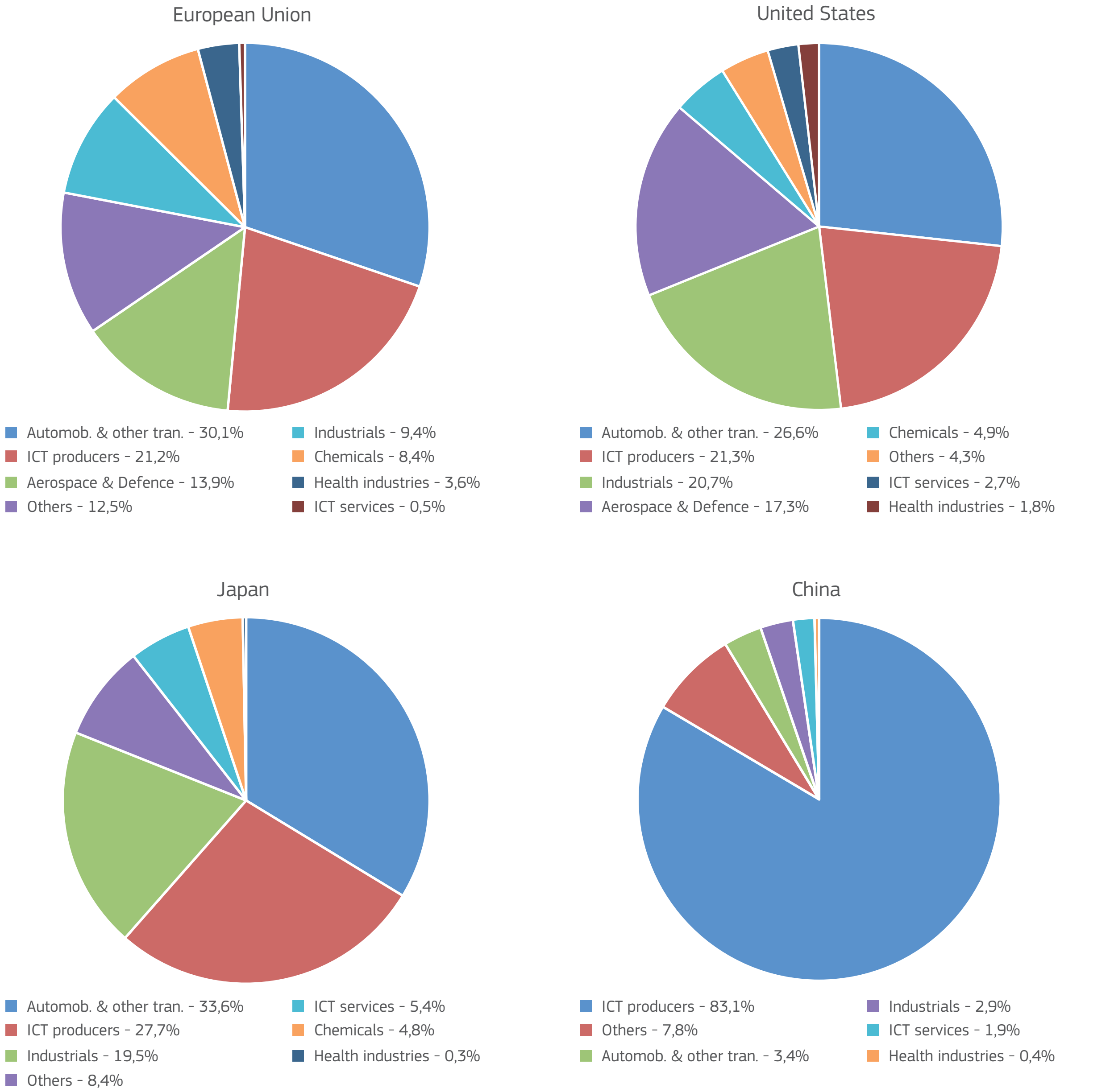

FIGURE 6.3: GREEN PATENTS OF TOP R&D INVESTORS BY GEOGRAPHICAL AREA AND INDUSTRY.
Note: Industry (ICB) shares of total green patents filed by SB companies of different geographical areas, 2012-2015. Caption: ICB = "Industry Classification Benchmark". Geographical areas refer to the SB companies' headquarter.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

Interesting results emerge when, instead of looking at the scale of SB companies' green patenting, its intensity is considered with respect to their total technological inventions. The highest share of green over total patents is revealed by SB companies operating in transport-related industries, in which environmental regulations play an important driving role (Figure 6.4, central panel in green): aerospace & defence (23.2%), totalising almost 3,900 green over more than 17,000 patents in the period 2012-2015 (Figure 6.4, other panels), and automobiles and other transports (20.1%), overcoming the threshold of 10,000 green patents over a total of more than 72,000 patents in the same period. In these two transport-related industries, SB companies concentrate their green inventions in green transportation technologies, and in the following two of the most patented green classes (their CR3 is of 95.1% and 92.7%, respectively).

FIGURE 6.4: GREEN PATENT INTENSITIES OF TOP R&D INVESTORS BY INDUSTRY AND INDUSTRY GREEN-TECH BREAKDOWN.
Note: Share (central panel) and number of green patents (other panels) by industry (ICB) and environmental technology (CPC), 2012-2015. Caption: CCS = "Carbon Capture and Storage", ICT = "Information and Communication Technologies" CCAT = "Climate Change Adaptation Technologies", ICB = "Industry Classification Benchmark".
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

Industrials (13.9%), chemicals (12%), others (8.7%), and ICT producers (6.8%), constitute a second group of industries with a green-patent intensity in-between about 5 and 10%. The focus of the relative SB companies is still on their most salient technologies – i.e., energy, production of environmentally sustainable goods and services, and green ICTs, respectively – though with a lower concentration (while still high, their CR3 is always lower than 85%). Overall, an expected tendency emerges for SB companies to intensify the green nature of their inventions in technologies related to their business industry, with limited diversification. Not surprisingly, in the heterogeneous bunch of sectors within the 'others' industry, the diversification of patenting across the considered green technologies is the highest (though with a CR3 still equal to 71%). On the contrary, SB companies in the provision of ICT services still concentrate their relatively few 1,282 green patents in green ICTs (Daiko et al., 2017)[29]. Interesting is the case of health industries. In spite of the intense regulation process that marks some industries of the sector (e.g. pharma), the relative companies show a very modest share (2.7%) and number (772) of green patents. Still, it is exclusively through these companies that the SB panel contributes to the development (about 400 patents) of crucial technologies for the green transition, that is, Climate Change Adaptation Technologies (CCAT), on which they concentrate their inventive outcomes in the domain (CR3 = 93.5%).

The extent to which SB companies diversify their involvement in the development of green technologies is also heterogeneous across the geographical areas in which they are headquartered (Table 6.1). On the one hand, SB companies based in the EU reveal, all together, a distributed pattern of specialisation (as measured by a Revealed Green-Tech Advantages indicator) in the eight green technologies that we consider (a specialisation is actually missing only in ICTs for energy). Conversely, SB companies with a Chinese base have a very concentrated pattern of specialisation, focusing in the same kind of ICTs and in the buildings industry. US, Japan and the Rest of the World stays in-between, with the relative headquartered SB companies specialising in about half of the eight green technologies. US and Japan-based companies show an interesting pattern in their specialisation and de-specialisation in CCAT, CCS, ICTs, transportation, water and waste (in favour of the US) and buildings, CCS, energy, and production of environmental goods (in favour of Japan).

[29] Daiko, T., Dernis, H., Dosso, M., Gkotsis, P., Squicciarini, M., and Vezzani, A. (2017). World Corporate Top R&D Investors: Industrial Property Strategies in the Digital Economy. A JRC and OECD common report. Luxembourg: Publications Office of the European Union.

Green Technology	EU	US	Japan	China	RoW
CCAT	1.38	1.18	0.794	0.285	0.635
Buildings	1.12	0.732	1.08	1.39	1.03
CCS	1.2	1.12	1.08	0.139	0.459
ICTs for energy	0.42	1.16	0.774	4.62	1.54
Energy	1.08	0.737	1.12	0.601	1.13
Production of Env. Goods	1.09	0.84	1.02	0.669	1.13
Transportation	1.02	1.18	1.01	0.233	0.761
Water & Waste	1.4	1.08	0.802	0.062	0.778

TABLE 6.1: REVEALED GREEN-TECH ADVANTAGES (>1) OF THE GEOGRAPHICAL LOCATION (HEADQUARTER) OF THE TOP R&D INVESTORS, 2012-2015.
Note: Caption: CCS = "Carbon Capture and Storage", ICT = "Information and Communication Technologies" CCAT = "Climate Change Adaptation Technologies". The Revealed Green-Tech Advantage of a geographical area in a certain green technology is calculated by dividing the share of patents in that green technology filed by the SB companies of that area, by the share of that technology at a global level over total green patents. A greater than 1 value (in-between 0 and 1) of this share reveals that the area (in terms of SB companies) at stake is (is not) specialised in the considered green technology.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

