European Commission

THE 2022 EU INDUSTRIAL R&D INVESTMENT SCOREBOARD

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Foreword
by Commissioner Mariya Gabriel

A few months after the adoption of the New European Innovation Agenda on 5 July, the 2022 EU Industrial R&D Investment *Scoreboard* brings encouraging news in the realm of innovation. I am pleased to see the rebound of EU companies' investment in research and development of 8.9% after a drop last year of 2.2% due to the COVID-19 pandemic.

Given that the focus of the Innovation Agenda is on Deep Tech Innovations, innovations to solve our deepest societal challenges, this rebound is timely. Innovations that do not have a solid industrial foundation can't create the innovations we need to address the most pressing challenges in our society.

The *Scoreboard* indicates a good EU base with broad sectoral diversification compared to its global competitors. EU *Scoreboard* companies retain the global lead for automotive R&D, contributing significantly to the EU's overall rebound, and it also features a number of R&D players in other sectors such as aerospace, defence and chemicals. A closer look at a wider sample of top 1000 EU R&D investors shows also a good number of smaller health and ICT companies investing in R&D.

This is promising and it is what we aim to achieve with the renewed European Research Area and the transition pathways for the different EU industrial ecosystems under the updated Industrial Strategy.

EU *Scoreboard* companies are also among the leaders in terms of green technologies and perform the best concerning UN's Sustainable Development Goals, which mean that their R&D investment has positive environmental and social impacts.

While these are encouraging signs for industries in the European Union, we cannot rest easy. The New Innovation Agenda is the most cutting-edge policy framework in the world for supporting innovations with a hardware component, with 25 actions arranged into 5 flagships. To reach the Innovation Agenda's flagship of access to capital, which aims to mobilise EUR 45 billion for deep tech startups in their scale up phase, we must keep growing the base of limited partners in VC funds that attract institutional investors. Moreover, large companies featured on the EU Scoreboard, the results of whose R&D investments have a trickle-down effect on their ecosystems, must keep up their spending. This is crucial for economic growth and solving some of society's most pressing problems, such as the energy and food crises and speeding up the digital and green twin transition. In the end, it will be worth it.

The EU invests in industrial research and innovation (R&I) with Horizon Europe, including through the European Innovation Council and EU partnerships with the industry and InvestEU facilitates startups and SMEs' R&I financing on the market. National Recovery and Resilience Plans under the NextGenEU programme also allocate significant funding in industrial R&I.

R&I growth reflects strategic investment decisions by companies and must serve as a key indicator for policymakers to understand the dynamics. I hope it can be also useful for industry to compare against peers and encourage R&I investments.

The effect of the war in Ukraine on R&D investment are not yet captured by the *Scoreboard* because it is based on 2021 data. However, the 2022 EU Survey on Industrial R&D Investment Trends, published together with the *Scoreboard*, reports that some existing R&I projects from top 1000 EU R&D investors are delayed in sectors like aerospace and defence, construction, health industries and automobiles. Other new R&D projects, however, were started as a consequence of the war.

I wish you an insightful reading.

EXECUTIVE SUMMARY

The EU Industrial R&D Investment Scoreboard has been published annually since 2004 – this is its 19th edition. It provides the most recent economic and financial information based on the latest published audited accounts of the world's top 2500 R&D investors, including the top 1000 EU-based ones. The world's top 2500 *Scoreboard* companies, with headquarters in 41 countries and more than one million subsidiaries all over the world, each invested over EUR 48.5 million in R&D in 2021.

The EU Industrial R&D Investment *Scoreboard* has been published annually since 2004 – this is its 19th edition. It provides the most recent economic and financial information based on the latest published audited accounts of the world's top 2500 R&D investors, including the top 1000 EU-based ones. The world's top 2500 *Scoreboard* companies, with headquarters in 41 countries and more than one million subsidiaries all over the world, each invested over EUR 48.5 million in R&D in 2021.

The *Scoreboard* is a tool to benchmark EU companies against their global competitors, understand industrial R&D dynamics and monitor trends going back up to ten years. Following the Open Science practice, the underlying database is publicly available to allow stakeholders such as companies, policy makers and scientists to undertake their own benchmarking and monitoring exercise.

The 2022 report shows that Europe's industry is back on track in research and development investments with an increase of 8.9% in 2021 compared to the -2.2 % pandemic-related dip in 2020. The EU remains the global leader in R&D investments by the automotive sector, where the transformation towards electric vehicles and digitalization is fully underway in both established companies and younger firms. The *Scoreboard* also shows a broad sectoral diversification for the EU, especially compared to the US, where R&D investment is highly concentrated in Information and Communication Technologies (ICT).

Globally the private sector R&D investment grew strongly beyond pre-pandemic levels (by 14.8% in 2021 vs. 2020). For the first time since the 2004 *Scoreboard,* total R&D investment by the world's top 2500 firms passed above one trillion euros (€1094 billion). An important change is that all Chinese *Scoreboard* firms together now have a slightly bigger share of the global total than the EU companies (17.9% Chinese and 17.6% EU, respectively). The leading share of US firms increased to 40.2% of the global total.

The *Scoreboard* highlights the intensification of the global tech race in the four key sectors which account for more than three-quarters of the total company R&D reported: ICT producers (22.6%), health industries (21.5%), ICT services (19.8%) and automotive (13.9%).

The R&D growth rates of US and Chinese companies - 16.5% and 24.9%, respectively - continued to outpace that of EU counterparts, due to the fact that US *Scoreboard* companies are leading R&D investors in ICT (both as producers and service providers) and health sectors, while Chinese *Scoreboard* firms are ahead of the EU not only as ICT producers, but also in ICT services. The number of Chinese *Scoreboard* companies more than tripled over the past decade (from 176 in 2011 to 678 in 2021), displacing EU and Japanese firms from more traditional manufacturing sectors.

It is encouraging that many EU Member States have significant R&D players in sectors such as aerospace, defence and chemicals industries, in addition to the automotive, ICT and health industries. The top 1000 EU companies include a substantial number of small- and medium-sized enterprises (SMEs) in health and ICT sectors with encouraging R&D growth in 2021. This is a welcome signal for important target groups of the New European Innovation Agenda, which among others addresses scale-up and growth in emerging deep tech and breakthrough technologies and triggers spillovers between sectors with the support of the European Innovation Council. The updated Industrial Strategy also promotes innovation policies in the broad industrial base in Europe including the high-technology sectors.

A patent-based positioning of *Scoreboard* companies in green technologies and circular economy technologies shows that EU and US companies lead in high-value patents, and the EU also leads in inventions relevant to circularity.

The 2022 report also analyses performance in relevant UN's Sustainable Development Goals (SDGs). EU companies achieved the highest scores in most SDGs and showed progress across the board. From a sectoral perspective, companies in the automotive and chemical sectors achieved on average high progress in SDGs. The review also reveals the high potential of deep technological solutions to tackle global challenges.

As a new aspect of corporate innovation strategies, Corporate Venture Capital (CVC) has also been analysed. CVC has been increasing over the past 20 years and is now used by two-thirds of *Scoreboard* companies. R&D and CVC complement and support each other, especially in ICT and health. CVC by EU companies amounts to around half of that by US companies. Moreover, 80% of funds from EU-based companies go to US-based start-ups, which triggers important spillovers.

The results of the 2022 *Scoreboard* reveal challenges and opportunities for the EU as it seeks to improve its technology capabilities and reinvigorate its industrial base in the context of increasing global competition pressure and ongoing green and digital transformations.

1 INTRODUCTION

This chapter first describes the economic and technological environment in which the EU Industrial R&D Investment Scoreboard firms (from here on the *Scoreboard*) operated in 2021 and 2022, before it presents the main characteristics of the sample. The top 2500 companies that invested the largest sums of R&D worldwide are analysed by geographical location and by sector, including an overview on their subsidiaries.

1.1 The economic and technological context

1.1.1 The economic context

The main macroeconomic factors affecting companies in the *Scoreboard* are interest rates, inflation, energy prices (mainly oil and gas) and expectations of changes in these factors. The COVID pandemic was still a major problem at the end of 2020 when both interest rates and inflation were still low. But inflation was rising by the end of 2021. For example, EU-27 inflation was 0.7% for 2020 but 2.9% for 2021 (with Germany 3.1%, UK 2.5%, France 1.6%), the US 1.2%/4.7% and Japan 0.1%/-0.2% for 2020/2021. But by April 2022 these figures had increased to EU-27 8.1%, US 8.3% and Japan 2.5%[1]. US inflation seemed to moderate in mid-2022 since it fell from 9.1% in June to 8.5% in July. Central bank interest rates had been kept very low for several years after the financial crisis of 2008/09 but were raised as inflation began to rise[2]. Oil and gas prices contribute to inflation and are rising. For example, West Texas Intermediate (WTI[3]) was USD 61.7 in early January 2020, down to USD 49.8 in early January 2021 (because of reduced demand during the pandemic), up to USD 77.9 in early January 2022. Rising oil and gas prices have been a major contributor to increased transport and heating costs and rising food prices because they increase fertiliser costs, greenhouse heating costs and fuel costs for farm machinery. The World Bank gives real GDP growth for the world as 2.6% in 2019 falling to -3.3% in 2020 because of the pandemic but recovering to 5.7% in 2021[4].

The pandemic, extensive lockdowns in China, and Russia's invasion of Ukraine have all contributed to big changes in the economic environment and have disrupted global value chains. They have radically modified the way many companies organise their operations and finances. In addition, the recent steep rises in energy prices are leading companies to urgently evaluate ways of reducing costs by minimising their energy use, such as by replacing some manufacturing processes with more energy-efficient alternatives. Five major examples of the way company operations and financing are changing are supply chains and reshoring, just-in-time manufacture changing to resilient manufacturing, working from home, the need to reduce reliance on China and the importance of reducing debt. We will briefly discuss each of these.

The pandemic highlighted the dangers of long supply chains which, coupled with pandemic-related reductions in airline services and restrictions on key staff travelling to many countries, left many manufacturers with inadequate supplies of essential components. This has led to a substantial move for reshoring with key components being made in a manufacturer's home country or a nearby stable economy. This means that in many sectors globalisation is giving way to regional distributed manufacturing.

1 https://www.oecd-ilibrary.org/economics/data/prices/consumer-prices-complete-database_0f2e8000-en
2 https://commonslibrary.parliament.uk/research-briefings/sn02802/
3 https://tradingeconomics.com/commodity/crude-oil
4 https://www.worldbank.org/en/news/press-release/2022/06/07/stagflation-risk-rises-amid-sharp-slowdown-in-growth-energy-markets

Just-in-time manufacturing (JITM) is very cost-efficient but relies on component suppliers delivering with 100% reliability just before the components are needed. Experience during the pandemic shows that resilience is more important and that points to reshoring and holding stocks of key components. Recent examples that emphasise this include the shortage of chips for cars and the effects on customer companies of the 2022 lockdowns in Shanghai and other major Chinese cities.

Controlling the spread of the COVID pandemic in 2020 required as many people as possible to work from home (WFH) and a substantial proportion of employees in many companies proved to be keen to continue WFH in 2021 and 2022 or at least to embrace hybrid working. It has proved to be difficult for many employers to enforce a substantial return to the office because of labour shortages. Studies of WFH vs. office productivity give mixed results but one detailed Japanese study found that WFH productivity was only 61% of office working in 2020 rising with experience to 78% in 2021[5]. Associated with WFH was an increase in the proportion of retail sales taking place online which peaked in early 2021 but in mid-2022 remained well above its pre-pandemic level. This has benefited Amazon and other mainly online companies.

Many companies started to rely on China for cheap goods and components in the early years of this century. However, the risks of this practice have been emphasised by rising costs, experiences of delivery delays during the pandemic and the effects of recent strict lockdowns in Shanghai and other cities over the Omicron variant. Adding to this is the Chinese government's increasing tendency to control private sector companies and pressure them to follow the communist party's agenda. Other Asian countries now offer more business-friendly environments and labour costs which are substantially lower than China's.

During the decade after the financial crisis, interest rates were very low and companies could expand at low cost by taking on substantial debt. However, now that interest rates are rising and are likely to rise further, high debt/equity ratios have become a problem since a company can reduce dividends but not debt interest. Indebted companies therefore need to reduce debt particularly if there is a potential danger of breaching their banking covenants. If cash flow is high this is possible but rising energy prices, inflation of labour and materials costs and rising interest rates on debt are shrinking profit margins for some companies and therefore reducing cash flow to dangerously low levels. Companies are therefore likely to face cost pressures with particular problems looming for heavily indebted companies as interest rates rise and profit margins are squeezed. These pressures may lead some CEOs to propose reductions in their R&D budgets which would lead to project cancellations and a reduced new product pipeline. R&D managers can point to experience in previous recessions which shows that those companies that increase (or at least maintain) their R&D emerge from a recession with improved ranges of products and services that give them a competitive edge in the upturn.

1.1.2 The technological context

Technological change is most rapid in the high R&D intensity sectors of biotechnology, pharmaceuticals, health, software, and technology hardware. But there are also major changes taking place in sectors where renewable energy is starting to replace fossil fuels – notably in transport (automotive and aerospace) and energy generation.

The potential of 21st century biotechnology was demonstrated in 2020 by the rapid development and approval of COVID-19 vaccines by AstraZeneca/Oxford University, BioNTech/Pfizer and Moderna in just less than a year from the publication of the virus' genome in January 2020. This compares with the 5-10 years previously required to develop a new vaccine. The mRNA technology underlying two of these vaccines is now being used to develop cancer vaccines and there are mRNA treatments in clinical trials for advanced melanoma and prostate, head and neck, ovarian and pancreatic cancer (BioNTech) and a personalised

[5] https://www.weforum.org/agenda/2022/03/productivity-dynamics-of-working-from-home/

cancer vaccine and treatments for solid tumours and lymphomas (Moderna). Recently, a small clinical trial at Memorial Sloan Kettering Cancer Centre of a BioNTech/Genentech vaccine for pancreatic cancer – a very difficult to treat cancer – showed promising results that indicate the vaccine can train the immune system to kill pancreatic cancer cells. And the team behind the AstraZeneca vaccine has just completed a Phase IIb trial of their new malaria vaccine which offers an unprecedented 77% rate of protection[6]. It is hoped the vaccine can be licensed in 2023. Progress is also being made with new antibiotics to treat superbugs resistant to the usual antibiotics. For example, Fetroja (Shionogi & Co) can treat complex urinary tract infections and some forms of antibiotic resistant pneumonia. There have been many recent advances in the health sector such as in medical electronics (e.g. pacemakers unaffected by MRI and cardiac resynchronisation therapy) and in areas such as 3D printing. For example, a first ever transplant on a patient of a 3D-printed ear was successful in a clinical trial. The new ear was formed from cells grown from a one-half gram of ear cartilage from the remnant ear[7]. And para-olympian Jessica Smith has now been fitted with a bionic hand having 29 grips that she even uses to apply her makeup[8].

Substantial progress is being made in Artificial Intelligence (AI) often in seemingly routine areas such as the reduction of returns for online fashion goods or the detection of fraudsters posing as telephone banking customers. And a machine-learning algorithm, the UrbanDenoiser, has been developed to detect weak earthquake signals close to tectonic plate boundaries such as in Los Angeles by filtering out city noise. The UrbanDenoiser improves signal to background by 15db and already detects 10% more events but can be improved further. AI is increasingly used in robotics with applications such as AI-enabled manipulation and grasping (with no need for a human controller) and AI-enhanced navigation and motion control[9]. Dyson is investing GBP 2.75 bn by 2025 into creating AI-enhanced robots that will perform a range of domestic tasks beyond cleaning[10]. AI is also moving into the professions with AI already being quicker and cheaper than junior lawyers for reviewing documents[11]. And AI/robotics is being used in surgery (e.g. Intuitive Surgical's da Vinci robotic surgery systems), diagnosis and the interpretation of diagnostic scans. For example, a recent trial showed that AI analysis of a single MRI brain scan could spot early Alzheimer's in 98% of people who had it. Early detection is vital since it is then easier to slow or halt its spread with the latest drugs[12]. And Faculty, the AI company, has developed an AI tool in partnership with Genomics England that can predict how quickly tumours will progress and hopefully this will bring in a new era of personalised cancer treatments. The large tech companies are moving into healthcare with Oracle paying USD 28 bn for Cerner, a clinical software company, Amazon buying One Medical (a chain of healthcare practices) and Pillpack (an online pharmacy) and Bytedance buying Amcare (one of China's largest hospital chains). The rapid progress being made in AI, software and cybersecurity mean that there is a shortage of tech talent for companies in these fields. The Korn Ferry Institute has estimated that, by 2030, there will be a world shortage of 4.3 million skilled tech people which will cost lost output of USD 450 bn[13].

The new frontier in AI and tech hardware is in quantum technologies – large quantum computers together with their control systems and associated engineering infrastructure. The US is currently leading in quantum computing with Google, Microsoft, IBM and 12 other listed companies working in the field and 78 start-ups[14]. IBM has made a 127-qubit computer and plans to have a 4158+qubit processor in 2025[15]. ExxonMobil

6 https://www.ox.ac.uk/news/2021-04-23-malaria-vaccine-becomes-first-achieve-who-specified-75-efficacy-goal
7 https://www.thetimes.co.uk/article/surgeons-attach-3d-printed-ear-built-with-cells-from-patients-own-cartilage-20grg3kp9
8 https://news.sky.com/story/amazing-bionic-hand-can-be-updated-with-new-movements-from-anywhere-in-the-world-12674248
9 https://www.techtarget.com/searchenterpriseai/feature/Application-of-AI-in-robotics-boosts-enterprise-potential#:~:text=With%20the%20help%20of%20AI,navigation%20paths%20and%20process%
10 https://www.business-live.co.uk/manufacturing/dyson-reveals-275bn-investment-robotics-19354180
11 https://futurism.com/ai-contracts-lawyers-lawgeex
12 https://www.imperial.ac.uk/news/237494/single-brain-scan-diagnose-alzheimers-disease/
13 https://thefintechtimes.com/tech-industry-talent-shortage-could-reach-an-unrealised-output-of-449-70billion-globally-by-2030/#:~:text=According%20to%20the%20Korn%20Ferry,a%20hub%20
14 https://www.businessofbusiness.com/articles/whos-winning-the-quantum-computing-race
15 https://www.forbes.com/sites/moorinsights/2022/05/18/ibms-newest-quantum-computing-roadmap-unveils-four-new-quantum-processors-and-future-plans-for-a-quantum-supercomputer/

and IBM are working on quantum algorithms that will enable Exxon to use IBM quantum computers to solve complex maritime routing problems to optimise the management of large shipping fleets[16]. Goldman Sachs is developing quantum optimisation algorithms to price assets based on the inherent risk associated with different options or stocks and Daimler is investigating how quantum computers can simulate new materials for high performance car batteries[17]. One of the major advances needed to enable quantum computers to reach their full potential is an effective error correction system and Riverlane & Rigetti, for example, are working together to achieve this[18]. Microsoft has a topological qubit which incorporates some error correction[19]. The US government is well aware of the potential of quantum computers in cryptography and has started a multi-year programme to shift vulnerable computer networks to quantum-resistant cryptography.

Major changes are occurring in manufacturing through the combination of digitisation, the use of AI and robotics/automation, additive manufacturing and regional distributed manufacturing. These and other technological trends are coming together as smart manufacturing which will extend from high value products into mass produced products. Robotics is transforming farming with a 3-year project demonstrating a complete hands-free cropping cycle by a group of businesses working with Harper Adams University on a 35-hectare area[20]. And John Deere, the world's largest agricultural equipment manufacturer, plans to build a world of fully autonomous farming by 2030[21].

Materials developments include interesting work at Berlin's BAM Institute on the use of muon detectors to image large concrete structures to identify internal faults that could lead to the collapse of buildings or bridges[22] such as the 2021 Florida apartment block collapse which killed 100 people. Graphene materials development is proceeding at a rapid pace and applications in batteries and supercapacitors are likely to be amongst the first to reach the market.

Battery electric vehicles (BEVs) doubled their global market share from 2020 to 2021 reaching 8.4%. China accounts for around half of all BEV sales[23]. Recent work at the Idaho National Laboratory has used AI to optimise the charging protocol for electric car batteries and this enables charging from zero up to 90% of capacity in 10 minutes while protecting the battery's long-term health[24]. Hydrogen fuel cells are likely to be a better long-term solution for long haul trucks than heavy batteries.

The aerospace and shipping industries are also developing zero emission technology. For example, Heart Aerospace of Sweden has orders from Air Canada, United and Mesa Airlines for its 30-passenger electric planes[25]. These planes have a range of 124 miles on one charge but this can be extended to 500 miles with a fuel-powered generator. The company says its planes could be ready by 2028 subject to regulatory approvals. Hurtigruten of Norway has said it is launching its first zero-emission passenger ship by 2030 and the German state of Saxony has commissioned its first fleet of passenger trains running solely on hydrogen.

CO_2-free energy generation methods that do not use fossil fuels have become increasingly important, especially in the context of the Green Deal and twin transitions. This means increased investment in wind, solar and nuclear. Nuclear reactor technology is advancing with small modular fission reactors (SMRs) that can be constructed as modules in factories and then transported and commissioned on site relatively

16 https://www.zdnet.com/article/ibm-and-exxonmobil-are-building-quantum-algorithms-to-solve-this-giant-optimization-problem/
17 Physics World Vol. 35, #9, 2022
18 https://www.riverlane.com/news/2022/06/riverlane-and-rigetti-partnership-to-tackle-quantum-error-correction/#:~:text=Riverlane%20and%20Rigetti%20will%20work,by%20using%20a%20quantum%
19 Physics World Vol. 35, #9, 2022
20 https://www.fwi.co.uk/arable/crop-management/video-hands-free-farm-turns-to-drilling-after-good-harvest
21 https://www.cnbc.com/2022/10/02/how-deere-plans-to-build-a-world-of-fully-autonomous-farming-by-2030.html
22 https://link.springer.com/article/10.1007/s10921-021-00797-3
23 https://www.autocar.co.uk/car-news/business-dealership%2C-sales-and-marketing/battery-electric-vehicles-doubled-global-market#:~:text=Battery-electric%20vehicles%20(BEVs),3.1%25%20just%20
24 https://www.newscientist.com/article/2334799-supercharging-tweak-could-fill-electric-car-batteries-90-in-10-mins/
25 https://www.smithsonianmag.com/smart-news/electric-planes-are-taking-flight-180980821/

quickly. The Rolls-Royce SMR consortium plans to produce 470MW reactors (which each have output equivalent to 150 wind turbines and can power 1 million homes) costing around GBP 2.3 bn each with 90% of the manufacturing and assembly carried out in controlled factory conditions. Regulatory approval is expected in mid-2024 and, with an order placed in late 2022, Rolls says the first SMR can be online in 2029. The US is also developing SMR designs. A longer-term solution will use nuclear fusion in which major advances have recently been made. For example, in February 2022, JET (Joint European Torus) at Culham, UK demonstrated a world record sustained fusion output of 59MJ[26]. Laser induced fusion is also a promising approach and is being developed at Lawrence Livermore Laboratory which achieved the threshold of fusion ignition in August 2021[27]. Several start-up companies are exploring alternative and lower cost approaches to fusion such as First Light Fusion which has demonstrated the feasibility of its technique of firing high velocity slugs at fuel pellets to release energy[28]. And an Australian start-up, HB11, has demonstrated hydrogen/boron fusion using high power lasers[29].

In summary, rapid technological progress is being made in high R&D intensity sectors such as biotech, pharmaceuticals, software, technology hardware, health and also in transport and energy generation where the move away from fossil fuels is accelerating because of the advent of new technologies. Progress is being made in Europe but more needs to be done to close the gap with the US and, increasingly, with China.

1.2 The industrial R&D landscape[30]

The top 2500 global companies invested a total of EUR 1093.9 billion in 2021 in R&D[31], which is 14.8%[32] more than what they invested in the previous year[33]. The threshold to enter the sample this year - in other words, the amount invested in R&D by the company ranked 2500th in the *Scoreboard* - is EUR 48.5 million, about one third higher than the one of last year (EUR 36.5 million).

After the relative slowdown of the 2021 *Scoreboard*– R&D investments at global level grew at 6.0% compared to 8.9% in the 2020 *Scoreboard* – the pace of R&D growth increased again and even surpassed pre-pandemic levels.

26 https://ccfe.ukaea.uk/fusion-energy-record-demonstrates-powerplant-future/
27 https://www.llnl.gov/news/national-ignition-facility-experiment-puts-researchers-threshold-fusion-ignition
28 https://firstlightfusion.com/media/fusion#:~:text=First%20Light%20has%20achieved%20fusion,other%20fusion%20scheme%20in%20history
29 https://www.powerengineeringint.com/nuclear/australias-hb11-energy-demonstrates-laser-powered-nuclear-fusion/
30 There is one large R&D-investing company absent from the *Scoreboard* – this is Amazon, which unfortunately only records a combined figure for 'Technology and Content' investment in its accounts. Since no information is given on how to extract the technology (R&D) component, it is not possible to include Amazon in the *Scoreboard*. However, using statements in Amazon's accounts over the past few years we estimate that Amazon's R&D could be larger than Alphabet's so Amazon should probably have been #1 in the 2022 *Scoreboard* R&D ranking.
31 The *Scoreboard* is based on information taken from the companies' latest published accounts. For most companies, these correspond to the calendar year 2021. However a significant number of companies' financial years ended on 31 March 2022. This is the case for many Japanese companies and many UK firms. Few companies included in the sample have financial years that end as late as the end of June 2022. A small number had accounts available only up to the end of 2020. Therefore, we should refer to the data of the last available year as 2021/22 and those of the previous years as 2020/21, and so on. However, for most companies the last available year corresponds to the calendar years 2021, 2020, and so on. For reasons of clarity and consistency, we refer to the last available year as 2021, the previous year as 2020, and so on.
32 This growth rate is very similar in terms of order of magnitude to the rate predicted using an early sample dataset in June 2022, which forecast a 12.7% R&D growth rate. See Grassano, N. and Hernandez Guevara, H., Top R&D investors recovering fast from the Covid-19 crisis: Preliminary insight to the 2022 EU Industrial R&D Investment Scoreboard, European Commission, 2022, JRC130014.
33 The 2021 *Scoreboard* reported R&D for the top 2500 companies as €908.9 billion in 2020, which is an increase of 20.3% – not 14.7%. Exchange rates are the main reason for this apparent discrepancy. The US dollar depreciated from €1=$1.23 at end 2020 to €1=$1.13 at end 2021. If the 2022 *Scoreboard* R&D is expressed at 2021 *Scoreboard* exchange rates, the total R&D for the 2 500 companies is EUR 1033.8 bn. This represents a 13.7% increase. The remaining 1% difference is explained by the entry-exit of companies. See details on exchange rates in Annex 2 Box 1 and Table 1). Overall, the significant appreciation of the USD against the Euro favoured the increase of US companies and decrease of EU companies in the R&D ranking.

1.2.1 Company location and R&D investment by world region

The top 2500 *Scoreboard* includes companies from 41 countries. 16 of these 41 countries are EU Member States, down from 17 last year. The total R&D investment made by these 2500 companies accounts for 86.3% of global business-funded R&D (see Box 1.2).

Table 1.1 shows the breakdown of the companies in the *Scoreboard* by country/region. The figure in parentheses shows the number of companies present in the same country in the previous edition of the *Scoreboard.*

Table 1.1: Distribution of companies and R&D by country/region

EU countries	No. of companies in	R&D (€bn)	Non-EU countries	No. of companies in 2022 (2021)	R&D (€bn)
Germany	114 (124)	91.03	US	822 (779)	439.7
France	57 (66)	28.78	China	678 (597)	195.9
Netherlands	38 (34)	24.08	Japan	233 (293)	113.8
Sweden	26 (34)	11.50	Switzerland	55 (57)	34.9
Ireland	24 (27)	8.28	South Korea	53 (60)	34.3
Denmark	25 (29)	7.14	UK	95 (105)	32.8
Finland	12 (15)	5.30	Taiwan	84 (86)	24.8
Italy	20 (21)	5.21	India	24 (25)	5.6
Spain	12 (14)	4.48	Canada	28 (26)	5.2
Belgium	12 (13)	3.11	Israel	22 (21)	4.1
Austria	13 (14)	2.04	Australia	10 (11)	3.1
Luxembourg	3 (4)	1.25	Singapore	7 (6)	1.6
Portugal	2 (2)	0.18	Norway	9 (11)	1.4
Hungary	1 (1)	0.17	Saudi Arabia	1 (1)	0.9
Slovenia	1 (1)	0.15	Brazil	4 (5)	0.5
Malta	1 (1)	0.06	Other 10 countries	14 (9)	2.5
Total EU	**361 (401)**	**192.8**	**Total**	**2139 (2099)**	**901.1**

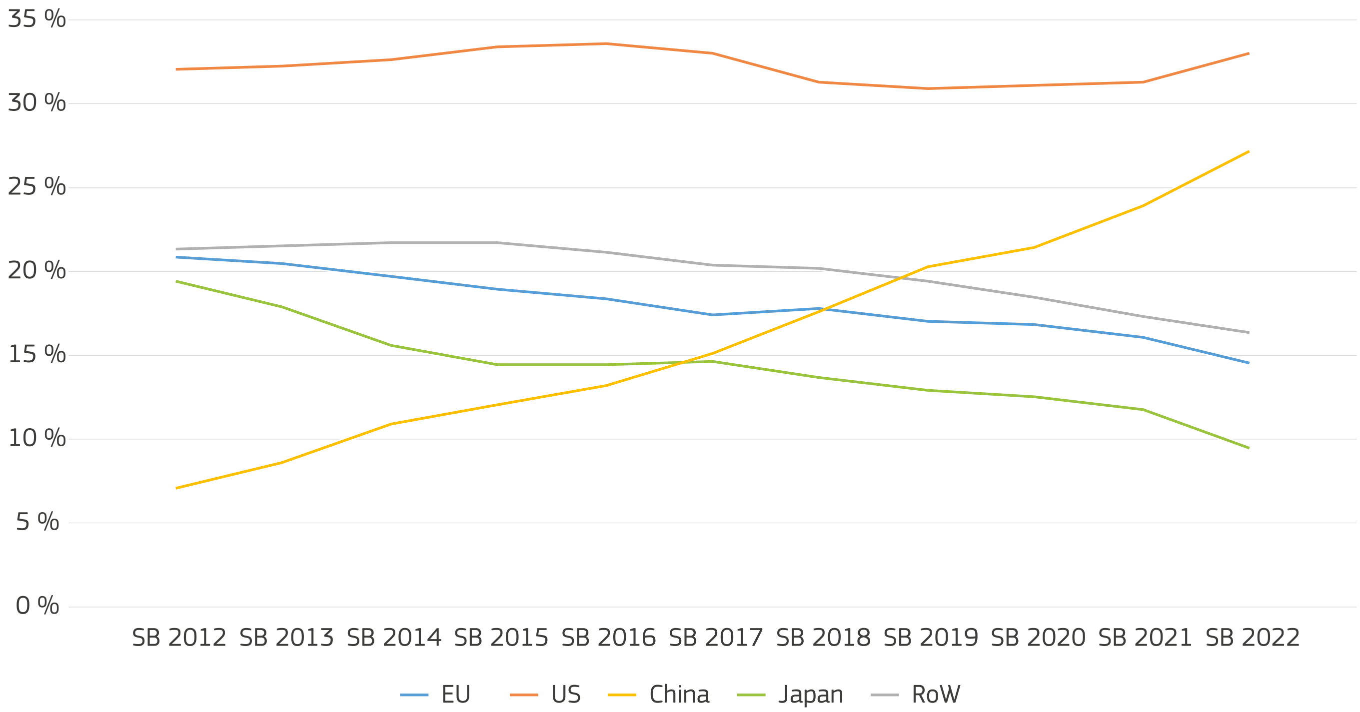
Note: Figures in parentheses show the number of companies from the 2021 edition of the *Scoreboard*.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The US has again the highest number of top R&D investing companies in the *Scoreboard* (822 companies), followed by China (679), the EU (361), Japan (233), UK (95), Taiwan (84), Switzerland (55), South Korea (53), Canada (28) and India (24). The top 10 countries/regions is the same as last year, except for Switzerland which overtook South Korea. The difference between the results from the 2021 and the 2022 *Scoreboard* is the relative weight of each country or region. For example, there was a notable increase of 81 Chinese and 43 US companies on the *Scoreboard* compared to last year. Japan saw a considerable decrease by 60 companies, as did the EU with 40 companies less than last year[34]. With this reduction, twice as many EU companies left the top 2500 than last year, whereas the number of new Chinese companies increased by one third.