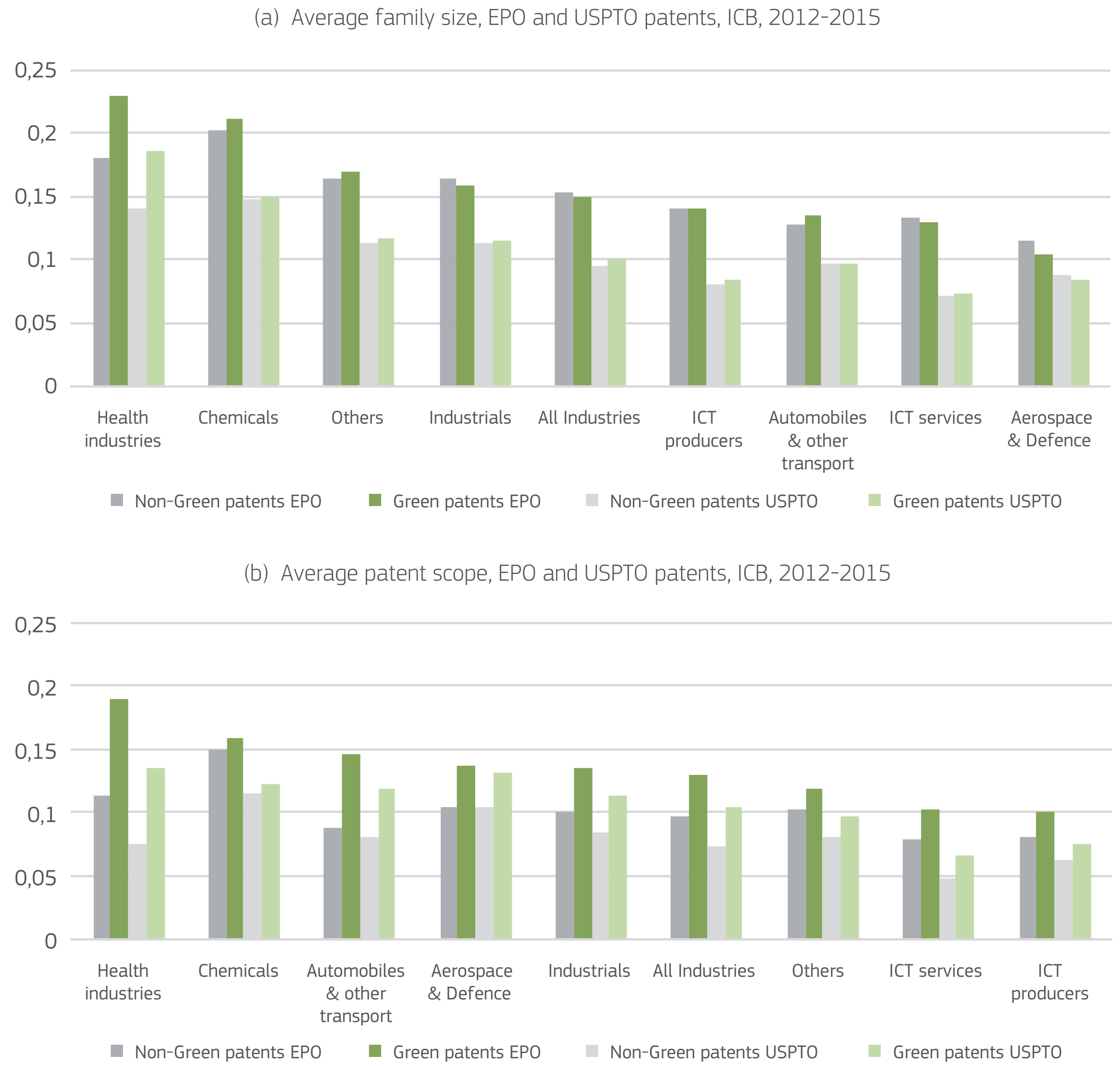

FIGURE 6.5: VALUE OF GREEN- AND NON-GREEN PATENTS OF TOP R&D INVESTORS BY INDUSTRY.
Note: Caption: ICT = "Information and Communication Technologies", ICB = "Industry Classification Benchmark". Green (Grey) bars refer to green (non-green) patent families. Upper (lower) panel refers to patents filed at the EPO (USPTO). The family size indicator is normalised according to the maximum value observed for patents in the same cohorts (filing date and WIPO technological fields). Patent indicators are obtained from the OECD Patent Quality Indicator database (Squicciarini et al., 2013).
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG RTD.

Delving into the value (or quality) of the green patents filed by SB companies (Squicciarini et al., 2013)[30], Figure 6.5 shows interesting differences with respect to their non-green ones. First of all, in as many as four of the eight industries in which they are classified – health, chemicals, 'others' industries, and automobiles and other transport – SB companies tend to file green patents across a higher number of patent offices (countries) with respect to non-green patents (Figure 6.5.a): their average patent size is larger. In the industries at stake, green inventions thus appear to have more geographically widespread market opportunities (and thus protection needs) than non-green ones. Across all the considered industries, instead, the green patents filed by SB companies are classified through a higher number of technological codes (Figure 6.5.b) – higher average scope – and thus reveal a wider need/coverage of relevant technological fields for their introduction. Results are invariant to the considered patent office and confirm what emerges from other studies (e.g. Barbieri et al., 2018)[31]. Green technologies appear marked by a higher degree of technological complexity, suggesting a possible interpretation of their still limited diffusion also across SB companies.

6.2 | The green-patent ranking of top R&D investors

Moving to the company level (Table 6.2), we find that, consistent with the previous industry-level results, five out of the top 10 green inventors (number of patents) within the SB - assignee of more than 800 green patents each - are in the automobiles & other transport industry. Toyota (head-quartered in Japan) leads this industry group, having filled 0.46% of the total SB companies' green patents, followed by Ford (US), Hyundai Motor (Korea), and General Motors (also US), with the first European companies (Robert Bosch and Volkswagen, in 11th position) further behind. The most green-patenting European company of the top 10 is Siemens, in the ICT producers industry, which has filled less than half the share of the SB green patents (0.21%) than Toyota. On the other hand, companies like General Electric (industrials) and United Technologies (Aerospace & Defence) make the US more represented in this "highest club" than Japan (including Toshiba), Korea (including Samsung) and, as we said, Europe. Extending the rank to the top 25 green inventors, Japan overtakes the US in terms of number of listed companies; Europe overtakes Korea, while Huawei (ICT producers) is the only Chinese company to enter the top 25.

Still in terms of rankings (Table 6.2), Toyota, with its notable engagement in the development of full hybrid electric cars (the Toyota Prius being one of the earliest hybrids), is also the first company in the top 25 by intensity of green patents (more than 35% of its total patents). While it is only in the 87th position in this respect, higher intensities than that are apparently revealed by companies with a relatively smaller portfolio of green patents over the period 2012-2015 (i.e., less than the 440 green patents filed by the 25th company, Fujitsu). At the opposite extreme, the remarkable green patents number of the 5th ranked, Samsung Electronics, is apparently explained by the large patent mass of the company, whose green intensity is negligible (4%), making it fall down at the 660th position of the total SB ranking in that respect. Rolls-Royce, Ford Motor and Mitsubishi Heavy are the only other top 25 green patent companies that appear in the highest quartile of the two distributions (green and non-green patents) with 30% or more of green patent shares. For the remaining companies, such a share is lower, and one if not even two quartiles of difference emerge between the relative rankings (in terms of number of green and non-green patents). All in all, a thick and simultaneously non-unbalanced portfolio of green patents is revealed by very few SB companies. These SB companies mainly operate in the automobiles & other transport industry, and mainly outside of European boundaries.

Confirming the conditional role that the literature on eco-innovation has assigned to R&D as one of its drivers in general – that is, to non-green dedicated R&D projects

[30] Squicciarini, M., Dernis, H. and Criscuolo, C. (2013). Measuring Patent Quality: Indicators of Technological and Economic Value. OECD Science, Technology and Industry Working Papers, 2013/03, OECD Publishing, Paris.

[31] Barbieri, N., Marzucchi, A., and Rizzo, U. (2018). Knowledge sources and impacts on subsequent inventions: Do green technologies differ from non-green ones? *SPRU Working Paper Series* 2018-11 (http://sci-hub.tw/10.2139/ssrn.3164197).

(Ghisetti & Pontoni, 2015)[32] – Figure 6.6 reveals that SB companies differ in their ranking across green patents and R&D expenditures, respectively. Some of the first quartile SB companies in terms of (number of) green patents, like for example Toshiba and Hyundai, are overcome by a number of companies of the relative third and even fourth quartile in terms of R&D expenditure. Conversely, while with the 10 highest level of R&D expenditure among the top green-inventors, BMW ranks only in the last quartile of the green patent distribution. In general, the correlation between the rankings is quite weak (with a Spearman's rho not higher than 0.51). This is an interesting result, which points to the complex set of regulations, scientific advancements, demand factors, and firm capabilities that, in the case of green technologies, are found to substitute the linear model of innovation based on R&D (Horbach et al., 2012)[33].

			(1)	(2)	(3)	(4)	(5)	(6)	(7)
Company	**Industry (ICB)**	**Nationality**	**Green patents (N.)**	**Non-green patents (N.)**	**Share of total SB green patents (%)**	**Share of green over total patents (%)**	**Ranking sub (1)**	**Ranking sub (4) (over 2000 SB companies)**	**Quartile difference between ranking 1-2**
TOYOTA MOTOR	Automobiles & other transport	JP	2344	4272	0.46	35.43	1	87	1
GENERAL ELECTRIC	Industrials	US	2024	5475	0.39	26.99	2	134	0
UNITED TECHNOLOGIES	Aerospace & Defence	US	1577	4045	0.31	28.05	3	126	1
FORD MOTOR	Automobiles & other transport	US	1558	3516	0.30	30.71	4	109	1
SAMSUNG ELECTRONICS	ICT producers	KR	1458	29491	0.28	4.71	5	660	0
HYUNDAI MOTOR	Automobiles & other transport	KR	1413	4195	0.27	25.20	6	143	1
SIEMENS	ICT producers	DE	1087	5207	0.21	17.27	7	224	1
GENERAL MOTORS	Automobiles & other transport	US	941	3115	0.18	23.20	8	160	1
ROBERT BOSCH	Automobiles & other transport	DE	912	6419	0.18	12.44	9	328	0
TOSHIBA	Industrials	JP	845	8353	0.16	9.19	10	418	0
VOLKSWAGEN	Automobiles & other transport	DE	726	2493	0.14	22.55	11	165	2
QUALCOMM	ICT producers	US	720	5994	0.14	10.72	12	368	0
MITSUBISHI HEAVY	Industrials	JP	654	1555	0.13	29.61	13	115	2
HITACHI	ICT producers	JP	647	5690	0.13	10.21	14	381	-1
MITSUBISHI ELECTRIC	ICT producers	JP	596	4026	0.12	12.89	15	311	0
AIRBUS	Aerospace & Defence	NL	539	2143	0.10	20.10	16	184	1
HONDA MOTOR	Automobiles & other transport	JP	538	2522	0.10	17.58	17	218	1
INTEL	ICT producers	US	538	4809	0.10	10.06	18	384	0
SAMSUNG SDI	ICT producers	KR	509	1857	0.10	21.51	19	174	1
DENSO	Automobiles & other transport	JP	502	3656	0.10	12.07	20	333	0
ROLLS-ROYCE	Aerospace & Defence	GB	500	971	0.10	33.99	21	91	2
HUAWEI	ICT producers	CN	493	7521	0.10	6.15	22	565	-1
LG CHEM	Industrials	KR	477	1605	0.09	22.91	23	163	2
NISSAN MOTOR	Automobiles & other transport	JP	456	714	0.09	38.97	24	77	2
FUJITSU	ICT services	JP	440	7140	0.09	5.80	25	589	-1

TABLE 6.2: TOP 25 GREEN INVENTORS (NUMBER OF GREEN PATENTS) AMONG THE TOP R&D INVESTORS, 2012-2015.
Note: ICT = "Information and Communication Technologies", ICB = "Industry Classification Benchmark".
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

[32] Ghisetti, C., Pontoni, F. (2015), Investigating policy and R&D effects on environmental innovation: A meta-analysis, *Ecological Economics*, 118, 57-66.

[33] Horbach, J., Rammer, C. and Rennings, K. (2012). Determinants of eco-innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull. *Ecological Economics*, 78, 112-122.

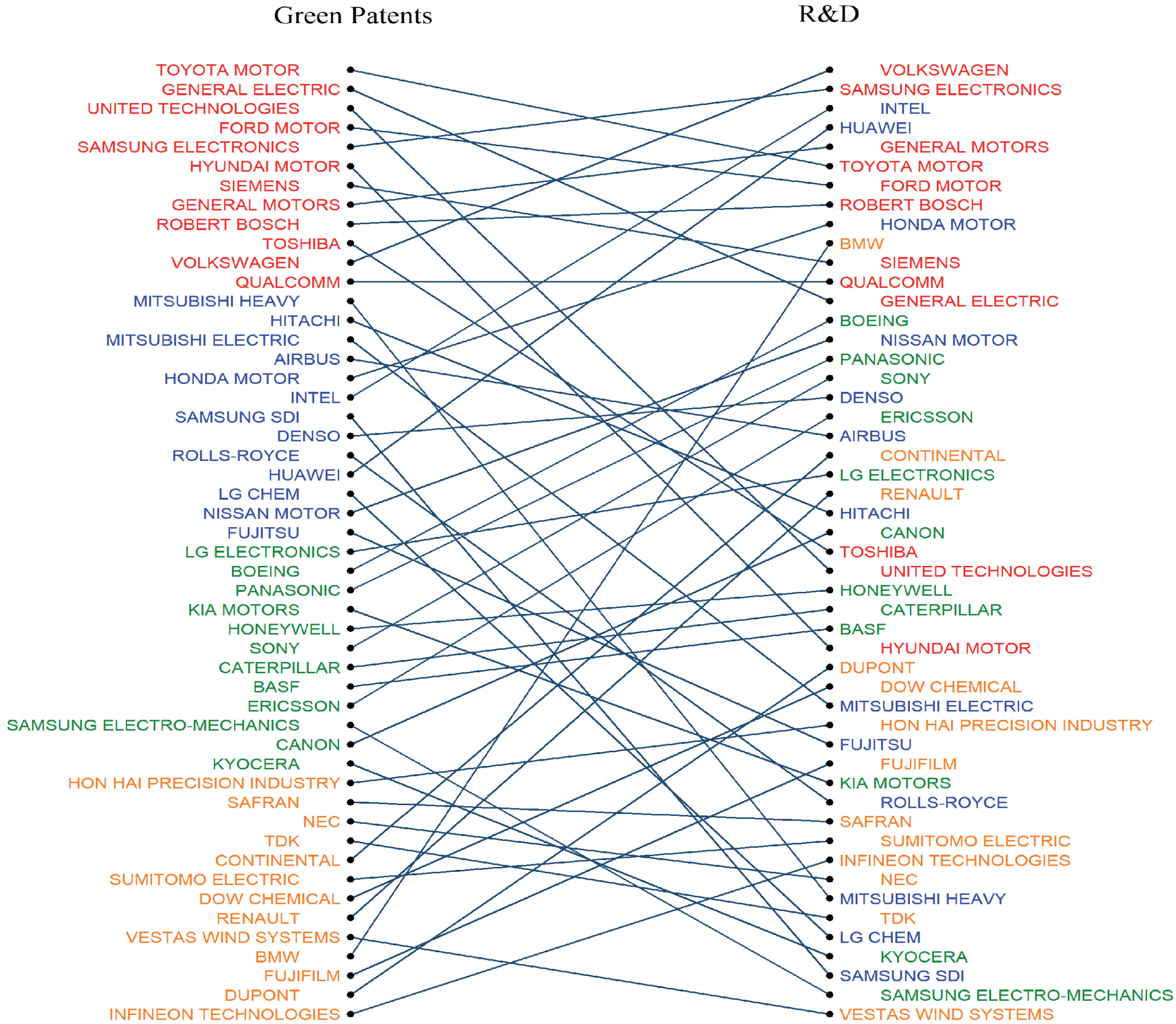

FIGURE 6.6: TOP 50 GREEN INVENTORS (2012-2015) VS TOP R&D INVESTORS (OF THE 50) (2016): QUARTILES AND QUARTILE SWITCHES.
Note: ICT = "Information and Communication Technologies", ICB = "Industry Classification Benchmark". On the left column, firms are ranked according to the number of green patent families. On the right column, these same firms are ranked according to their R&D expenditure in 2016. Colours refer to the quartiles of the green patent and R&D distribution.
Source: The 2019 EU Industrial R&D Investment Scoreboard. European Commission. JRC/DG RTD.

All of these and possible other factors represent crucial elements to consider in further exploring the determinants of the green-tech portfolio of the SB companies that emerged from this chapter.

6.3 | Concluding remarks

- Top R&D investors appear a major player in the development of green inventions at EPO and/or USPTO. More than half (53%) of the still limited share of green patents obtained at these offices in-between 2012 and 2015 actually belongs to the top R&D companies.
- Environmental regulations seem to play an important driving role also for top R&D investors. Their intensity of green over total patents is actually the largest in regulatory driven sectors, like transport-related industries. Unlike with respect to other technologies (e.g. ICT), SB companies intensify their green inventions in environmental technologies related to their salient business, with limited diversification. Finally, also in the case of SB companies, green technologies appear marked by a higher degree of complexity than non-green one, suggesting a possible interpretation of their still limited diffusion, especially in the most incipient

ones, like Climate Change Adaptation Technologies and Carbon Capture and Storage.

- EU companies show comparative advantages in most green technologies, with the exception of ICTs for energy. Quite interestingly, this contrasts the patterns of specialisation revealed by the US, Japan and especially China, which instead focus on a limited set of green technologies.
- SB companies rank differently among them in terms of green patents and R&D expenditure, with Hyundai Motor and BMW providing remarkable examples of their relative low correlation. This suggests that other internal capabilities than R&D and demand-related factors, in addition to environmental regulations, could drive the development of environmental technologies by top R&D investors.

7

PATENTING ACTIVITY OF *SCOREBOARD* FIRMS IN THE **AUTOMOTIVE SECTOR**

7 Patenting activity of *Scoreboard* firms in the automotive sector

The automotive sector owns 13% of total patents belonging to the Scoreboard companies of which 35% are held by EU companies.

Most of these patents refer to current automotive technologies but an increasing proportion refer to green technologies including electric and autonomous vehicles and newer components such as novel batteries and fuel cells.

EU companies which appear highly diversified and competitive in most technological fields, but in green technologies related to hybrid cars, batteries and fuel cells their Japanese counterparts are leading the race.

For emerging technology, current automotive companies are being joined in patent filing by companies from the software, IT hardware, electronics and chemicals sectors. This is a major challenge for the EU, whose lead in the automotive sector may be eroded as digital technologies take a higher proportion of the value added in this sector.

The Automobiles & other transport sector[34] (automotive) recovered rapidly from the economic crisis in 2009 and then has been growing significantly its R&D investments for the tenth consecutive year, reaching €123bn in 2019 – a 91% increase over the past 10 years. The technology race in this sector is driven by both regulatory and market challenges. Companies have to comply with stricter regulations, namely on local and global emissions (reduce both energy consumption and urban pollution), use of new materials and related recycling issues[35]. On the other hand, companies rely on innovation to keep or increase competitiveness, as they have to face tougher global competition from incumbent and new industrial players, especially regarding the manufacturing of alternative transport means and the incorporation of ICT applications by companies such as Tesla and Alphabet.

Past *Scoreboard* editions have shown how EU companies are specialised in this sector and outperform their non-EU counterparts in economic and R&D terms and in particular show higher R&D intensities as compared with companies based in China and the US. The objective of this chapter is to assess further the position of the EU in this sector from technological and environmental viewpoints, based on the analysis of the patent portfolio of companies.

7.1 | Overview

This chapter makes use of company data from the *Scoreboard* 2017 edition combined with patent data retrieved from Patstat 2019 spring edition[36] to offer deeper insights on the competitiveness of the EU firms in the *Automobiles* sector putting special emphasis on the development of sustainable technologies[37]. It is also attempted to identify patents related

[34] This sector comprises companies from the following ICB 4-digits sectors: Automobiles, Auto parts, Commercial Vehicles & trucks and Tyres.