[34] The location of companies is where they have their headquarters. This can cause some over (or under) statement for some countries such as the Netherlands or Ireland, where companies are registered but whose principal activities are carried out elsewhere.

The gap in terms of number of companies among the top R&D investors between the US and China on one side and the EU, Japan and the rest of the world from the other side is widening, as shown in Figure 1.1. Even if we take the total number of companies located in Europe (adding to the EU[35] also UK, Swiss, Norwegian and other European based companies), China would still be second in the ranking by a wide margin (678 Chinese companies against 522 European companies). The EUR 1093.9 bn invested in R&D by the companies

Figure 1.1: Share of companies by region – SB 2012 to 2022



Note: Data from *Scoreboard* (SB) editions 2012 to 2022.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

in the sample is distributed across world regions as shown in Figure 1.2. Since the *Scoreboard* was first published in 2004, the US accounts for the majority of companies and of R&D invested – in this *Scoreboard* it is 822 companies and 40.2% of all R&D.

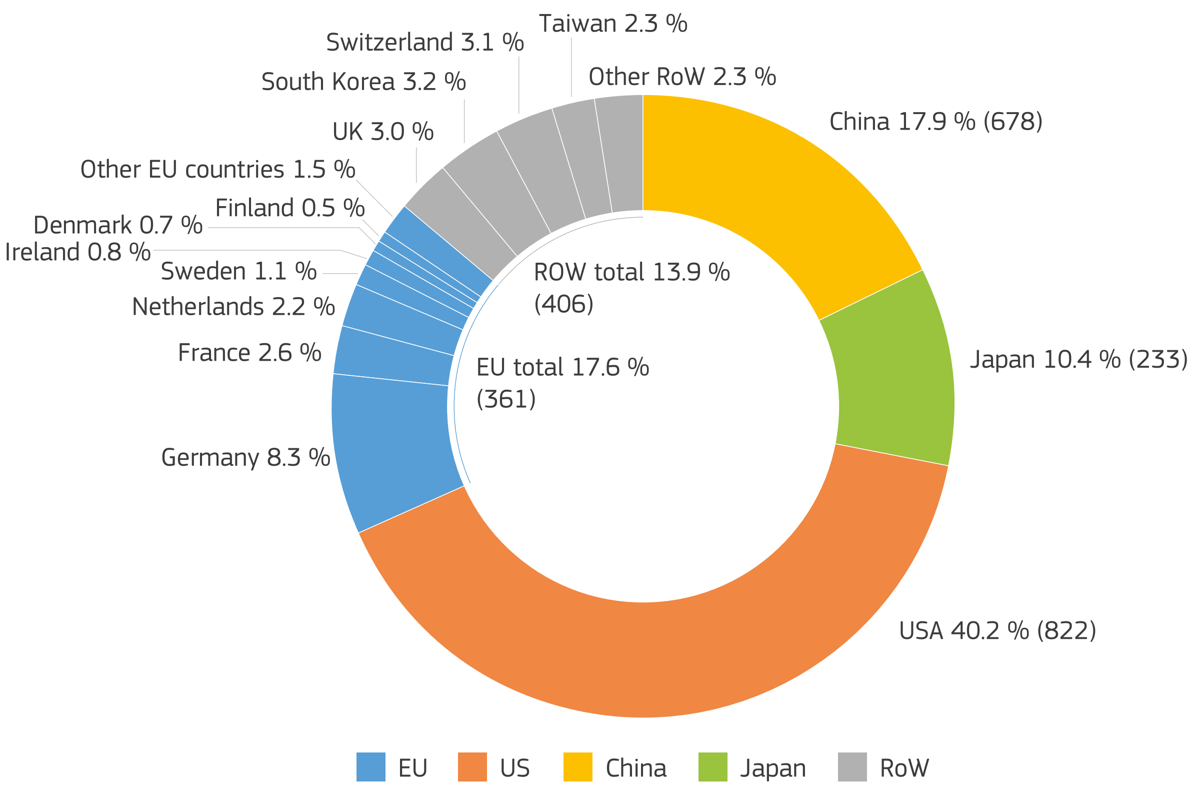
The constant and fast growth of China's number of companies in the *Scoreboard* and their R&D, in contrast to investment in the EU and Japan, as reported in past editions of the *Scoreboard* continues this year and has produced a significant change. For the first time, China overtook the EU, both in the number of companies and also in the total volume of R&D invested.

EU companies invested EUR 192.8 bn of R&D in 2021, against EUR 195.9 bn from Chinese companies. The US remains the largest investor, investing EUR 439.7 bn. Japan is behind both the EU and China with

[35] In this report, when we refer to the EU we always refer to the EU-27. Data from past *Scoreboard* (where UK companies where part of the EU) have been re-codified to include in the EU group only companies headquartered in one of the EU-27 Member States.

EUR 113.8 bn. The previous edition of the *Scoreboard* predicted that China would overtake the EU. However, the growth rate of R&D investment in China combined with the considerable increase in Chinese companies in the top 2500 ranking resulted in this change happening in 2021 rather than in 2022 or 2023 as forecasted.

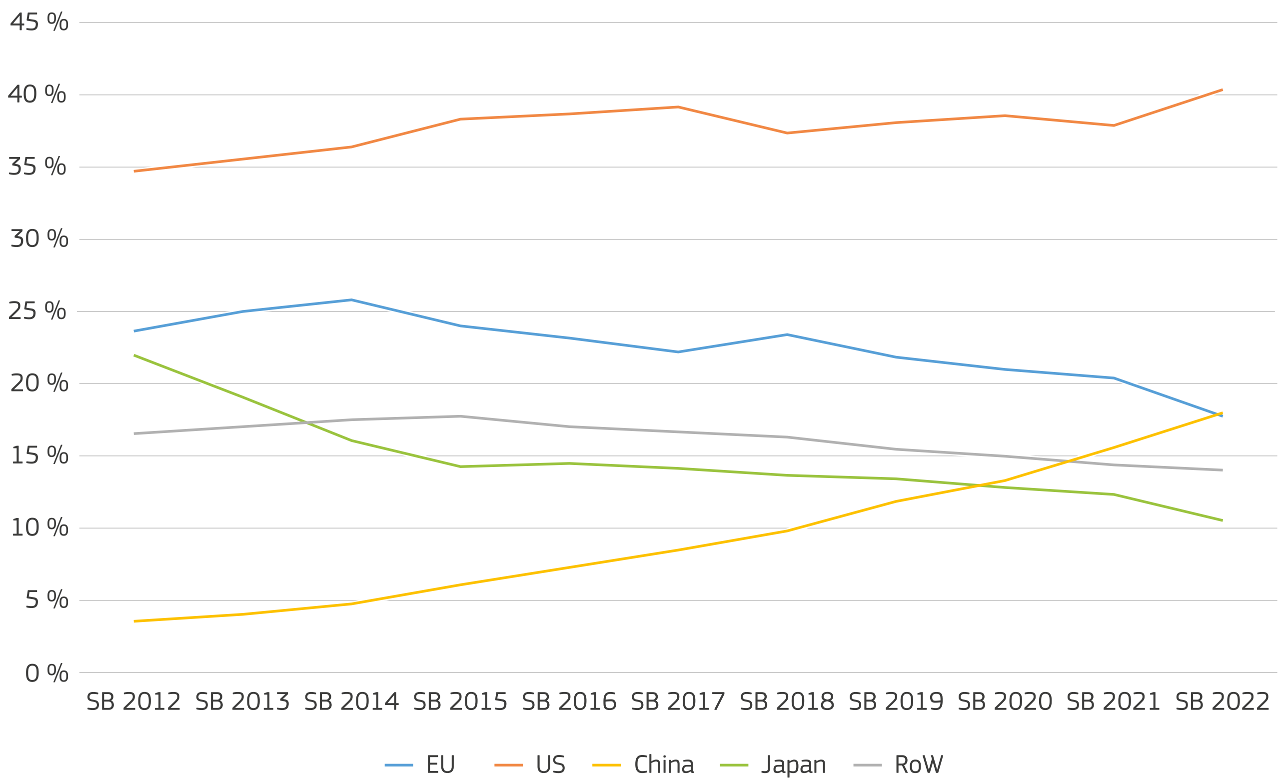
Figure 1.2: R&D investment by region and country



Note: The figure in parentheses shows the number of companies per country/region.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 1.3 reports the trends of R&D shares by region in the *Scoreboard* since 2012. This shows the steady rise of the US and China and the progressive decline of R&D investment shares of the EU and Japan.

Figure 1.3: Share of global R&D investment by region – SB 2012 to 2022



Note: Data from *Scoreboard* (SB) editions 2012 to 2022.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

1.2.2 Breakdown of companies and R&D investment by sector

Large and multinational companies often operate in multiple sectors. This makes it difficult to categorise a company in a specific sector. Since the *Scoreboard*'s first edition in 2004, we have categorised a company by the main sector in which they carry out their business using taxonomies, such as the International Classification Benchmark (ICB). This is usually the sector indicated by the companies themselves in their annual reports. Table 1.2 shows the breakdown of companies by sector according to this indicator and grouped in broad macro sectors. It is also interesting to aggregate companies according to the role they play in industrial ecosystems (comprising all industrial players operating in a value chain). See in Box 1.1 the distribution of the *Scoreboard* companies following the ecosystem definition applied by the European Commission in its new industrial strategy.

Table 1.2: Industrial classifications applied in the *Scoreboard:* 11 industrial sectors.

Industrial Sector	Sector classification ICB4 digits	No. of firms	R&D 2021 (EUR bn)	R&D intensity (%)	Total R&D (%)	R&D per firm (EUR million)
Aerospace & Defence	Aerospace; Defence	44 (43)	17.7	3.9	1.6	402.3
Automobiles & other transport	Auto Parts; Automobiles; Commercial Vehicles & Trucks; Tires	179 (184)	152.4	4.9	13.9	846.7
Chemicals	Commodity Chemicals; Specialty Chemicals	115 (125)	25.1	2.4	2.3	218.6
Construction	Building Materials & Fixtures; Construction and Materials; Heavy Construction	65 (67)	30.9	2.3	2.8	474.7
Energy	Alternative Energy; Alternative Fuels; Conventional Electricity; Electricity; Exploration & Production; Gas Distribution; Gas, Water & Multiutilities; Integrated Oil & Gas; Multiutilities; Oil & Gas Producers; Oil Equipment & Services; Oil Equipment, Services & Distribution; Renewable Energy Equipment; Water	80 (82)	19.5	0.5	1.8	243.7
Financial	Banks; Financial Services; Full Line Insurance; Insurance Brokers; Investment Services; Life Insurance; Real Estate Holding & Development; Real Estate Investment & Services; Real Estate Services; Reinsurance; Specialty Finance	61 (67)	19.1	2.7	1.7	313.9
Health industries	Biotechnology; Health Providers; Medical Equipment; Medical Supplies; Pharmaceuticals	567 (525)	235.3	12.4	21.5	415.0
ICT producers	Computer Hardware; Electrical Components & Equipment; Electronic Equipment; Electronic Office Equipment; Semiconductors; Telecommunications Equipment	456 (458)	246.8	7.0	22.6	541.2
ICT services	Computer Services; Internet; Software; Mobile Telecommunications	365 (355)	216.3	9.3	19.8	592.5
Industrials	Aluminium; Containers & Packaging; Diversified Industrials; Delivery Services; Industrial Machinery; Iron & Steel; Nonferrous Metals; Transportation Services	260 (274)	54.8	2.5	5.0	210.7
Others*	Beverages; Food & Drug Retailers; Food Producers; Forestry & Paper; General Retailers; Household Goods & Home Construction; Leisure Goods; Media; Mining; Personal Goods; Support Services; Tobacco; Travel & Leisure	308 (320)	75.9	2.6	6.9	247.3
Total		**2500**	**1093.8**	**4.7**	**100.0**	**437.7**

Note: * Sectors listed under 'Others' are presented at ICB-3 digits level. Figures in parentheses are the number of companies in these sectors in the 2021 *Scoreboard*. R&D intensity is defined as R&D investment over net sales, R&D per firm constitutes the average per sector.
Source: The 2022 EU Industrial R&D Investment Scoreboard. European Commission, JRC/DG R&I.

With 567 companies, which represent a share of 22.7%, the health sector has the highest share of companies in the sample. There are 42 more companies in this sector compared to the 2021 *Scoreboard*, which is the largest increase in numbers recorded for any sector since last edition. This is followed by ICT producers who, despite the slight drop in number of firms, have a share of 18.2% of companies in the sample. ICT services has the third highest share with 14.6% and 10 more companies than last year. The industrials and chemical sectors saw the largest decrease in companies since last year, with 14 and 10 less companies, respectively. This is in line with the trend that companies from sectors frequently investing less in R&D than in high-tech sectors such as health and ICT, drop out of the *Scoreboard* as ICT companies (notably from China) and health companies enter (see Chapter 3 for more details).

Table 1.3 gives a breakdown of the number of companies by sector and region, illustrating a trend towards specialisation observed in several past editions of the *Scoreboard*.

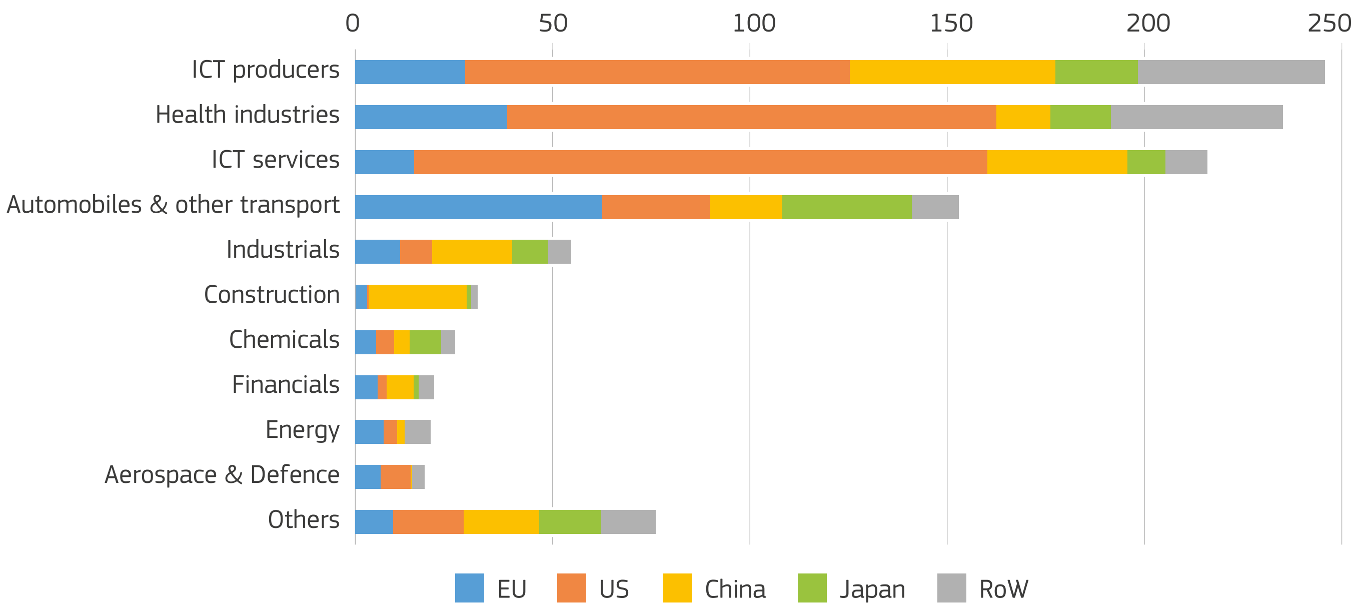
Table 1.3: Distribution of global 2500 companies by industrial sector and region – number of companies.

Industry	EU	US	China	Japan	RoW	Total
Aerospace & Defence	10 (22.7%)	**15 (34.1%)**	5 (11.4%)	0	14 (31.8%)	44 (1.8%)
Automobiles & other transport	34 (18.9%)	37 (20.6%)	**54 (30%)**	28 (15.6%)	27 (15%)	180 (7.2%)
Chemicals	16 (13.9%)	21 (18.3%)	**33 (28.7%)**	28 (24.3%)	17 (14.8%)	115 (4.6%)
Construction	9 (13.8%)	4 (6.2%)	**35 (53.8%)**	10 (15.4%)	7 (10.8%)	65 (2.6%)
Energy	**26 (32.5%)**	10 (12.5%)	20 (25%)	10 (12.5%)	14 (17.5%)	80 (3.2%)
Financial	**22 (36.1%)**	9 (14.8%)	12 (19.7%)	0	18 (29.5%)	61 (2.4%)
Health industries	68 (12%)	**309 (54.5%)**	92 (16.2%)	31 (5.5%)	67 (11.8%)	567 (22.7%)
ICT producers	42 (9.2%)	112 (24.6%)	**153 (33.6%)**	45 (9.9%)	104 (22.8%)	456 (18.2%)
ICT services	30 (8.2%)	**203 (55.6%)**	83 (22.7%)	6 (1.6%)	43 (11.8%)	365 (14.6%)
Industrials	57 (21.9%)	35 (13.5%)	**99 (38.1%)**	36 (13.8%)	33 (12.7%)	260 (10.4%)
Others	47 (15.3%)	67 (21.8%)	**92 (30%)**	39 (12.7%)	62 (20.2%)	307 (12.3%)
Total	**361 (14.4%)**	**822 (32.9%)**	**678 (27.1%)**	**233 (9.3%)**	**406 (16.2%)**	**2500**

Note: The figures in brackets show each sector's regional percentages of total number of firms in the sector. The cell representing the higher sectoral share of firms by region is highlighted. The total in the final column shows the number of firms in the sector, with the share of the total number of firms between brackets. The total in the final row shows the number of firms in the region, with their overall share of the sample in brackets.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

US firms lead in ICT services and health and China maintains its digital leadership in ICT proders, construction and the industrial sector. EU firms have a relative majority in the energy and financial sectors. However, this changes slightly if we look at the volume of R&D investment instead of the number of companies. Just as last year, ICT producers and health industries are still the top two sectors in terms of R&D invested. Together they account for almost 44.1% of R&D investment globally in 2021 (43.7% in the 2021 *Scoreboard*). Figure 1.4 presents the share of R&D by sector and region.

Figure 1.4: R&D investment by sector and country/region in EUR bn



Source: The 2021 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

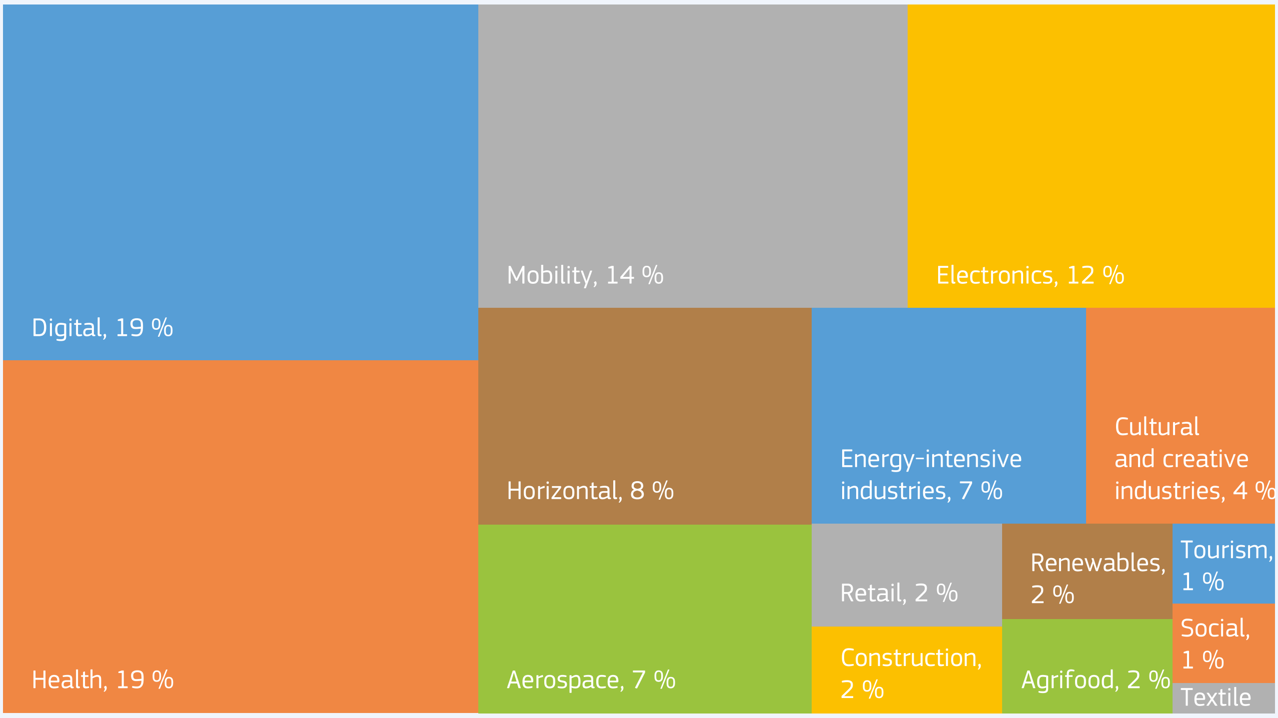
Although the ICT producers sector has the second highest number of companies behind the health sector (see Table 1.2), it invests slightly more. The ICT services sector remains the third largest sector in terms of share of R&D. It overtook the automotive sector and is edging closer to the health sector. This year's data also confirms the sector shift reported in last year's edition of the *Scoreboard*: high-tech sectors are progressively widening the gap with mid- and low-tech sectors. Lastly, the EU specialisation in the automobile industry is still strong. In spite of having fewer companies in this sector than China and the US, EU companies are responsible for 41.1% of the total R&D investment in this sector.

Box 1.1: The *Scoreboard* from an ecosystem perspective

In the *Scoreboard* the analysis is done by grouping companies in macro sectors based on the ICB classification. An alternative way of looking at it could be to follow the ecosystem approach introduced by the Communication “A new Industrial Strategy for a green and digital Europe[36]”, put forward by the European Commission in March 2020.

Using the correspondence between ICB codes and ecosystems (via NACE code) and fractionally counting R&D for companies belonging to ICB sectors falling in more than one ecosystem, it is possible to see what the *Scoreboard* would look like from an ecosystem perceptive (Figure B.1).

Figure B.1: R&D investment 2021 by ecosystem.



Source: : The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The majority of R&D is concentrated in the digital, health, mobility and electronics ecosystems, which account for 64.3% of R&D. This is in line with both the analysis carried out using ICB sectors and the ecosystem approach in the previous edition of the *Scoreboard*.

Converting ICB codes to ecosystems via NACE codes is not straightforward. Some codes fall in more than one ecosystem and some ecosystems overlap. We used value added as a weighting for NACE codes that fall into multiple ecosystems and rescaled weights to equal one. Further analysis is needed to check the accuracy of conversions from ICB codes to ecosystems.

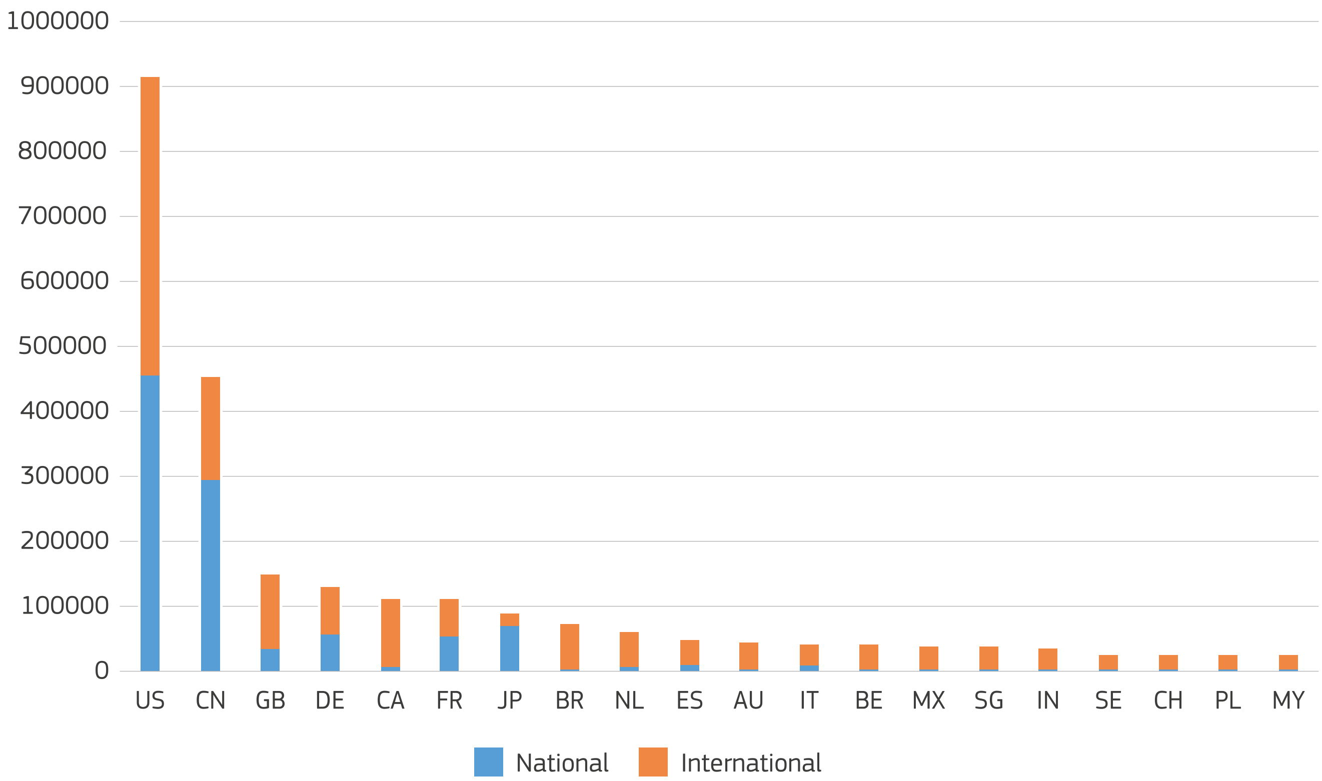
[36] See https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en

1.2.3 The subsidiary structure of the *Scoreboard* companies

The top 2500 companies investing in R&D control about 935 000 subsidiaries. Almost 300 000 of these are corporate subsidiaries[37]. While companies' headquarters are located in only 41 different countries, there is at least one subsidiary[38] of a *Scoreboard* company in 201 countries/territories.

The distribution of corporate subsidiaries, as the distribution of headquarters, is quite concentrated. As shown in Figure 1.5, 72% of subsidiaries are located in 20 countries. In line with the distribution of headquarters, the country where the majority of subsidiaries are located is the US, which accounts for 30.7% of the total. This is followed by China with 15.2%. The countries with the highest number of subsidiaries (US, China, UK, Germany and Canada) are the same top four as last edition (2021 *Scoreboard*), plus Canada which has overtaken France.

Figure 1.5: Subsidiaries of the top 2500 companies for R&D investment by location – top 20 host countries



Note: Corporate subsidiaries are labelled as 'national' if they are located in the same country as their parent company. Otherwise, they are 'international'.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

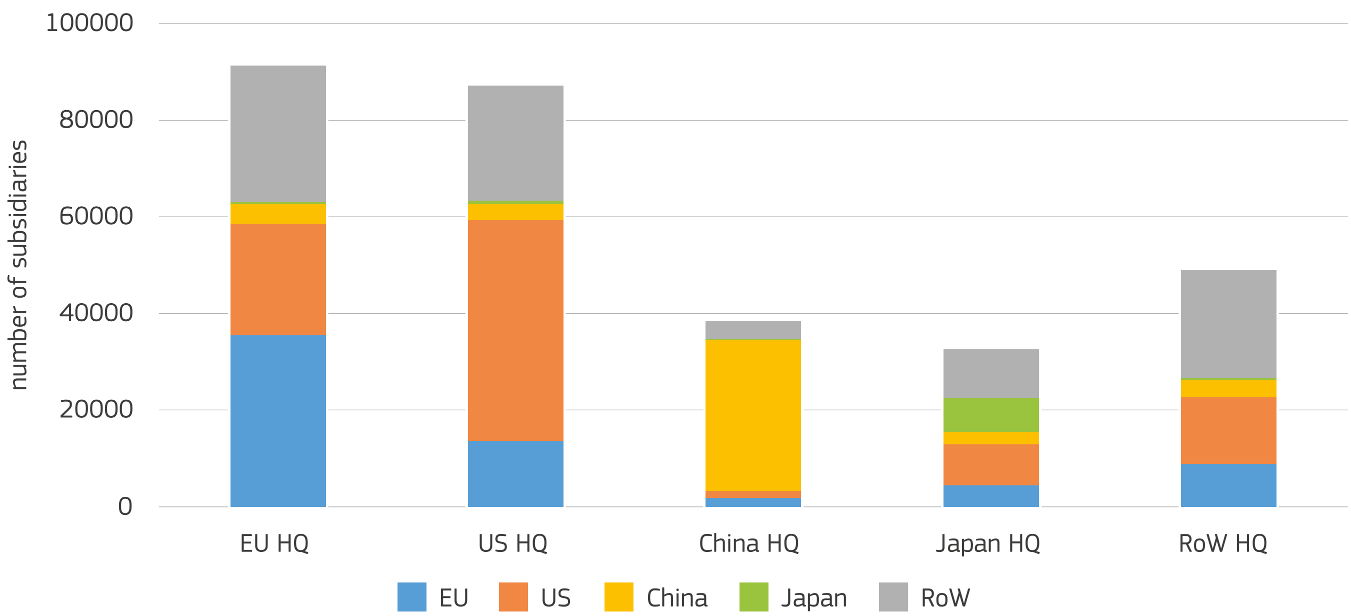
[37] Corporate subsidiaries are all companies that are not banks, financial companies or insurance companies. They may be involved in manufacturing activities but also in trading activities (wholesalers, retailers, brokers, etc.). They also include companies active in B2B or B2C non-financial services.
[38] It should be noted that not all subsidiaries necessarily carry out R&D.

International corporate subsidiaries are those located in a different country from the headquarter of their parent company. By focusing on these, we can gain an insight into how attractive a country is as a subsidiary location for a top R&D investor. The orange bars in Figure 1.5 indicate international corporate subsidiaries. The top 20 locations for international corporate subsidiaries are the same 20 countries that account for the majority of all subsidiaries. However, a significant exception is Japan, which dropped outside the top 20 locations (it ranks 21). The top 3 locations are the same, while the rankings of some other countries change. Apart from Japan exiting the top 20, the most interesting differences are that Canada is ahead of Germany at the fourth rank, and Brazil ranks 6th ahead of France.

Figure 1.6 shows how corporate subsidiaries of *Scoreboard* companies are distributed across five of the world's countries and regions. As in the previous edition of the *Scoreboard*, companies headquartered in the EU own the relative majority of subsidiaries – 30.6% located in 191 different countries. US companies follow closely, owning 29.2% of subsidiaries in 175 countries. Chinese and Japanese companies own a similar share of subsidiaries – 12.9% and 11% respectively; China's subsidiaries are located in 147 countries, and similarly Japan has subsidiaries located in 151 countries.