[35] Alonso Raposo, M. (Ed.), Ciuffo, B. (Ed.), Ardente, F., Aurambout, J-P., Baldini, G., Braun, R., Christidis, P., Christodoulou, A., Duboz, A., Felici, S., Ferragut, J., Georgakaki, A., Gkoumas , K., Grosso, M., Iglesias, M., Julea, A., Krause, J., Martens, B., Mathieux, F., Menzel, G., Mondello, S., Navajas Cawood, E., Pekár, F., Raileanu, I-C., Scholz, H., Tamba, M., Tsakalidis, A., van Balen, M., Vandecasteele, I., The future of road transport - Implications of automated, connected, low-carbon and shared mobility, EUR 29748 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-03409-4, doi:10.2760/9247, JRC116644.

[36] Patent families published in USPTO and EPO were considered. Patent families were retrieved based on the priority application date but we limit the analysis to the three years prior to 2017 because for this period we can assume that the subsidiary structure of the SB companies is relatively stable.

[37] Sustainable technologies have been identified based on the Y02 and Y04 classes of the Cooperative Patent Classification scheme (CPC). For technologies related to autonomous cars see "Eight great technologies: robotics and autonomous systems, UKIPO 2014".

to autonomous, driverless cars. There are 116 firms in the *Automobiles* sector, which represent 6.7 % of the firms with patent families in EPO, USPTO in the *Scoreboard* 2017 edition (1733 firms). The firms in this sector own 12.9 % of the patent families filed with priority between 2012 and 2015 (65453 families) and have invested €383 billion in R&D. This is almost 16 % of the total R&D investment from the 1733 *Scoreboard* companies of the sample.

The geographic distribution of firms comprising the sector based on the location of the firms' headquarters is in Table 7.1. The 33 EU based companies in the sector invested in total €176 billion during the period between 2012- 2015, which represents 46 % of the total R&D investment in the sector. These companies have filed 23339 patent families during this period.

World region	Number of firms	RD EUR billions (2012-15)	Patent Families (2012-15)	Share R&D (2012-15)	Share of families (2012-15)
EU	33	176	23339	46.0%	35.7%
Japan	33	112	23324	26.4%	35.6%
RoW	29	29.5	7453	7.7%	11.4%
US	21	64.4	11335	16.8%	17.3%

TABLE 7.1: THE GEOGRAPHY THE SECTOR BY THE LOCATION OF FIRMS' HEADQUARTERS.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

In Figure 7.1 the patent families owned by the companies in the sector are distributed across the WIPO 35 technological classes for each year of the period under study. Most of these families fall under the general category of "transport" technologies. The number of patent families developed annually across most fields is relatively stable[38], however "transport", "computer technologies" and "measurement" show clear increasing trends.

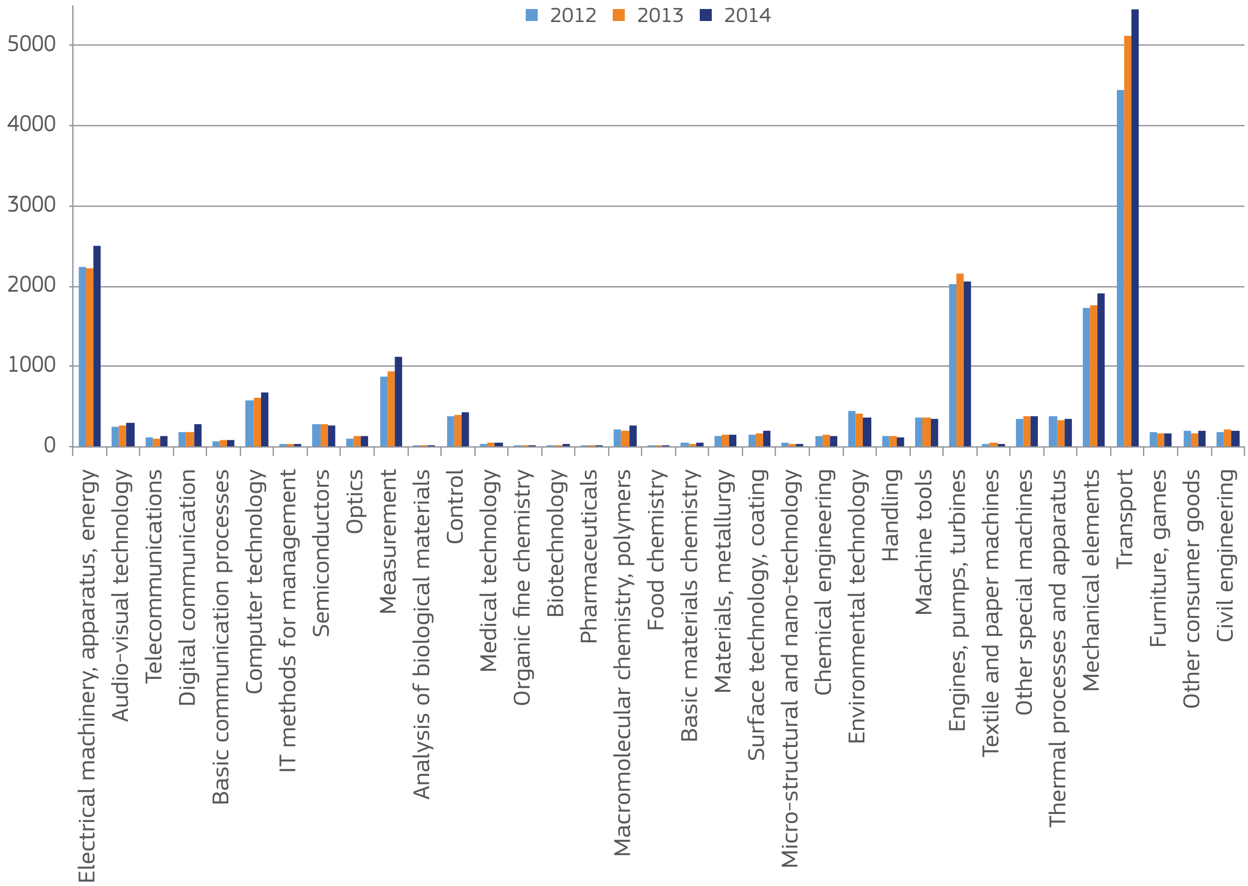

FIGURE 7.1: DISTRIBUTION OF PATENT FAMILIES ACROSS THE WIPO 35 TECHNOLOGY CLASSES BY YEAR OF FIRST FILING.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

[38] The use of patent priority date as reference results in truncation of numbers for 2015 and data for this year are excluded from graphs on trends.

It is interesting to note the increased importance "computer technology" and "measurement" technological fields gain in the portfolio of firms in the sector, as they become crucial in the development of modern cars. In fact, the analysis of "ICT-related" technologies by the world top R&D investors[39] also revealed that firms related to *transport* are developing a significant share of patents related to "Large-capacity information analysis". This also holds true when it comes to "AI-related" scientific and technological developments due to the emergence of autonomous and driverless cars applications[40].

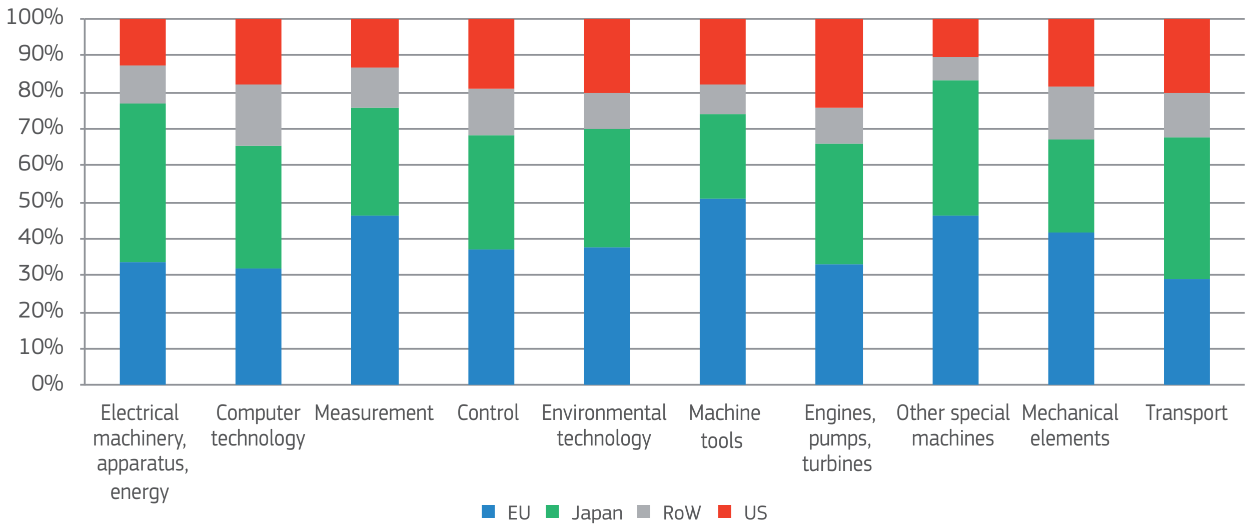

FIGURE 7.2: SHARE OF FAMILIES BY WORLD REGION ACROSS THE TOP 10 WIPO 35 TECHNOLOGY CLASSES BY NUMBER OF PATENT FAMILIES.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Focusing further on the top 10 WIPO 35 technological fields by number of patent families from firms in the sector, we analyse in Figure 7.2 the shares by world region. The analysis is based on the location of the headquarters of the firms. We see that EU based firms own over 35% of the patent families pertaining to these fields, reaching as high as 50% in the case of "Machine tools". The main competitor is Japan with Japanese firms owing significant shares of families in these fields as well.