Companies headquartered in the EU have most of their subsidiaries located in the EU (39.1%), followed by the US (25.0%). Companies headquartered in the US have just over half of their subsidiaries located in the US (52.3%) and about a sixth located in the EU (15.7%). Four out of every five subsidiaries owned by Chinese companies are located in China (81.6%). Opposite to this, Japanese companies confirm also in this year's *Scoreboard* that they are the most internationalised ones, as only 21.8% of their subsidiaries are located in Japan.

Figure 1.6: Distribution of the number of subsidiaries by country/region

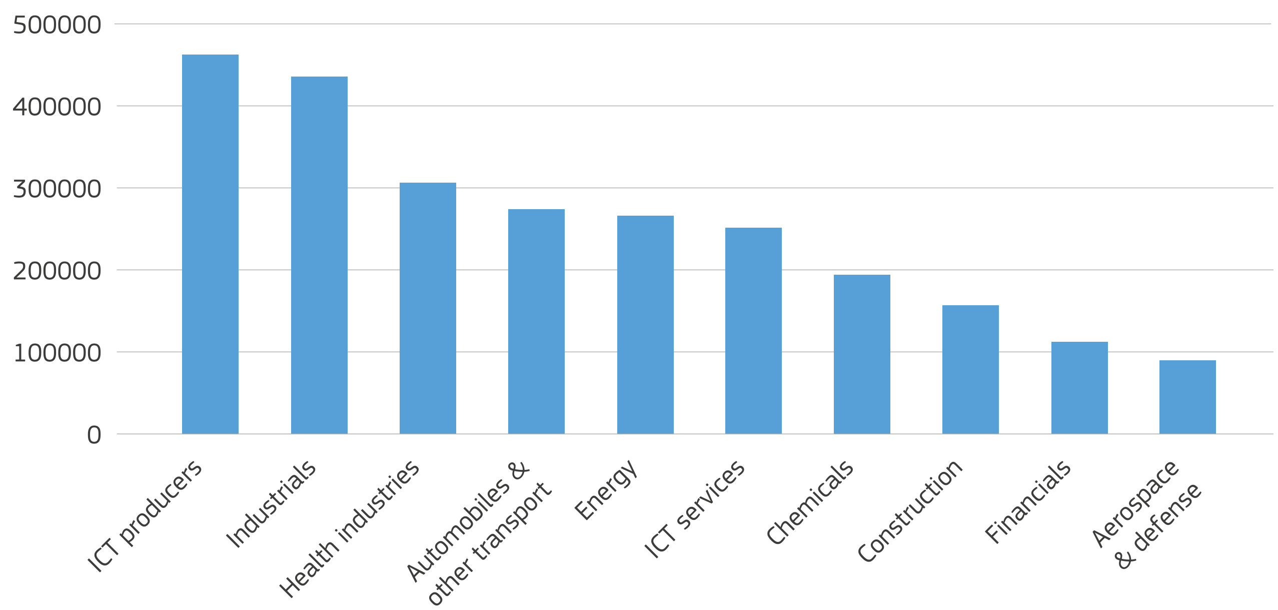


Note: Data refers to 2310 companies (accounting for 97.2% of R&D invested in 2021 by the 2022 *Scoreboard* companies) for which data on subsidiaries are available.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The overall number of corporate subsidiaries is a bit lower than last year. However, their location across different economies is similar to last year. This means that the industrial structure of the top R&D investors has remained stable through the COVID-19 crisis.

As reported in Figure 1.7, companies in the ICT producers and industrial sectors have the highest number of subsidiaries. Energy and automobile companies have a number of corporate subsidiaries not much lower than the health companies and slightly higher than the ICT services companies, which are both sectors where there are considerably more mother companies. This means the energy and automobile sectors typically have relatively larger company networks.

Figure 1.7: Number of subsidiaries of the top 2500 companies by sector of the mother company



Note: Data refers to 2310 companies. These account for 97.2% of R&D invested in 2021 by the 2022 *Scoreboard* companies for which data on subsidiaries are available.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Box 1.2: Comparing R&D figures from the *Scoreboard* with territorial statistics

R&D figures used in the *Scoreboard* are conceptually different from, but complementary to, those provided by statistical offices. Following the Frascati Manual[39], the *Scoreboard* refers to all R&D financed by companies from their own funds, regardless of where the R&D activities are performed. Conversely, statistical offices report R&D expenditures funded by the business enterprise sector and performed within a given territorial unit (BES-R&D), regardless of the location of the business' headquarters. Thus, the main differences are due to the fact that R&D takes place across borders; the *Scoreboard* reports R&D figures from companies headquartered there, including R&D performed abroad through their subsidiaries (outward R&D). On the other hand, territorial statistics report the 'intramural' R&D by local companies, and R&D by foreign-controlled companies (inward R&D) in the country. While, at the global level, the *Scoreboard* and BES-R&D figures are comparable, the former is lower because it excluded R&D whose source of funding is public and it does not include all private companies.

To illustrate the coverage of the *Scoreboard* R&D figures, we compare the latest available territorial statistics (2020) with the R&D data from the 2021 *Scoreboard* (company data for 2020). This comparison shows that the amount of R&D investment by the top 2500 companies (EUR 908.9 bn) is equivalent to 58.2% of the total expenditure on R&D worldwide (GERD, EUR 1479.8 bn) and to 86.3% of the R&D expenditure financed by the business sector worldwide (BES-R&D, EUR 1093.7 bn).

Note: Latest figures reported by Eurostat including most countries reporting R&D, extracted on 24/10/2021. GERD, from all funding sources and performed in all sectors. BES-R&D performed in all sectors and funded by the business enterprise sector.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

1.3 Key points

- The top 2500 global companies invested a total of EUR 1093.9 billion in R&D in 2021, which is 14.8% more than in the previous year.
- After the relative slowdown of the 2021 *Scoreboard* – R&D investments at global level grew at 6.0% compared to 8.9% R&D growth in the 2020 *Scoreboard* – the pace of R&D growth increased again and even surpassed pre-pandemic levels.
- For the first time, China overtook the EU, both in the number of companies on the *Scoreboard* and also in terms of the total volume of R&D invested.
- This year's data also confirms the sector shift reported in last year's edition of the *Scoreboard:* high-tech sectors are progressively widening the gap to mid- and low-tech sectors.
- EU specialisation in the automobile industry is still strong.
- Despite having fewer companies in this sector than China and the USA, EU automotive companies invest 41.1% – by far the biggest share of the total R&D investment in the sector.

[39] See https://www.oecd.org/sti/inno/frascati-manual.htm

2 WHERE THE EU STANDS COMPARED TO OTHER WORLD REGIONS

This chapter analyses trends in R&D and economic indicators of the world's top 2500 investors in R&D, aggregated by main industrial sector and world region, focusing on the comparison of EU companies' performance against that of their global counterparts.

The first part describes companies' performance over the previous year, whereas the second part analyses EU performance relative to its main competitors, over the past 10 years with particular attention to 4 selected industries (ICT producers, ICT services, health and automobiles) with higher R&D intensity that account for the majority of global R&D investment.

The sample of 2500 is divided into 5 sets, based on the location of companies' headquarters: the EU (361), the US (822), China (678), Japan (233) and the rest of the world (RoW) (406). The RoW group comprises companies from the UK (95), Taiwan (80), South Korea (53), Switzerland (54), Canada (28), India (24), Israel (22) and a further 18 countries. The EU group includes companies from 16 EU countries[40].

In 2021, the 361 companies based in the EU invested EUR 192.8 billion in R&D, which is an increase of 8.9% compared to 2020, in contrast with the reduction seen in the year before (-2.2%). The global R&D share of EU companies (17.6%) decreased compared to the previous year (20.3%). The number of EU companies in the global ranking (361) fell by 40 compared to the 2020 *Scoreboard*.

2.1 Main changes in companies' *Scoreboard* indicators in 2020-2021

The main indicators, ratios and 1-year changes for the 2500 companies by country/region are presented in table 2.1

[40] Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Slovenia, Spain and Sweden.

Table 2.1: Main R&D and economic indicators by country/region in the 2022 *Scoreboard*.

	EU	US	China	Japan	RoW	Total
Number of firms	361	822	678	233	406	2500
R&D in 2021, EUR bn	192.8	439.7	195.9	113.8	151.8	1 093.9
One-year change, %	8.9	16.5	24.9	6.6	12.4	14.8
Net Sales, EUR bn	4 865.7	5 540.2	5 414.8	2 886.3	4 382.8	23 089.8
One-year change, %	18.0	20.8	24.0	13.0	20.3	19.8
R&D intensity, %	3.9	7.8	3.6	3.9	3.4	4.7
Operating profits, EUR bn	538.4	921.9	442.4	215.8	748.6	2 867.2
One-year change , %	125.7	72.7	33.6	11.1	102.3	71.9
Profitability, %	11.2	16.8	8.2	7.6	17.2	12.5
Capex, EUR bn	270.9	301.3	380.5	185.3	305.5	1 443.4
One-year change , %	5.2	15.1	11.7	3.9	15.2	10.8
Capex / net sales, %	6.0	5.4	7.0	6.5	7.5	6.4
Employees, million	14.8	10.7	15.1	7.4	5.6	53.5
One-year change, %	0.7	5.1	5.9	0.44	1.5	3.1
R&D per employee, EUR	12 917.5	40 759.2	12 888.4	14 161.6	15 834.7	18 947.0
Market Cap[41], EUR bn	5 950.5	22 766.4	5 654.8	2 979.4	8 240.3	45 591.4
One-year change, %	33.0	30.5	13.2	22.6	22.9	26.5

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.1.1 EU companies

The 361 EU companies are headquartered in 16 of the 27 EU countries (17 countries in 2020). Of these, 3 countries (Germany, France and the Netherlands) account for the majority of companies and of R&D investment. Companies headquartered in Germany, France and the Netherlands are responsible for 47.2%, 14.9% and 12.5% of R&D investment by the EU companies, respectively. The figure for the Netherlands overstates R&D investment in the country as the list of Dutch companies includes some whose main operations are in other countries[42]. The top 20 EU companies by R&D range from Volkswagen at #7 in the global rankings to Novo Nordisk at #90.

There are 12 EU companies in the global top 50 group (see further details in Chapter 3):

- 8 German companies (Volkswagen (ranking 7th in the world), Mercedes-Benz (14th), BMW (21st), Robert Bosch (26th), Bayer (33rd), Siemens (37th), SAP (38th) and Boehringer Sohn (45th);
- 1 French company (Sanofi (32nd);
- 1 Finnish company (Nokia (44th));
- 1 Swedish company (Ericsson (47th)); and
- 1 Dutch-headquartered company (Stellantis[43] (29th)).

41 Market prices at close on 31.08.2022 for all listed companies

42 Several top R&D investors, e.g. Airbus, Stellantis, STMicroelectronics and CureVac, are headquartered in the Netherlands but have most of their operations in other countries.

43 Stellantis is a multinational automotive company formed in 2021 based on a merger between the Italian-American conglomerate Fiat Chrysler Automobiles and the French PSA Group. Its operations are distributed across many countries in particular France, Italy, the US and Brazil.

Of these companies, 5 belong to the automotive sector, 3 to the health sector, 3 to the ICT producers sector and one to the ICT services sector. Table 2.2 shows the main performance indicators for the top 20 companies in the EU group.

Table 2.2: Top 20 companies by R&D investment in the EU.

Company	Country	Sector	RD 2021 (€ million)	RD 2021 1 year growth (%)	Net sales 2021 (€ million)	Net sales 2021 1 year growth (%)	Employment 2021 N of employees	Employment 2021 1 year growth (%)
Volkswagen	DE	Automobiles & other transport	15 583.0	12.2	250 200.0	12.3	643 297	-2.9
Mercedes-Benz	DE	Automobiles & other transport	8 973.0	6.3	167 971.0	8.9	172 425	-40.2
BMW	DE	Automobiles & other transport	6 870.0	9.4	111 239.0	1.,4	118 909	-1.5
Robert Bosch	DE	Automobiles & other transport	6 328.0	4.7	78 748.0	10.1	402 614	1.9
Stellantis	NL	Automobiles & other transport	5 889.0	52.3	149 419.0	72.4	292 434	52.5
Sanofi	FR	Health industries	5 689.0	2.9	37 761.0	4.8	95 442	-4.0
Bayer	DE	Health industries	5 515.0	1.0	44 081.0	3.6	99 637	0.1
SAP	DE	ICT services	5 168.0	16.2	27 842.0	1.8	107 415	4.9
Siemens	DE	ICT producers	5 136.0	2.3	62 265.0	9.0	303 000	3.4
Nokia	FI	ICT producers	4 141.0	7.8	22 202.0	1.6	87 927	-4.5
Boehringer Sohn	DE	Health industries	4 127.0	11.7	20 618.0	5.4	n.a.	n.a.
Ericsson	SE	ICT producers	4 046.2	6.0	22 694.5	0.0	101 322	0.5
Airbus	NL	Aerospace & Defence	2 898.0	-2.1	52 149.0	4.5	126 495	-3.7
Continental	DE	Automobiles & other transport	2 636.6	-25.8	38 197.9	1.3	190 875	-19.3
ZF	DE	Automobiles other transport	2 466.0	21.8	38 313.0	17.5	157 549	2.6
Asml Holding	NL	ICT producers	2 431.1	17.5	18 611.0	33.1	32 016	4.0
Medtronic Public Limited	IE	Health industries	2 474.5	10.1	27 976.3	5.2	95 000	5.6

Company	Country	Sector	RD 2021		Net sales 2021		Employment 2021	
			(€ million)	1 year growth rate (%)	(€ million)	1 year growth rate (%)	N of employees	1 year growth rate (%)
Merck DE	DE	Health industries	2 400.0	6.1	19 687.0	12.3	60 334	3.9
Renault	FR	Automobiles & other transport	2 361.0	-14.1	46 213.0	6.3	156 466	-8.0
Basf	DE	Chemicals	2 248.0	4.6	78 598.0	28.9	111 047	0.7

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

In 2021, the 361 EU-based companies invested EUR 192.8 billion in R&D, which is an increase of 8.9% compared to 2020, in contrast with the reduction seen in the year before (-2.2%). The global R&D share of EU companies (17.6%) decreased compared to the previous year (20.3%). The number of EU companies in the global ranking (361) fell by 40 compared to the 2020 *Scoreboard*.

Considering sectoral variations, the financial and health sectors showed the largest R&D investment increase (14.7% and 11.5% respectively). The automotive is the EU's largest R&D sector, accounting for 33% of total R&D investment. It sustained the overall R&D growth of the EU group, increasing R&D investment by 8.9%, bouncing back from the drop of 7.2% reported in 2020. The chemicals and aerospace & defence sectors recovered from last year drop but showing only modest R&D growth figures (4.8% and 0.6%, respectively).

In terms of countries, R&D growth was sustained by companies based in Germany, which is the country that invests the most in R&D, accounting for 47.2% of the EU's total R&D investment. The set of German companies increased R&D investment by 8.1%, driven by companies from the automotive sector, e.g. Volkswagen (12.2%), BMW (9.4%) and Mercedes-Benz (6.3%) and from the health and ICT sectors, e.g. Boehringer Sohn (11.7%), BioNTech (86.6%), SAP (16.2%) and Infineon Technologies (30.2%).

Other countries whose companies reported significant R&D increases are

- the Netherlands (21.4%), e.g. by companies such as Stellantis (52.3%), CureVac (725.8%), CNH Industrials (27.9%), NXP Semiconductors (14.8%), and
- Denmark (15.7%), mainly by Novo Nordisk (18.8%) and Vestas (34.1%).

France is the second-largest R&D investor, accounting for 14.9% of the EU's R&D investment. Its companies showed a modest R&D investment increase (2.6%). The high R&D growth from companies such as Alstom (66.2%) were offset by poor results of other companies, e.g. Renault (-14.1%).

Table 2.3 lists the 10 companies that contributed most to the R&D growth of the EU sample (top) and those that significantly held back the EU's R&D growth (bottom). The top 10 EU companies that contributed most to R&D growth are from the sectors that invest the most in R&D: 5 from the automotive sector, which bounced back from the poor results of the previous year due to the pandemic; 3 from the health sector and 2 from ICT sectors. However, R&D growth varied significantly within these sectors, which also comprise companies that showed the poorest performance in terms of R&D investment growth (i.e. Renault, Continental, Amadeus and Telefonica).

Large changes in companies' R&D investment are not necessarily due to organic growth, but may be explained by mergers, acquisitions, divestment or accounting practices (see Section 2.1.4). For example, the remarkable 52.3% increase of Stellantis' R&D investment is entirely due to the merger of FiatChrysler with the French PSA Group.

Table 2.3: Companies most affecting the R&D growth of the EU sample in 2021

Company	Country	Sector	1-year R&D growth (%)
Companies that contributed most to the R&D growth of the EU sample			
Stellantis	Netherlands	Automobiles & other transport	52.3
Volkswagen	Germany	Automobiles & other transport	12.2
SAP	Germany	ICT services	16.2
CureVac	Netherlands	Health industries	725.8
BMW	Germany	Automobiles & other transport	9.4
Mercedes-Benz	Germany	Automobiles & other transport	6.3
ZF	Germany	Automobiles & other transport	21.8
Boehringer Sohn	Germany	Health industries	11.7
Infineon Technologies	Germany	ICT producers	30.2
BioNTech	Germany	Health industries	86.6
Companies that affected the R&D growth of the EU sample most negatively			
Company	**Country**	**Sector**	**1-year R&D growth (%)**
Continental	Germany	Automobiles & other transport	-25.8
Renault	France	Automobiles & other transport	-14.1
Philips	Netherlands	Industrials	-7.5
Telefonica	Spain	ICT services	-12.9
Amadeus	Spain	ICT services	-10.6
Ing Groep	Netherlands	Financial	-36.6
Mallinckrodt	Ireland	Health industries	-29.4
Dsm	Netherlands	Chemicals	-15.7
TotalEnergies	France	Energy	-7.9
AIRBUS	Netherlands	Aerospace & defence	-2.1

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Trends in sales, capex, profits and employees for the 361 EU companies

The main financial indicators of the EU sample of companies were hit hard by the pandemic in 2020 but showed a solid recovery in 2021.

The 361 EU companies' net sales increased substantially by 20.8%, reaching EUR 4.9 trillion. The sectors showing the largest increases in net sales were energy (41.2%), chemicals (29.2%) and automotive (16.3%). The sectors that reported the lowest growth of net sales were ICT services (3.3%), aerospace & defence (4.9%) and financial (9.3%).

The overall operating profits of the EU sample showed an outstanding recovery, jumping 126%, with many sectors showing a double-digit or triple-digit increase of profits. The ICT services sector only showed a modest increase in profits (3.4%)

The 361 EU companies' capital expenditures (CAPEX) increased by 5.2% (an increase of EUR 13.2 billion, somewhat lower than the R&D investment increase of EUR 15.7 billion). The sectors showing the largest increase in CAPEX were financials (23.5%), construction (20.1%) and ICT producers (14.9%). The only sector that reduced its CAPEX was automotive (-11.0%), in contrast to the CAPEX increase of the sector worldwide

(8%) and the good performance of the sector within the EU in terms of R&D (8.9%).

The 361 companies based in the EU employed 14.8 million people, a slight increase of 0.7% compared to the previous year. Employment decreased in construction, aerospace & defence and automotive sectors and increased in health, ICT producers and chemicals.

The market capitalisation of the listed companies based in the EU increased considerably by 33% (between 31 August 2021 and 30 August 2022) as stock markets recovered in 2021.

2.1.2 The global picture

R&D trends

The top R&D investors showed a fast recovery from the COVID-19 crisis in 2021. Industrial R&D investment continued to grow significantly for the 12th consecutive year. The 2500 *Scoreboard* companies invested EUR 1093.9 billion in R&D, a 14.8% increase compared to 2020, which is much higher increase than the year before (6.0%).

R&D investment increased across the board with most sectors showing a double-digit R&D growth. Global R&D growth was driven by the ICT services sector (19.5%), followed by the health and ICT producers sectors (16.8% and 11.9% respectively). Most other sectors showed double-digit R&D growth, except energy and aerospace & defence sectors (7.4% and 2.0%, respectively). The automotive sector that was hit hard by the crisis in 2020 showed a substantial recovery (12.3%). The chemicals sector broke the negative trend observed in the past few years by increasing its R&D significantly (13.1%).

EU companies' share in global R&D investment decreased to 17.6% (20.3% in last year's *Scoreboard*), US companies increased their share to 40.2% (37.8% in 2020) and Chinese companies continued to increase their share sharply, reaching 17.9% (from 15.6% in the last *Scoreboard*). In contrast, Japanese companies' share of R&D continued to shrink (10.4%, from 12.2% in the last *Scoreboard*).

Trends in company financial indicators

Across the 2500 companies, most financial indicators that had been negatively affected by the pandemic showed a significant recovery in 2021, particularly operating profits, net sales and CAPEX.

Companies' operating profit increased substantially across most world regions and sectors. Several sectors (aerospace & defence, automotive, energy and financial) showed a triple-digit profit increase. Most other sectors had a double-digit increase in profits, except for the ICT services sector, which showed a modest increase of 2.0%.

The overall net sales of the 2500 companies increased by almost 20%, reaching EUR 23.1 trillion, in contrast with the 4.6% drop in the year before. Most sectors showed a double-digit growth of net sales, except the aerospace & defence sector (4.0%). The largest increases in net sales were reported by sectors such as energy (40.1%), chemicals (29.9%), industrials (21.8%) and ICT producers (19.1%).

CAPEX increased by 10.8% worldwide recovering from the significant drop in the previous year (-4.6%). The increase in CAPEX (EUR 139.8 billion) is of the same order of magnitude as the increase in R&D investment (EUR 140.8 billion). Companies in the ICT producers (26.7%), financials (20.4%), health (12.4%) and chemicals (12.0%) sectors showed the largest increases in CAPEX. Aerospace & defence had a slight CAPEX increase (0.6%) and construction reduced it by 1.3%.

The overall number of employees of the 2500 companies increased modestly by 3.1% to 53.5 million (compared to 0.9% increase from 2019 to 2020). Three industries reported a drop in the number of employees: energy (-2.8%), construction (-2.4%) and aerospace & defence (-0.6%). The main sectors that increased employment were ICT producers (5.8%), health (5.7%) and ICT services (5.3%)

2.1.3 Non-EU companies

Companies based in the US

The top 2500 R&D investors worldwide include 822 US companies. Among the top 10 companies in the US sample, the top five are from the ICT sectors: Alphabet (ranking first in the world), Meta (2nd), Microsoft (3rd), Apple (5th); and Intel (8th). The next 4 companies are from the health sector: Johnson & Johnson (ranking 10th in the world), Pfizer (11th), Bristol-Myers Squibb (12th) and Merck US (13th). The 10th company is from the automotive sector, General Motors (ranking 20th in the world). Table 2.4 shows the main indicators of the top 20 companies in the US group which range from #1 (Alphabet) to #42 (Broadcom) in the global ranking.

Table 2.4: Top 20 companies by R&D investment in the US

Company	Sector	RD 2021		Net sales 2021		Employment 2021	
		(€ million)	1 year growth (%)	(€ million)	1 year growth (%)	N of employees	1 year growth (%)
Alphabet	ICT services	27 866.8	14.5	227 473.9	41.2	156 500	15.7
Meta	ICT services	21 768.5	33.7	104 122.3	37.2	71 970	22.8
Microsoft	ICT services	21 642.2	18.3	175 057.3	18.0	221 000	22.1
Apple	ICT producers	19 348.4	16.9	322 988.6	33.3	154 000	4.8
Intel	ICT producers	13 411.6	12.1	69 772.2	1.5	121 100	9.5
Johnson & Johnson	Health industries	12 991.3	21.0	82 796.2	13.6	141 700	5.4
Pfizer	Health industries	10 239.3	20.6	71 771.1	95.2	79 000	0.6
Bristol-Myers Squibb	Health industries	9 283.1	1.9	40 954.4	9.1	32 200	6.4
Merck Us	Health industries	9 133.8	1.2	43 001.9	17.3	68 000	-8.1
General Motors	Automobiles & other transport	6 975.1	27.4	112 134.9	3.7	157 000	1.3
Ford Motor	Automobiles & other transport	6 710.2	7.0	120 378.7	7.2	183 000	-1.6
Oracle	ICT services	6 373.8	10.6	37 471.3	4.8	143 000	8.3
Qualcomm	ICT producers	6 335.9	20.1	29 636.2	54.5	45 000	9.8
Eli Lilly	Health industries	6 203.3	15.4	25 003.0	15.4	35 000	0.0
Abbvie	Health industries	6 164.6	13.0	49 617.7	22.7	50 000	6.4
Cisco Systems	ICT producers	5 782.3	3.2	43 985.5	1.0	79 500	2.6
IBM	ICT services	5 248.1	3.1	50 635.7	3.9	307 600	-18.0
Gilead Sciences	Health industries	4 735.1	6.4	24 108.2	10.6	14 400	5.9
Nvidia	ICT producers	4 651.2	34.3	23 763.0	61.4	22 473	18.4
Broadcom	ICT producers	4 285.7	-2.3	24 236.3	14.9	20 000	-4.8

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The US companies' R&D investment continued to be concentrated in three high R&D-intensive sectors accounting for 83.4% of total R&D investment (comprising 624 companies, 76% of the total number of companies in the US sample). These sectors are ICT services (33.1%), health industries (28.2%) and ICT producers (22.2%).

The 822 companies based in the US invested EUR 439.7 billion in R&D, reflecting a significant increase of 16.5% over the previous period. The US companies' share in global R&D investment reached 40.2%, somewhat higher than in the previous year.

The R&D growth of the 822 US companies was driven by double-digit increases in the sectors that invest the most in R&D, namely ICT services (21.2%), health (18.5%), ICT producers (10.0%) and automotive (27.1%). The US companies reduced R&D investment only in the energy sector (-7.4%).

Companies based in the US increased net sales substantially (20.8%), with most sectors reporting double-digit growth except for the industrials and aerospace & defence sectors (8.5% and 6.5% respectively). Operating profits of the US companies were hit hard by the crisis in 2020 but recovered significantly in 2021. Profits increased by double or triple digits and in most sectors, except the energy sector, which reported significant losses.

The US companies' capital expenditures also increased significantly by 15.1%, (an increase of EUR 39.6 billion, much lower than the R&D investment increase of EUR 62.4 billion). Many sectors showed a double-digit CAPEX increase and two sectors reported a CAPEX decrease: energy (-15.5%) and aerospace & defence (-2.4%). The number of employees of US companies (10.7 million) increased by 5.1%. The market capitalisation of listed companies based in the US increased substantially (30.5%) in the reference period (from 31 August 2021 to 30 August 2022).

Companies based in China

The top 2500 investors in R&D worldwide comprise 678 Chinese companies, 81 companies more than in the 2021 *Scoreboard*. Of the top 10 Chinese companies, 5 are from ICT industries: Huawei (ranking 4th in the world), Alibaba (17th), Tencent (18th), Baidu (53rd) and ZTE (70th). Another 4 companies operate in the construction sector: China State Construction Engineering (34th in the world), China Railway (54th), China Communications Construction (56th) and China Railway Construction (62nd). Moreover, one company is from the automotive sector (Saic Motor (61st in the world). Huawei is by far the biggest R&D investor in China, accounting for 10% of total R&D investment in the Chinese sample. Table 2.5 shows the main indicators of the top 20 companies in the Chinese group. The top 20 by R&D range from Huawei at #4 in the global ranking to Lenovo at #116.

Table 2.5: Top 20 companies by R&D investment in China

Company	Sector	RD 2021		Net sales 2021		Employment 2021	
		(€ million)	1 year growth (%)	(€ million)	1 year growth (%)	N of employees	1 year growth (%)
Huawei Investment & Holding	ICT producers	19 533.8	0.7	121 786.3	-1.4	195 000.0	-1.0
Alibaba Group Holding	ICT services	7 687.3	-3.1	118 232.6	18.9	254 941.0	1.4
Tencent	ICT services	7 190.5	33.1	77 631.2	16.2	112 771.0	31.3
China State Construction Engineering	Contruction	5 509.5	35.2	259 594.3	17.3	368 327.0	3.3
Baidu	ICT services	3 456.4	27.8	17 254.5	16.3	45 500.0	11.0
China Railway	Contruction	3 431.1	13.4	148 753.2	10.1	294 013.0	1.8

Company	Sector	RD 2021		Net sales 2021		Employment 2021	
		(€ million)	1 year growth (%)	(€ million)	1 year growth (%)	N of employees	1 year growth (%)
China Communications Construction	Contruction	3 112.2	13.7	94 606.8	9.3	136 772.0	2.6
Saic Motor	Automobiles & other transport	2 854.5	37.6	102 623.0	5.1	207 246.0	1.2
China Railway Construction	Contruction	2 807.2	8.9	139 565.5	12.0	267 760.0	-6.5
Zte	ICT producers	2 498.4	20.7	15 317.9	8.9	72 584.0	-1.5
Meituan	Others	2 250.7	53.4	24 826.8	56.0	100 033.0	44.5
Power Construction Corporation Of China	Contruction	2 231.0	5.4	61 611.8	11.9	133 207.0	0.8
Metallurgical Corporation Of China	Industrials	2 188.9	29.0	68 834.4	25.1	97 972.0	-3.0
Petrochina	Energy	2 113.8	6.8	362 343.3	35.2	417 173.0	-3.4
Kuaishou Technology	Others	2 055.8	128.6	11 237.7	37.9	28 098.0	30.7
Netease	ICT services	1 950.9	33.5	12 142.0	18.9	32 064.0	13.5
CRRC China	Automobiles & other transport	1 706.6	-3.6	30 410.6	-1.2	160 656.0	-2.1
Midea Group	Others	1 665.2	18.7	42 506.3	18.0	165 799.0	11.1
Xiaomi	ICT producers	1 635.6	40.0	45 503.0	33.5	33 427.0	51.4
Lenovo	ICT producers	1 632.1	42.7	63 233.4	17.9	75 000.0	4.9

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The Chinese companies' R&D investment mainly takes place in the ICT producers sector (26.4% of total R&D investment), followed by the ICT services sector (18%) and the construction sector (12.6%).

The 678 companies based in China invested EUR 195.9 billion in R&D in 2021, a substantial increase of 24.9% over the previous year. The Chinese companies showed double-digit R&D growth in all sectors. The sectors that contributed most to the R&D growth of China are ICT producers (18.0%), ICT services (22.8%), industrials (32.2%), construction (21.7%), health (35.8%) and automotive (26.5%). The Chinese companies' share in global R&D investment continued to increase in 2021, reaching 17.9%.

Also in terms of net sales, the 678 Chinese companies continued to show outstanding growth (24.9%). All sectors grew by double digits driven by strong sales in sectors such as chemicals, industrials and energy. The Chinese companies' CAPEX continued to grow in 2021 but at slower pace than the other indicators (11.5%). This represents a CAPEX increase of EUR 39.7 billion (similar to the increase of R&D of EUR 39.0 billion), driven by the sectors that invest the most in R&D (automotive, health and ICT). In contrast, the highly capital-intensive construction sector decreased its CAPEX by 7.3%. The operating profits of the Chinese companies showed a mixed performance, increasing much less than those of their US and EU competitors (33.6%), showing triple-digit growth in health and chemicals but reporting losses in the automotive sector. In 2021 the number of employees in the Chinese companies increased by 5.9%, almost twice the global average (3.1%). The market capitalisation of the listed Chinese companies rose by 13.2% between 31 August 2021 and 30 August 2022.