In order to better understand and compare firms based on their technological competences the relative technology advantage (RTA) is calculated as a relative metric of specialisation in Table 7.2. A value of RTA above 1 in a specific technology field shows a relative specialisation in that field. From Table 7.2 we see that the patent portfolio of EU based firms is highly diversified as they specialise in 13 out of 15 fields in which firms in the sector specialise in general.

We analyse further the technological competences of firms in the sector by calculating the share of patents by world region of firms' headquarters, for the top 10 technological classes in terms of number of patent filings (CPC 3 digit level). The top four fields are related to "vehicles" and "engines" development and in particular "combustion engines" development. The increased importance of "measuring, testing" and "computing" technologies commented above at the WIPO 35 level analysis is confirmed in Table 7.3 at this level of aggregation as well. We see that EU and Japan based firms develop and own over 60% of patents pertaining to these technology groups (almost 80% in the case of "generation, conversion and distribution of energy power"). Given the contribution of transport in total emissions and the emphasis that regulations put on controlling the environmental impact of transport in general, firms in the sector put significant part of their efforts in the development of "technologies or applications against climate change".

[39] Daiko T., Dernis H., Dosso M., Gkotsis P., Squicciarini M., Vezzani A. (2017). World Corporate Top R&D Investors: Industrial Property Strategies in the Digital Economy. A JRC and OECD common report. Luxembourg: Publications Office of the European Union.

[40] Dernis H., Gkotsis P., Grassano N., Nakazato S., Squicciarini M., van Beuzekom B.,Vezzani A. (2019). World Corporate Top R&D investors: Shaping the Future of Technologies and of AI. A joint JRC and OECD report. EUR 29831 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-09670-2 , doi:10.2760/16575, JRC117068.

	World region			
	EU	Japan	RoW	US
Electrical machinery, apparatus, energy	**1.4**	**1.8**	**1.3**	**1.1**
Measurement	**1.5**	0.9	**1.1**	0.9
Control	**1.4**	**1.2**	**1.5**	**1.5**
Macromolecular chemistry, polymers	0.4	**1.4**	0.5	0.3
Materials, metallurgy	0.5	0.7	**1.0**	0.6
Micro-structural and 0no-technology	**3.2**	0.3	0.6	0.1
Environmental technology	**2.8**	**2.3**	**2.3**	**3.0**
Machine tools	**1.7**	0.8	0.8	**1.3**
Engines, pumps, turbines	**2.7**	**2.7**	**2.6**	**4.0**
Other special machines	**1.5**	**1.2**	0.6	0.7
Thermal processes and apparatus	**3.1**	0.8	**1.2**	**1.1**
Mechanical elements	**4.2**	**2.5**	**4.4**	**3.8**
Transport	**4.1**	**5.5**	**5.4**	**5.9**
Furniture, games	**1.6**	**2.1**	0.2	0.5
Other consumer goods	**2.4**	0.2	0.3	0.4

TABLE 7.2: RELATIVE TECHNOLOGY ADVANTAGE BY WORLD REGION.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

	World region			
	EU	Japan	RoW	US
Vehicles in general	30,45%	36,39%	12,22%	20,94%
Land vehicles for travelling	23,61%	46,53%	12,97%	16,88%
Machines or engines	33,79%	32,06%	14,21%	19,94%
Combustion engines	32,35%	33,63%	8,24%	25,78%
Engineering elements and units	41,46%	24,93%	14,20%	19,41%
Measuring tesitng	47,36%	29,23%	10,73%	12,67%
Computing	34,36%	34,26%	15,60%	15,78%
Basic electric elements	27,94%	49,14%	10,66%	12,26%
Generation, conversion and distribution of electric power	35,35%	45,49%	8,34%	10,83%
Technologies or applications against climate change	26,94%	36,57%	14,06%	22,44%

TABLE 7.3: SHARE OF PATENT FAMILIES BY WORLD REGION FOR THE TOP 10 TECHNOLOGY CLASSES BY NUMBER OF PATENTS.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

In Table 7.3 the distribution of patent families on environmental technologies across world regions based on the location of the *Scoreboard* company headquarters is also shown. Japanese companies own the majority of these patents (almost 37%) with EU and USA based firms following with approximately 27% and 23% respectively.

7.2 | Technologies and applications for mitigation and adaptation against climate change

There are 92 firms in the sector, which own 11762 patent families pertaining to environmental related technologies according to the CPC classification. These families are distributed over the different subclasses of the Y- section of the CPC scheme according to Table 7.4[41]. The number of firms owing patents pertaining to the specific subclass is also reported. The most frequent subclass is "climate change mitigation technologies related to transportation" (Y02T) followed by "reduction of greenhouse gas emissions related to energy generation, transmission or distribution"

[41] Patent families are calculated based on whole counting.

(Y02E) and “Climate change mitigation technologies in the production or processing of goods” (Y02P) and “Technologies for adaptation to climate change” (Y02A).

The companies mainly responsible for the development of environmental technologies are shown in table 7.5. At the top of the list we find Toyota Motor from JP followed by Ford Motor (US) and Hyundai Motor (KR). Interestingly from the top 10 companies in this list, four are based in JP, 2 in the US, 2 in the EU and 2 in KR. The EU based firms, which are most active in filing patents related to “technologies and applications for mitigation and adaptation against climate change”, are Robert Bosch and Volkswagen from Germany.

CPC4	Description	Patent families	Firms
Y02T	Climate change mitigation technologies related to transportation	9675	84
Y02E	Reduction of greenhouse gas emissions related to energy generation, transmission or distribution	995	56
Y02P	Climate change mitigation technologies in the production or processing of goods	359	52
Y02A	Technologies for adaptation to climate change	295	35
Y02B	Climate change mitigation technologies related to buildings, e.g. housing, house appliances or related end-user applications	275	41
Y02D	Climate change mitigation technologies in information and communication technologies [ICT], i.e. information and communication technologies aiming at the reduction of thir own energy use	78	21
Y04S	Systems integraring technologies related to power network operation, communication or information technologies for improving the electrical power generation, transmission, ditribution, management or usage i.e. smart grids	40	28
Y02W	Climate change mitigation technologies related to wastewater treatment or waste management	27	11
Y02C	Capture, storage, sequestration or disposal of greenhouse gases	18	11

TABLE 7.4: ENVIRONMENTAL RELATED SUBCLASSES (CPC CLASSIFICATION).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

7.2.1 Climate change mitigation technologies related to transportation.

Scoreboard firms in the sector own 9675 patent families related to “climate change mitigation technologies for transportation”. The top ten technologies by number of patent families are related to the improvement of the efficiency and the control of emissions of traditional internal combustion engines and to technologies related to hybrid and electric cars (Table 7.6). At the top of the list we find technologies of the former type, such as “non-naturally aspirated engines, e.g. turbocharging, supercharging” and “exhaust feedback” followed by “fuel cells for transport” and “batteries” which are technologies of the latter type.

We see that the sector is adapting to current developments related to the electrification of transport as a means of tackling air pollution and the associated impact on the climate and the environment with e.g. 46 firms active in developing patents relevant to “batteries”[42]. However, investment is still channelled to the development of technologies improving the efficiency of internal combustion engines, lowering the environmental footprint of transport in the short- medium term.

Company name	Country	Patent families
TOYOTA MOTOR	JP	2344
FORD MOTOR	US	1558
HYUNDAI MOTOR	KR	1413
GENERAL MOTORS	US	941
ROBERT BOSCH	DE	912
VOLKSWAGEN	DE	726
HONDA MOTOR	JP	538
DENSO	JP	502
NISSAN MOTOR	JP	456
KIA MOTORS	KR	354

TABLE 7.5: TOP 10 COMPANIES BY NUMBER OF PATENT FAMILIES (ENVIRONMENTAL TECHNOLOGIES).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

[42] There are companies outside the automotive sector that are making important contributions to the technological areas described. Examples are Johnson Matthey, Umicore and BASF (chemical sector), which make catalysts and Panasonic (leisure goods), which makes the lithium batteries for Tesla’s electric cars.

CPC class	Technological description	Patent Families	Number of Firms
Y02T10/144	Turbocharging, supercharging	710	36
Y02T10/47	Exhaust feedback	570	28
Y02T90/32	Fuel cells for transport	461	26
Y02T10/7005	Batteries	455	46
Y02T10/24	Selective catalytic reactors for reduction in oxygen rich atmosphere	396	23
Y02T10/6286	Control systems for power distribution between ICE and other motor or motors	351	27
Y02T10/146	Charge mixing enhancing outside combustion chamber	335	35
Y02T10/6239	Differential gearing distribution type for hybrid vehicles	314	17
Y02T10/6221	Hybrid vehicles of parallel type	257	32
Y02T10/48	Stop and go systems	249	30

TABLE 7.6: TOP 10 CPC CLASSES AND THEIR DESCRIPTION BY NUMBER OF PATENT FAMILIES (Y02T).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Another interesting finding is the development of competing technologies related to future electric vehicles. Although patents on batteries for storage of electric energy do attract a lot of research interest, important efforts are put on the development of fuel cells specially adapted to transport applications for producing electricity using hydrogen as an alternative. EU based firms own relatively high shares of patent families related to "Selective catalytic reactors", "hybrid vehicles of parallel type" and "batteries" (Figure 7.3). On the other hand the share of patent families related to "fuel cell for transport", "differential gearing for distribution type for hybrid vehicles" and "stop and go systems" is relatively low (around 10%).