Companies based in Japan

The top 2500 investors in R&D worldwide include 233 Japanese companies. Among the top 10 Japanese companies, 4 are from the automotive sector: Toyota (ranking 15th in the world), Honda (24th), Denso (50th) and Nissan (51st). Another two are leisure goods companies, Sony (ranking 39th in the world) and Panasonic (52nd), one is a health company (Takeda Pharmaceutical (46th)) and 3 are ICT companies: NTT (31st), Hitachi (66th) and Canon (86th). All of these 10 companies lost places in the global R&D ranking except Takeda, which rose 3 positions. Table 2.6 shows the main indicators of the top 20 companies in the Japanese group. The top 20 Japanese companies by R&D range from Toyota at #15 in the global rankings to Tokyo Electron at #165.

Table 2.6: Top 20 companies by R&D investment in Japan

Company	Sector	RD 2021		Net sales 2021		Employment 2021	
		(€ million)	1 year growth (%)	(€ million)	1 year growth (%)	N of employees	1 year growth (%)
Toyota Motor	Automobiles & other transport	8 691.3	3.1	242 585.8	15.3	372 817	1.8
Honda Motor	Automobiles & other transport	6 372.7	4.1	112 502.6	10.5	204 035	-3.5
Ntt	ICT services	5 732.1	4.7	93 977.9	1.8	333 840	2.8
Sony	Others	4 901.6	20.7	76 700.3	10.2	108 900	-0.7
Takeda Pharmaceutical	Health industries	4 064.8	15.4	27 590.9	11.6	47 347	0.5
Denso	Automobiles & other transport	3 846.5	1.1	42 638.8	11.7	154 493	-8.3
Nissan Motor	Automobiles & other transport	3 742.2	-3.9	65 128.0	7.1	n.a.	n.a.
Panasonic	Others	3 513.3	-1.5	57 120.6	10.3	240 198	-1.4
Hitachi	ICT producers	2 658.1	12.7	79 352.6	17.6	368 247	5.0
Canon	ICT producers	2 221.3	5.5	27 160.7	11.2	184 034	1.2
Daiichi Sankyo	Health industries	2 011.7	14.5	8 077.8	8.6	16 458	2.7
Astellas Pharma	Health industries	1 901.8	9.6	10 020.3	3.7	14 522	-0.6
Otsuka	Health industries	1 795.8	7.1	11 582.7	5.3	33 226	0.2

Company	Sector	RD 2021		Net sales 2021		Employment 2021	
		(€ million)	1 year growth (%)	(€ million)	1 year growth (%)	N of employees	1 year growth (%)
Softbank	ICT services	1 551.4	12.7	48 096.9	10.5	59 721	1.6
Mitsubishi Electric	ICT services	1 508.6	2.4	34 608.5	6.8	145 696	0.0
Aisin	Automobiles & other transport	1 501.0	2.3	30 284.5	11.1	117 177	-1.0
Sumitomo Chemical	Chemicals	1 329.1	-1.6	21 377.9	20.9	34 703	-0.1
Tdk	ICT producers	1 277.5	30.1	14 704.8	28.6	116 808	-9.7
Suzuki Motor	Automobiles & other transport	1 242.7	9.9	27 586.1	12.3	69 193	0.7
Tokyo Electron	ICT producers	1 223.4	15.8	15 490.8	43.2	15 634	8.0

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The Japanese companies' R&D investment mostly takes place in the automotive sector (30.4%) and the ICT producers sector (18.3%) sectors. The sector specialisation pattern is similar to that in the EU sample, which is also led by the automotive sector.

The 233 companies based in Japan invested EUR 113.8 billion in R&D, 6.6% more than in the previous year. The Japanese companies' share in global R&D investment continued to decline (10.4% in 2021 compared to 22% in 2009), as it has done for 12 years. The sectors that contributed most to the R&D growth of the Japanese group are health (13.2%), leisure goods (9.6%), and chemicals (8.8%). In contrast, the Japanese sector that invests the most in R&D, automotive, increased R&D only by a modest 2.4%.

The other financial indicators of the Japanese companies showed a mixed performance. Net sales increased significantly (13.0%), with companies showing sales increases in all sectors. In comparison to other world regions, operating profits showed a moderate increase (11%) due mainly to construction, energy and ICT services sectors (the decline in the ICT services sector was mostly to considerable losses reported by Softbank).

CAPEX increased by a modest 3.9% (an increase of EUR 7 billion, similar to the R&D investment increase of EUR 7.1 billion). This CAPEX increase was mostly due to companies from the health, automotive and ICT producers sectors, while the construction and energy sectors showed a decrease. The number of people employed by the Japanese companies remained almost unchanged (7.4 million) and the market capitalisation of the listed companies increased by 22.6% (between 31 August 2021 and 30 August 2022).

Companies based in the rest of the world (RoW)

This group comprises 406 companies from 25 countries. Most R&D investment is concentrated in 4 countries, which account for 83.2% of the total R&D investment of the group: Switzerland (22.7%), South Korea (22.6%), the UK (21.4%), and Taiwan (15.9%). See Table 2.7.

Table 2.7: Performance of companies based in the largest countries of the RoW group

	No. of companies	R&D (EUR million)	World R&D share (%)	R&D 1-year growth (%)	Net sales (EUR million)	Sales 1-year growth (%)	R&D intensity (%)
Switzerland	55	34 866.9	3.2	11.4	427 773.5	9.5	8.1
South Korea	53	34 274.4	3.1	6.4	970 315.3	18.5	3.5
UK	95	32 819.1	3.0	12.8	1 031 974.1	9.8	3.1
Taiwan	84	24 782.3	2.3	16.8	690 962.3	13.3	3.6

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

In 2021, the 406 companies in the RoW sample invested EUR 151.8 billion in R&D, 12.4% more than the year before. As in other world regions, companies in health, ICT and automotive sectors drove R&D growth. The companies that contributed most to R&D growth were AstraZeneca (34.0%), Roche (12.8%), Samsung (6.5%), Tata Motors (46.5%), SK Hynix (25.0%), Novartis (7.8%), TSMC (13.9%), and Mediatek (24.3%).

Most other financial indicators of the 406 companies of the RoW showed a solid recovery from the pandemic, in particular operating profits (102.3%), net sales (20.3%) and CAPEX (15.2%). The number of employees increased slightly by 1.5%, reaching 5.6 million. The market capitalisation of the RoW listed companies increased by 22.9% between 31 August 2021 and 30 August 2022.

Largest contributions to R&D growth in the non-EU sample of companies

Table 2.8 lists the companies that contributed most to R&D growth in the non-EU sample of companies (top) and those that significantly held back R&D growth (bottom).

The 10 best-performing companies operate in the sectors that invest the most in R&D: 5 in ICT services, 4 in health industries and one in the automotive sector. The 10 worst-performing companies are also from ICT (5) and health (2) and one each from aerospace & defence, chemicals and travel & leisure sectors ("others").

Table 2.8: Companies most affecting R&D growth in the non-EU sample in 2021

Companies that contributed most to R&D growth in the non-EU sample			
Company	**Country**	**Sector**	**1-year R&D growth (%)**
Meta	US	ICT services	33.7
Alphabet	US	ICT services	14.5
Microsoft	US	ICT services	18.3
Apple	US	ICT producers	16.9
Johnson & Johnson	US	Health industries	21.0
Astrazeneca	UK	Health industries	34.0

Companies that contributed most to R&D growth in the non-EU sample			
Company	**Country**	**Sector**	**1-year R&D growth (%)**
Tencent	China	ICT services	33.1
Pfizer	US	Health industries	20.6
Roche	Switzerland	Health industries	12.8
General Motors	US	Automobiles & other transport	27.4
Companies that most negatively affected R&D growth in the non-EU sample			
Company	**Country**	**Sector**	**1-year R&D growth (%)**
Dell Technologies	US	ICT producers	-51.1
Biogen	US	Health industries	-37.3
Airbnb	US	Others	-48.2
Incyte	US	Health industries	-33.4
Harris	US	ICT producers	-31.7
Mcafee	US	ICT services	-61.3
Alibaba Group Holding	China	ICT services	-3.1
Dupont	US	Chemicals	-25.7
Boeing	US	Aerospace & Defence	-9.6
Corning	US	ICT producers	-20.0

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.1.4 Large R&D changes in big companies

Large changes in sales and/or R&D from the prior year are sometimes the result of organic growth but can be the result of large acquisitions. This section lists the larger acquisitions made in 2020 and 2021 by *Scoreboard* companies. The list has been compiled both from lists of recent large acquisitions in high R&D intensity sectors and by looking at large companies whose sales have increased by 30% or more over the previous year. Some of the acquisitions listed were agreed in 2021 but will not now be completed until 2022, therefore they will affect the data in the 2023 *Scoreboard.* These are still included for completeness. Acquisitions where the cost was less than approximately USD 1 billion have been excluded to limit the size of Table 2.9. The increase in an acquirer's R&D due to the acquisition can be estimated by looking at the target's R&D in its last independent year's accounts.

Table 2.9: Major company mergers, acquisitions & divestments

Company name	R&D EUR m	Acquisition's Name	Date of close	Cost (USD bn)	Comment
AstraZeneca	7 110	Alexion	7/21	39	
Bristol-Myers Squibb	9 283	MyoKardia	11/20	13.1	
Johnson & Johnson	12 991	Momenta Pharma	10/20	6.5	
Gilead Sciences	4 735	Forty Seven	4/20	4.9	
		Immunomedics	10/20	21	
Sanofi	5 689	Principia Biopharma	9/20	3.9	
		Translate Bio	9/21	3.2	
		Kadmon	11/21	1.9	
		Kymab	6/21	1.1 to 1.45	
Merck	9 134	Velos Bio	11/20	2.75	
		Acceleron Pharma	11/21	11.5	
		Pandion	3/21	1.85	
Eli Lilly	6 203	Protomer	7/21	1	
Pfizer	10 239	Arena Pharma	3/22	6.7	
		Trillium Therapeutics	11/21	2.2	
Amgen	4 255	Five Prime Therapeutics	4/21	1.9	
Novo Nordisk	2 192	Dicerna Pharma	11/21	3.3	
Bayer	5 515	Asklepios Biopharma	12/20	4	
CSL	1 020	Vifor	8/22	16.4	Affects 2 023 SB
Teladoc	312	Livongo	10/20	18.5	
Thermo Fisher Scientific	1 241	PPD	12/21	17.4	
Nestle	1 840	AImmune	10/20	2.1b	
Jazz Pharma	446	GW Pharma	5/21	7.6	
Horizon Pharma	321	Viela Bio	3/21	3	
Perrigo	107	HRA	5/22	2.1	
Servier	802	Agios Oncology	4/21	2	

Company name	R&D EUR m	Acquisition's Name	Date of close	Cost (USD bn)	Comment
Meta	21 769	Kustomer	2/22	1	Affects 2 023 SB
Stellantis	5 889	Fiat/PSA merger	1/21	52	
Oracle	6 374	Cerner	6/22	28.3	Affects 2 023 SB
Salesforce	3 942	Slack	7/21	27.7	
		Vlocity	2/20	1.3	
SK Hynix	3 087	Intel's NAND business	12/21	9	
UBER	1 813	Postmates	12/20	2.65	
		Drizly	10/21	1.1	
AMD	2 512	Xilinx	2/22	49	Affects 2 023 SB
Analog Devices	1 144	Maxim	4/21	20	
Adobe	2 243	Workfront	12/20	1.5	
Nvidia	4 651	Mellanox	4/20	6.9	
Intuit	1 545	Credit Karma	12/20	8.1	
Atlassian	1 234	Halp	5/20	n/a	Total deals of over USD 1 bn
HPE	1 747	Silver Peak	9/20	0.93	
Cisco	5 782	Thousand Eyes	5/20	1	
		Fluidmesh Networks	7/20	n/a	
Twilio	751	Segment	11/20	3.2	
Microsoft	21 642	Affirmed Networks	3/20	1.35	
		Activision Blizzard	1/22	68.7	Not yet completed
		Bethesda	3/21	7.5	
		Nuance	3/22	19.7	
Marvell technology	1 258	Inphi	4/21	10	
Teledyne Technologies	264	FLIR	5/21	8.2	
Sinochem Holdings Corporation		Now owns both Sinochem & ChemChina	5/21	-	Result of merger

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.2 Positioning of the EU in relation to main competitors

This section compares the R&D investment performance of the EU set of companies in the *Scoreboard* over the past 10 years with that of the US, Chinese and Japanese companies for the top 4 sectors in terms of R&D investment. These sectors accounting for 77.8% of total R&D investment in the *Scoreboard* are ICT producers (22.6%), health industries (21.5%), ICT services (19.8%) and automotive (13.9%).

Figure 2.1, 2.2 and 2.3 compare the sector specialisation of the EU companies with that of the US, Chinese and Japanese companies respectively. The figures present R&D investment for the 4 main sectors in 2012 and 2021. Each dot represents a sector. If the dot is placed below (above) the diagonal, this means that EU firms are investing more (less) than their counterparts in that sector. The distance from the diagonal represents how much more (less) the firms are investing compared to their counterparts in each sector.

2.2.1 The EU vs the US

In 2012, the EU and the US companies showed a distinctive R&D specialisation: in the automotive sector, the EU companies invested in R&D more than twice as much as their US counterparts. In contrast, in the health industries and ICT producers sectors the EU companies invested only 40% of the amount invested by their US counterparts, whereas in the ICT services sector they invested only 20%.

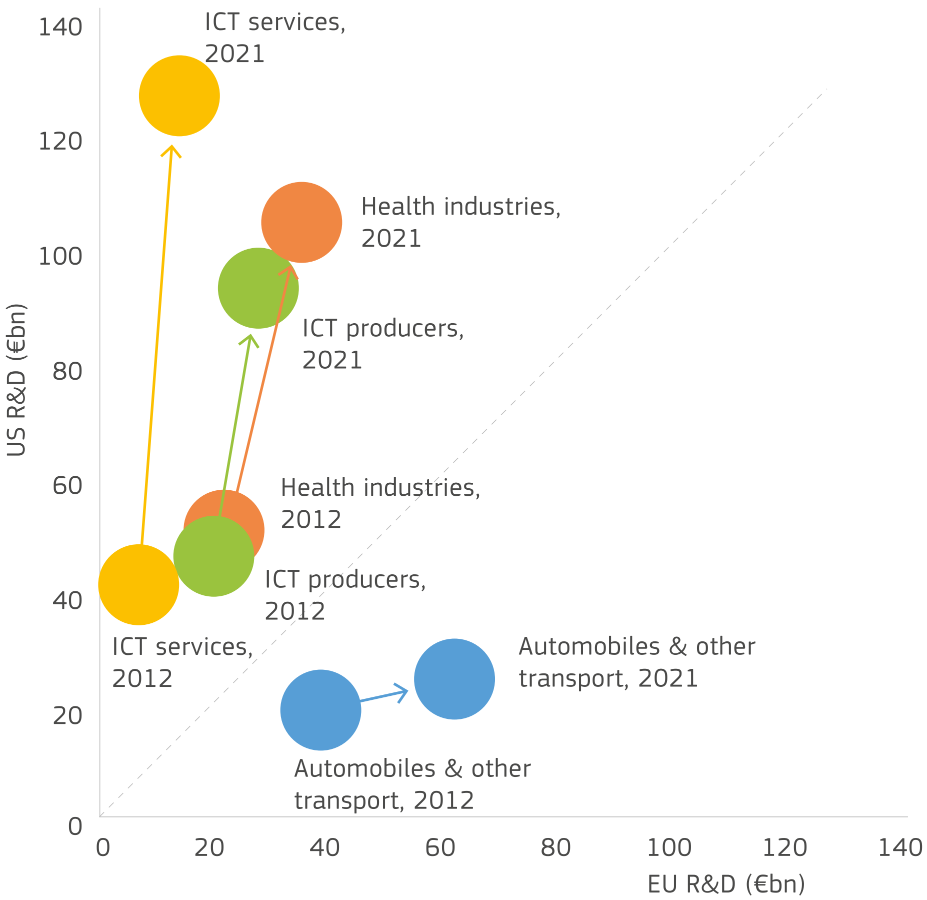
In 2021, this specialisation pattern continued: the EU companies invested 2.6 times more than their US counterparts in the automotive sector but only 30% of the US companies' R&D investment in the health industries and ICT producers sectors, and 10% in the ICT services sectors.