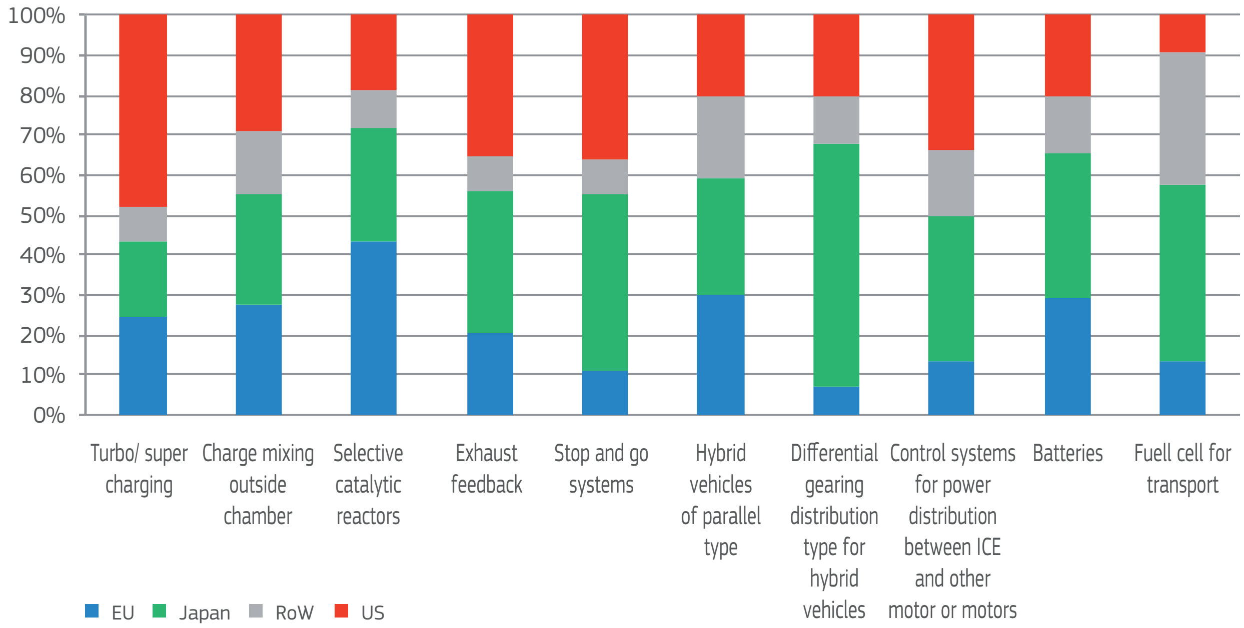

FIGURE 7.3: SHARE OF REGIONAL PATENT FAMILIES BY TRANSPORTATION TECHNOLOGY.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

In Figure 7.4 the top five patent assignees by number of families owned by technology field (CPC) are shown. There are 14 unique firms appearing in all 10 top 5 lists. Toyota Motors (JP) is among the top 5 firms by share of patents in all 10 fields followed by Ford Motors (US) (present in 8 fields), General Motors (US), Hyundai Motors (KR) and Volkswagen (DE) (7 fields). The development of these technologies appears to be highly concentrated with the top 5 firms owing more than 50% of the related patent families.

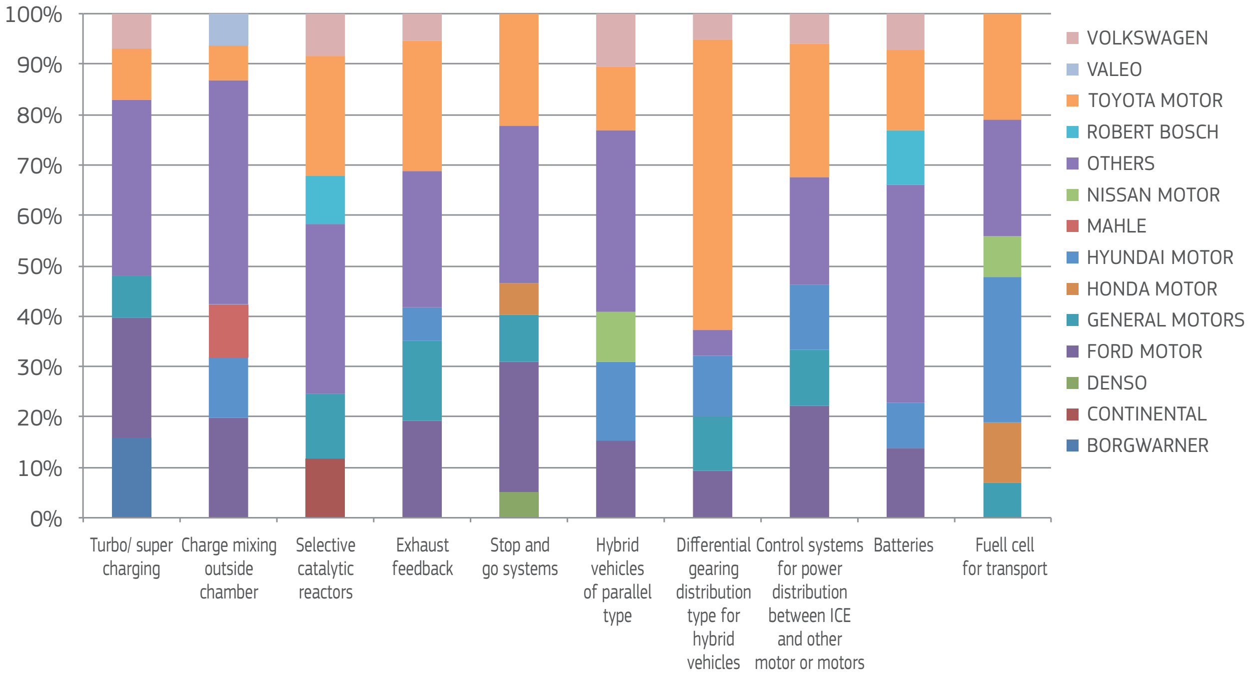

FIGURE 7.4: SHARE OF TOP FIVE FIRMS' PATENT FAMILIES BY TRANSPORTATION TECHNOLOGY.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

7.2.2 Reduction of greenhouse gas emissions related to energy generation, transmission or distribution

The second group of technologies and applications relevant to mitigation and adaptation against climate change which are important in terms of patent filings for firms in the sector are technologies for the "reduction of greenhouse gas emissions from energy generation and distribution". *Scoreboard* firms in the sector filed 995 patent families related to this group. The top 10 technologies of this type by number of patent families are reported in table 7.7. At the top of the list, we find "lithium-ion, lead-acid or alkaline secondary batteries" followed by "fuel cells" and "hybrid cells". This is in-line with the findings in the previous section showing the strong efforts in the development of novel technologies for electric energy production like "fuel cells" and electric energy storage like "batteries" with 36 firms active in developing patents relevant to "fuel cells" and 30 firms developing patents related to "lithium-ion, lead-acid or alkaline secondary batteries".

EU based firms own high share of patents on "latent and sensible heat storage systems" as well as on "hybrid type cells" (Figure 7.5). On the other hand, the share of EU families related to "fuel cells" and "proton exchange membranes" is below 10%.

Top patent assignees by share of families pertaining to each technology are shown in Figure 7.6. There are 17 firms within the top 5 list of the ten technologies for "reduction of greenhouse gas emissions related to production, transmission or distribution of energy". Robert Bosch (DE) and Toyota Motors (JP) are present 7 times in the top 5 list followed by Hyundai Motor (KR) and Honda Motor (JP) (6 times). The share of families owned by firms in the top 5 list is over 80% for all fields. Technology development is thus highly concentrated with few players owing a high share of patent families published in the two major IP offices.

CPC class	Tech description	Patent families	Number of Firms
Y02E60/122	Lithium- ion batteries	193	30
Y02E60/50	Fuell cells	181	36
Y02E60/128	Hybrid cells composed of a half-cell of a fuel-cell type and a half-cell of the secondary-cell type	73	13
Y02E60/321	Storage of liquefied, solidified, or compressed hydrogen in containers	65	6
Y02E60/13	Ultracapacitors, supercapacitors, double-layer capacitors	45	6
Y02E10/50	Photovoltaic energy	43	7
Y02E60/145	Latent heat storage	42	7
Y02E60/521	Proton Exchange Membrane Fuel Cells	34	8
Y02E60/366	Hydrogen distribution by electrolysis of water	32	6
Y02E60/142	Sensible heat storage	19	4

TABLE 7.7: TOP 10 CPC CODES BY NUMBER OF PATENT FAMILIES (Y02E).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

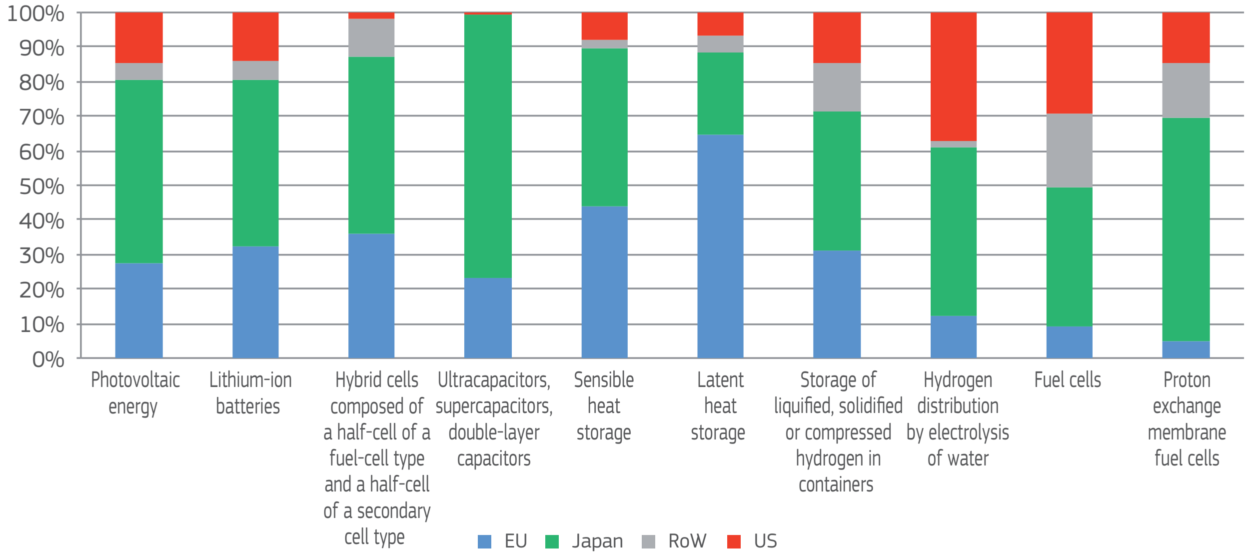

FIGURE 7.5: SHARE OF REGIONAL PATENT FAMILIES BY EMISSIONS TECHNOLOGY.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

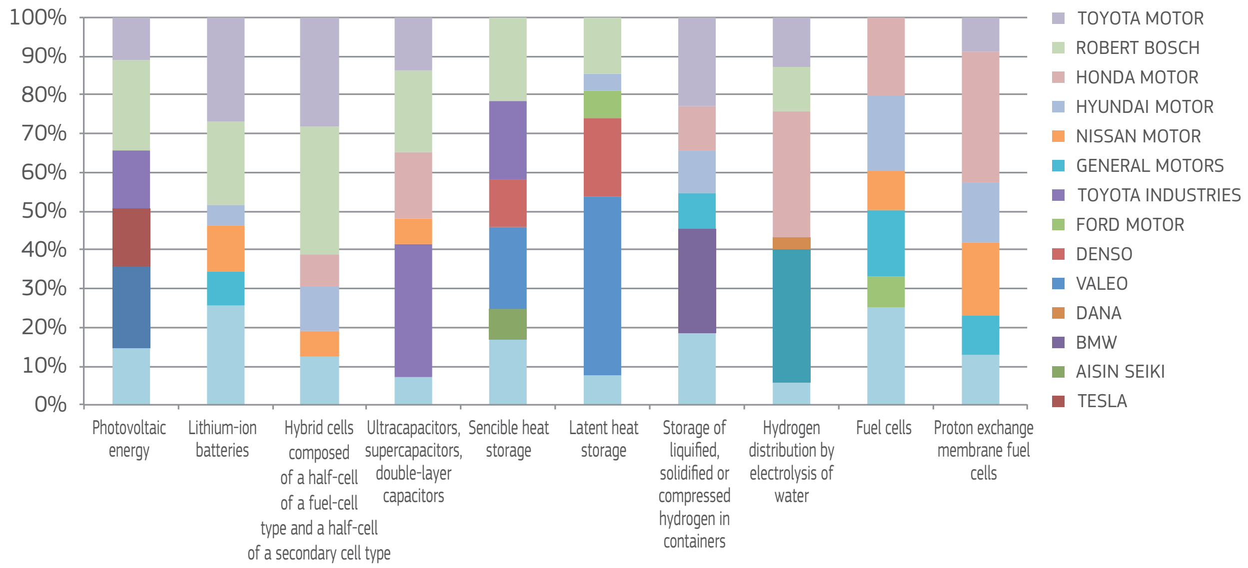

FIGURE 7.6: SHARE OF TOP FIVE FIRMS' PATENT FAMILIES BY EMISSIONS TECHNOLOGY.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

7.3 | Technologies related to autonomous vehicles

The sector undergoes a major paradigm shift not only due to regulatory challenges and constraints aimed at reducing the environmental impact of transport but also due to the development of disruptive technologies and services that are expected to minimise the negative impacts from traditional road transport such as decarbonisation, automation, connectivity and sharing. Automation refers to systems, which are able to perform part or all of the Dynamic Driving Tasks[43]. Depending on the level of automation offered and the level of monitoring needed by the driver these technologies can be classified in 5 categories: from driver-only to full automation.

The focus in this section is to identify patents from *Scoreboard* companies related to autonomous or driverless vehicles only. Based on the search strategy used the 581 families identified should correspond to high levels off automation (categories 3, 4 and 5). The majority of these families (192) are owned by 31 EU based firms followed by firms based in Japan (167 families by 20 firms) and in the US (160 by 23 firms) as shown in table 7.8.

Region	Patent Families	Number of companies
EU	192	31
US	160	23
JP	167	20
CN	4	2
KR	44	8
RoW	14	7

TABLE 7.8: THE GEOGRAPHY OF PATENT FAMILIES RELATED TO AUTONOMOUS CARS.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Sector	Number of firms	Patent Families
Automobiles & Parts	24	402
Electronic & Electrical Equipment	10	42
Industrial Engineering	20	34
Aerospace & Defence	8	24
Software & Computer Services	2	20
Technology Hardware & Equipment	7	18
Leisure Goods	5	13
General Industrials	4	9
General Retailers	1	5
Oil Equipment, Services & Distribution	1	4
Household Goods & Home Construction	2	4
Chemicals	2	1
Food & Drug Retailers	1	1
Health Care Equipment & Services	1	1
Industrial Metals & Mining	1	1
Oil & Gas Producers	1	1
Support Services	1	1

TABLE 7.9: TOP 10 SECTORS BY NUMBER OF FAMILIES RELATED TO AUTONOMOUS CARS.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Twenty-four firms within the *Automobiles* sector own almost 70% of these families. There are however many firms in other sectors active in patenting these technologies, most notably in *Electronic & Electrical Equipment* sector with 10 firms owning 42 families and the *Industrial Engineering* and *Aerospace & Defence* sectors with 20 firms and 34 families and 8 firms and 24 families respectively (table 7.9).

[43] SAE International, 2016.

Company	Country	Sector	Patent Families
FORD MOTOR	US	Automobiles & Parts	71
TOYOTA MOTOR	JP	Automobiles & Parts	59
ROBERT BOSCH	DE	Automobiles & Parts	55
VOLKSWAGEN	DE	Automobiles & Parts	36
HYUNDAI MOTOR	KR	Automobiles & Parts	25
NISSAN MOTOR	JP	Automobiles & Parts	21
HONDA MOTOR	JP	Automobiles & Parts	20
HITACHI	JP	Electronic & Electrical Equipment	19
GENERAL MOTORS	US	Automobiles & Parts	19
ALPHABET	US	Software & Computer Services	19

TABLE 7.10: TOP 10 SCOREBOARD FIRMS BY NUMBER OF PATENT FAMILIES RELATED TO AUTONOMOUS CARS.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

Focusing on the top 10 Scoreboard companies in terms of patents related to autonomous vehicles we find eight companies from the *Automobiles* sector among them. In fact the top seven out of ten firms in the list are from this sector with the US based Ford Motor at the top with 71 families followed by the Japanese based Toyota Motor with 59, and the German Robert Bosch and Volkswagen with 55 and 36 patent families respectively. Among the non-*Automobiles* firms making it to the top 10 we find Hitachi (JP) and Alphabet (US) with 19 patent families each (see table 7.10).

7.4 | Concluding remarks

- Firms in the "Automobiles" sector are active in patenting, owing almost 13% of the patent families from Scoreboard firms between 2012 and 2015. R&D investment from these firms accounts for almost 16% of total R&D spending from Scoreboard companies. Among the most important players in the sector are EU and JP based firms, which are responsible for almost 71% of total patent filings.

- Stricter environmental regulations and advances in technologies not related to conventional cars drive technological competition between firms in the sector and firms from other sectors as well. Environmental challenges are tackled, on one hand by developing technologies to improve efficiency and to better control emissions from conventional combustion engines, and on the other by technologies aiming at the electrification of transport.

- EU based Scoreboard "Automobile" firms are competitive, as they have invested almost 46% of the R&D investment reported by firms in the sector between 2012 and 2015, they are responsible for 35% of the patent families of this period and they have highly diversified patent portfolios in terms of technology profiles with significant share of patents related to autonomous vehicles.

- Japanese firms are leading the race when it comes to environmental technologies related to hybrid cars, batteries and fuel cells, while among the EU based firms, Volkswagen and Robert Bosch are the most active in patenting environmental related technologies as well as technologies related to autonomous cars.

ANNEXES

- **A1** – BACKGROUND INFORMATION
- **A2** – METHODOLOGICAL NOTES
- **A3** – COMPLEMENTARY TABLES
- **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[44] with a 3 % headline target for intensity of research and development (R&D)[45]. R&D investment from the private sector plays also a key role for other relevant European initiatives such as the Industrial Policy[46], Digital Agenda and New Skills for New Jobs flagship initiatives.

The project "Global Industrial Research & Innovation Analyses" (GLORIA)[47] supports policymakers in these initiatives and monitors progress towards the 3 % headline target. The *Scoreboard,* as part of the GLORIA project, aims to improve the understanding of trends in R&D investment by the private sector and the factors affecting it. The *Scoreboard* identifies main industrial players in key industrial sectors, analyse their R&D investment and economic performance and benchmark EU companies against their global counterparts.

The annual publication of the *Scoreboard* also intends 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[48]. 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 data, which are specific to a given territory. The R&D financed by business sector in a given territorial unit (BES-R&D) includes R&D performed by all sectors in that territorial unit[49]. **Therefore, the *Scoreboard* R&D figures are comparable to BES-R&D data only at the global level.**

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*

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[44] 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.

[45] 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).

[46] 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.

[47] GLORIA builds on the IRIMA project (Industrial Research and Innovation Monitoring and Analysis). See: http://iri.jrc.ec.europa.eu/home/. The activity is undertaken jointly by the Directorate General for Research (DG RTD F; 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).

[48] 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.

[49] 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 funded by businesses and performed by all sectors within a particular territory, regardless of the location of the business's headquarters. 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).

account for more than 90%[50] 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.

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.

[50] According to latest Eurostat statistics.

A.2 Methodological notes

The data for the 2019 *Scoreboard* have been collected from companies' annual reports and accounts by Bureau van Dijk – A Moody's Analytics Company (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 2018 fiscal year accounts, although due to different accounting practices throughout the world, they also include accounts ending on a range of dates between late 2017 and mid-2019. 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. However, it includes research contracted out to other companies or public research organisations, such as universities.

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[51] 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

[51] 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 and performed by all sectors within a given territorial unit (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 funded by businesses and performed within a particular territory, regardless of the location of the business's headquarters. ***Therefore, the Scoreboard R&D figures are directly comparable to BES-R&D data only at the global level.***

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[52], may lead to information

[52] 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/).

discontinuities due to the different treatment of R&D, i.e. R&D capitalisation criteria are stricter and, where the criteria are met, the amounts must be capitalised.

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

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 2018* as shown in Table A2.1[53]. The exchange rate conversion also applies to the historical data. The result is that over time the *Scoreboard* reflects the domestic currency results of the companies rather than economic estimates of current purchasing parity results. The original domestic currency data can be derived simply by reversing the translations at the rates above. Users can then apply their own preferred current purchasing parity transformation models.

Country	As of 31 Dec 2017	As of 31 Dec 2018
Australia	$ 1.54	**$ 1.62**
Brazil	3.97 Brazilian real	**4.44 Brazilian real**
Canada	$ 1.51	**$ 1.56**
China	7.81 Renminbi	**7.85 Renminbi**
Czech Republic	25.54 Koruna	**25.73 Koruna**
Denmark	7.44 Danish Kronor	**7.46 Danish Kronor**
Hungary	310.6 Forint	**321.54 Forint**
Hong Kong	9.37 HKD	**8.97 HKD**
India	76.69 Indiana Rupee	**79.94 Indiana Rupee**
Iraq	1428.57 IQD	**1351.35 IQD**
Israel	4.16 shekel	**4.29 shekel**
Japan	135.32 Yen	**126.9 Yen**
Malaysia	4.87 Ringgit	**4.74 Ringgit**
Mexico	23.73 Mexican Peso	**22.54 Mexican Peso**
New Zeland	1.69 NZD	**1.71 NZD**
Norway	9.85 Norwegian Kronor	**9.95 Norwegian Kronor**
Poland	4.18 Zloty	**4.30 Zloty**
Russia	69.06 Rouble	**79.55 Rouble**
Saudi Arabia	4.50 SAR	**4.29 SAR**
Singapore	1.60 SGD	**1.56 SGD**
South Africa	14.79 ZAR	**16.48 ZAR**
South Korea	1282.05 Won	**1277.14 Won**
Sweden	9.84 Swedish Kronor	**10.26 Swedish Kronor**
Switzerland	1.17 Swiss Franc	**1.13 Swiss Franc**
Taiwan	$ 35.79 new dollar	**$ 35.19 new dollar**
Thailand	39.20 THB	**39.20 THB**
Turkey	4.53 Turkish lira	**6.03 Turkish lira**
UK	**£** 0.89	**£ 0.9**
US	$ 1.20	**$ 1.15**
United Arab Emirates	4.40 dirham	**4.21 dirham**

TABLE A2.1: EURO EXCHANGE RATES APPLIED TO *SCOREBOARD* DATA FOR COMPANIES REPORTING IN DIFFERENT CURRENCIES (AS OF 31 DEC 2018).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

[53] Companies from some countries report their data in US dollars, e.g. in this edition, all companies based in Israel present their results in US dollars.

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 (31.12.2018). 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 5% and 6% against the US dollar and the Japanese Yen respectively, and appreciated by 1% 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 appreciation of the US dollar against the Euro (from $1.20 to $1.15). 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 2017) 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)[54].

[54] 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

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. However, it includes research contracted out to other companies or public research organisations, such as universities. 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 performed within a territorial unit that has been funded by the business enterprise sector (private or public companies).

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 Complementary tables

Rank	Sector	R&D in 2018, € billion	One-year change, %	Net Sales, € billion	One-year change, %	R&D intensity, %	Operating profits, € billion	One-year change , %	Profita-bility, %	Employees, million	One-year change, %
1	Pharmaceuticals & Biotechnology	153.8	7.3	967.8	4.8	15.4	130.4	-2.8	14.1	2.6	4.5
2	Technology Hardware & Equipment	127.8	7.4	1522.3	9.1	8.4	237.9	21.8	15.6	3.5	2.0
3	Automobiles & Parts	127.8	6.8	2708.3	2.5	4.7	149.0	-13.4	5.5	7.6	4.1
4	Software & Computer Services	117.7	19.3	1085.8	15.0	10.8	186.1	10.5	17.3	3.7	9.2
5	Electronic & Electrical Equipment	64.2	10.0	1282.3	6.1	5.0	136.0	3.3	10.6	5.4	4.2
6	Industrial Engineering	29.9	10.2	924.0	10.5	3.2	91.3	16.9	9.9	3.5	5.1
7	Chemicals	22.5	8.4	1010.4	11.2	2.2	115.0	11.0	11.4	1.7	5.0
8	General Industrials	20.4	-0.2	700.7	5.5	2.9	39.3	-12.7	5.7	2.2	-1.3
9	Aerospace & Defence	20.2	4.1	506.0	7.6	4.0	52.7	13.8	10.4	1.7	8.1
10	Health Care Equipment & Services	16.6	9.8	444.1	5.8	3.7	36.7	2.7	8.4	1.5	10.9
11	Construction & Materials	15.7	16.4	907.6	7.3	1.7	63.8	11.0	7.0	2.8	4.3
12	Leisure Goods	15.7	5.4	270.4	2.0	5.8	24.7	9.4	9.1	0.8	-3.7
13	Banks	10.7	-2.4	393.9	1.7	2.7	104.8	3.4	26.6	1.7	8.1
14	Oil & Gas Producers	9.3	9.4	2812.5	22.0	0.3	392.6	52.9	14.0	1.8	-2.3
15	Household Goods & Home Construction	8.5	6.8	337.1	4.1	2.5	24.1	-37.5	7.2	1.2	2.0
Total 38 industries		**823.4**	**8.9**	**20351.6**	**8.4**	**4.0**	**2275.7**	**9.1**	**11.2**	**55.6**	**3.6**

TABLE A3.1: MAIN STATISTICS FOR THE 2019 *SCOREBOARD* SAMPLE OF 2500 WORLD COMPANIES AGGREGATED BY INDUSTRIAL SECTORS (TOP 15 SECTORS, ICB 3-DIGITS).
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

The analysis of chapter 4 applies an extended sample of 1000 companies based in the EU. It consists of 551 companies included in the world R&D ranking of top 2500 companies and additional 449 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 A3.2 below.

Industry	Country codes																			
	AT	BE	CZ	DE	DK	ES	FI	FR	GR	HU	IE	IT	LU	NL	PL	PT	SE	SI	UK	Total
Aerospace & Defence				3		1		5			1	1		2			1		8	22
Alternative Energy				3	2			1												6
Automobiles & Parts	3			19		1	1	5			1	5		3			4		6	48
Banks		2		4	2	1			1		2	2		2		2	2		4	24
Beverages		1			1														2	4
Chemicals	2	3		14			2	2					2	3	1		3		8	40
Construction & Materials	2	2		6	1	5	2	3			2			1			2		3	29
Electricity	1	1	1	1		2	1	1				2				1	1		2	14
Electronic & Electrical Equipment	3	3		18	2		3	8			2	4		4			4		14	65
Financial Services				5	1			1									3		4	14
Fixed Line Telecommunications				1	1	1		1				1		1			1		1	8
Food & Drug Retailers					1									1					3	5
Food Producers	1			2	1		3	3			2			5					6	23
Forestry & Paper							3												1	4
Gas, Water & Multiutilities	1			2	1			3				2							3	12
General Industrials	1	1		13	1		1	1			1	1	1	3			3		6	33
General Retailers		2		5				2								1			8	18
Health Care Equipment & Services	1	2		11	3		1	3			2			2			3		11	39
Household Goods & Home Construction				6	1		1	3				1	1	1			1	1	2	18
Industrial Engineering	4	1		33	2	2	7	6			2	7	2	4			11		10	91
Industrial Metals & Mining	2	4		4		1	1	1					2	1			2			18
Industrial Transportation				1	1			3				2					1		2	10
Leisure Goods				1	2		1								1		1		3	9
Life Insurance																			2	2
Media	1							6									1		7	15
Mining													1				2		2	5
Mobile Telecommunications	1	1		2													1		3	8
Nonequity Investment Instruments					1															1
Nonlife Insurance				3				1											1	5
Oil & Gas Producers	1					1	1	1				1							3	8
Oil Equipment, Services & Distribution								1			1		1	1						4
Personal Goods				4				2				5	1						3	15
Pharmaceuticals & Biotechnology	1	7		16	12	4	2	23	1	1	11	5		10	1	1	13	1	57	166
Real Estate Investment & Services	1			5	2								2						4	14
Software & Computer Services	2	1		18	4	2	4	18					1	3	1		7		45	106
Support Services	1			10				3			1		1	1			2		22	41
Technology Hardware & Equipment	3	2		5	2		1	5	1		1			5			7		11	43
Tobacco																	1		1	2
Travel & Leisure	1			3							1						1		5	11
Total	**33**	**33**	**1**	**218**	**44**	**21**	**35**	**112**	**3**	**1**	**30**	**39**	**15**	**53**	**4**	**5**	**78**	**2**	**273**	**1000**

TABLE A3.2: DISTRIBUTION OF THE SAMPLE OF 1000 COMPANIES BASED IN THE EU BY COUNTRY AND INDUSTRY.
Source: The 2019 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

A.4 Access to the full dataset

The 2019 *Scoreboard* comprises two data samples:

- The world's top 2500 companies that invested more than €30 million in R&D in 2018.
- The top 1000 R&D investing companies based in the EU with R&D investment exceeding €8.5 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.

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

R&D ranking of world top 2500 companies:
https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard#field_data

R&D ranking of EU top 1000 companies:
https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard#field_data

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