R&D intensity (R&D/net sales) has grown in the past decade for both the EU and the US samples; however, the increase was higher for the US, widening the R&D intensity gap between the EU and the US. The EU-US R&D intensity gap increased in all high R&D-intensive sectors, especially in ICT services.

The average R&D investment per company for the four sectors has grown substantially in the two regions over the past 10 years. In the EU, it was EUR 466 million in 2012, and grew to EUR 933.5 million in 2021. In the US, it grew from EUR 290 million to EUR 974.4 million.

The trend in the number of companies also reflects the different dynamics of the EU and US samples over the past 10 years and the resulting difference in terms of R&D specialisation. The dynamics of companies entering and leaving the *Scoreboard* by sector and world region is analysed in Chapter 3. As mentioned in previous *Scoreboard* editions, most of the new companies in the global R&D ranking operate in fast growing sectors such as ICT services and health industries, where the US dominates.

Figure 2.1: EU-US comparison of R&D investment in 2012 and 2021, by sector



Note: Data refers to 502 (EU:149, US:353) of the 834 companies (EU:174, US:660) in the 4 sector groups in the 2 regions considered for which R&D data are available for the entire 2012-2021 period, accounting for 89.6% of the R&D investment in 2021.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

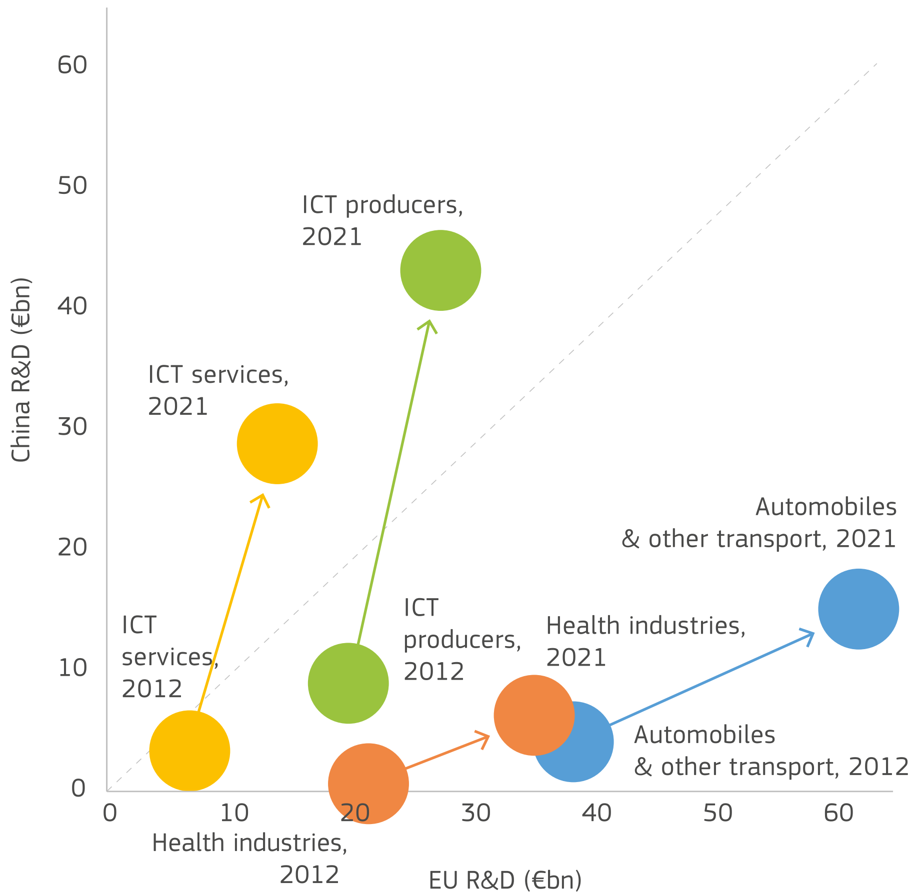
2.2.2 The EU vs China

In 2012, the EU invested more than China in all 4 major sectors under consideration. In the past 10 years, however, the Chinese companies operating in the ICT sectors have increased their R&D investment considerably. The result is that in 2021, the Chinese companies invested in R&D twice as much as their EU counterparts in the ICT services sector and 1.6 times more in the ICT producers sector. By contrast, the EU retained its lead in the automotive and health sectors (4.2 and 5.6 times more R&D investment respectively).

R&D intensity (R&D/net sales) was much higher for the EU companies in 2012 (6.0% vs 3.8%). It has grown in the past decade for the two samples, but at much higher pace for the Chinese companies, which are closing the gap with the EU (7.0% vs 6.3%). In the ICT services sector, the Chinese companies have overtaken the EU (5.1% vs 6.9%).

The average R&D investment per company in the *Scoreboard* grew significantly for both the EU sample and the Chinese sample, however, in 2021 it was still much higher in the EU (EUR 933.5 million vs EUR 399.6 million). This difference can be explained by the fact that more Chinese companies entered into these sectors than EU companies and the new companies inevitably start off in the lower reaches of the *Scoreboard*. See *Scoreboard* companies' dynamics in Chapter 3

Figure 2.2: EU-China comparison of R&D investment in 2012 and 2021 by sector



Note: Data refers to 382 (EU:149, CN:233) of the 557 companies (EU:174, CN:383) in the 4 sector groups in the 2 regions considered for which R&D data are available for the entire 2012-2021 period, accounting for 88.0% of the R&D investment in 2021.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.2.3 The EU vs Japan

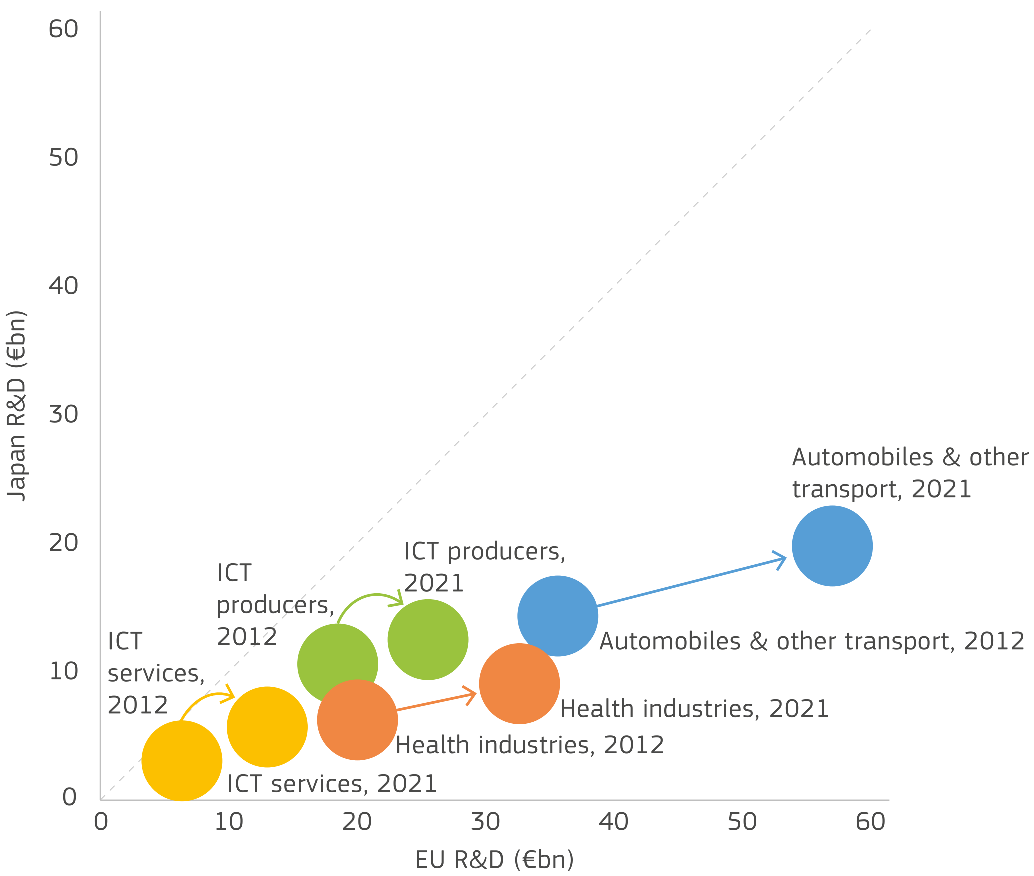
In 2012, the EU companies in the *Scoreboard* invested 1.5 times more than their Japanese counterparts in all 4 major sectors under consideration. In 2021, this difference increased to 1.8 because the number of Japanese companies declined significantly over the past 10 years (see Chapter 3).

In the automotive sector, which is the most important sector for both regions in terms of R&D investment, the ratio of R&D investment between the EU and Japan has increased from 1.6 to 1.9 in the past 10 years.

In the past decade, R&D intensity has grown in the EU, while it remained practically the same for the Japanese companies. This has resulted in the EU having a much higher R&D intensity than Japan in 2021 (7.0% vs 5.3%).

The average R&D investment per company has grown more rapidly in the EU than in Japan. In 2021, it was EUR 933.5 million for the EU companies and EUR 718.1 million for their Japanese counterparts.

Figure 2.3: EU-Japan comparison of R&D investment in 2012 and 2021 by sector



Note: Data refers to 258 (EU:149, JP:109) of the 284 companies (EU:174, JP:110) in the 4 sector groups in the 2 regions considered for which R&D data are available for the entire 2012-2021 period, accounting for 97.5% of R&D investment in 2021.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.3 Financing companies' innovation activities: Corporate Venture Capital

Corporate Venture Capital (CVC) investment is an innovation investment tool available to large companies to pursue their strategic interests. Its relevance has been steadily increasing during the past 20 years, thus making CVC activities in relation to start-ups and scale-ups an important policy focus. This section uses a matched dataset linking the top R&D investors from the 2020 *Scoreboard* and their subsidiaries with the companies listed as investors in Dealroom.co (DR). The analysis, which was included in the 2021 edition of the *Scoreboard*, comprised 1557 *Scoreboard* companies[44] investing in start-ups and scale-ups in the period 1999-2020[45]. It showed that almost two thirds of the 2500 *Scoreboard* companies invested in CVC, via dedicated subsidiaries and (less often) directly through the headquarters. Furthermore, an overall upward trend during the whole period was observed, with some slowdowns coinciding with periods of crisis. Total CVC investment grew constantly from USD 3.6 billion[46] in 2013 to USD 14.5 billion in 2019, followed by a small decline in 2020 coinciding with the outbreak of the COVID-19 pandemic. This subsection dives deeper into the geographical and sectoral patterns contained in the data.

CVC investments of EU-headquartered *Scoreboard* companies are 2.4% of own-funded internal R&D, compared to 4% of their US-headquartered peers (see Table 2.9 below); this suggests that, despite its growing importance, CVC still accounts for a relatively small amount of resources compared to R&D investments. The increasing relevance of CVC we observed for *Scoreboard* companies goes hand in hand with the steadily growing importance of venture capital overall. This is testified by the numerous policy schemes deployed over the last two decades to support innovative high-growth start-ups, especially in the early stages of their life[47], which have made access to seed funding considerably easier for innovative growth-oriented start-ups, and have systematically reduced the historical gap in seed funding compared to the US. However, there is still a sizeable gap between the EU and the US in growth funding, particularly for financing large later stage VC rounds, partly due to the smaller size of EU-based VC investors with respect to their non-EU counterparts[48].

Figure 2.4[49] depicts the shares of early round CVC investment flowing from the world regions hosting the *Scoreboard* companies and their subsidiaries (left side) and the world regions hosting the DR start-ups (right side). The height of each node is proportional, respectively, to the share of total investment made by companies located in the corresponding region or received by start-ups located therein. The plot shows that US-based corporations were responsible for the majority of CVC investment and that US-based start-ups attracted most of it. EU *Scoreboard* companies invested 80% of their VC funds in US-based start-ups. Overall, they invested just around half of their US counterparts in CVC between 2013 and 2020.

[44] The matching exercise from the 2021 edition of the *Scoreboard* identified 1557 distinct *Scoreboard* companies that invested in start-ups and scale-ups in the period 1999-2020. Overall, 62% of the 2500 *Scoreboard* companies invested in start-ups and scale-ups at least once in the period 2000-2020. Furthermore, 344 distinct *Scoreboard* Companies (22% of the matched distinct *Scoreboard* companies) took part in at least one start-up deal in the year 2019. The majority of these are in the top tier of the *Scoreboard* ranking, with 55% placing in the top 20% in terms of global R&D. Some *Scoreboard* companies operate via subsidiaries or the mother company has several financial vehicles for investment purposes. Thus, the number of legal entities carrying the investment (3 745) is higher than the *Scoreboard* companies we can match (1 557).

[45] At the time when the *Scoreboard* -Dealroom matching was established, Dealroom reported data about deals and investors from as early as 1999. However, Dealroom was first established only in 2013, suggesting that data referring to previous years might not be fully consistent with the rest. For this reason, we restrict our attention to the period 2013-2020 throughout the section. The interested reader is referred to the previous edition of the report for further details on the composition of the data sample.

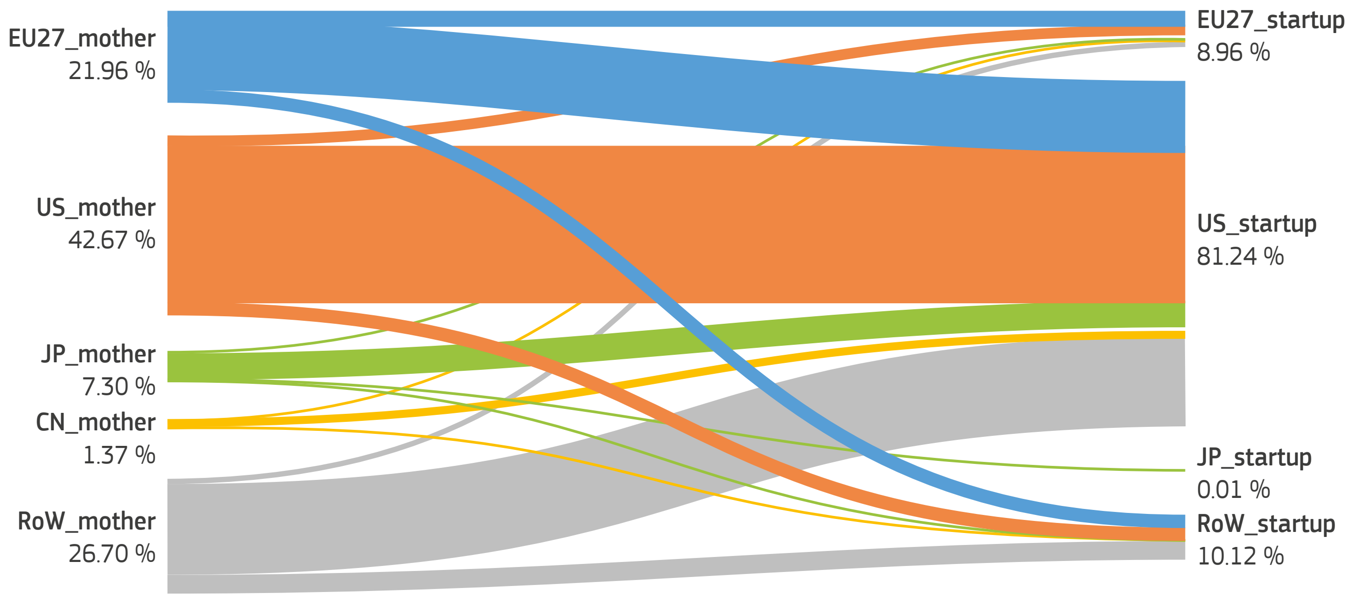
[46] Dealroom reports investment in several currencies. Values are converted to 2014 PPP US Dollars for greater comparability.

[47] Audretsch, D., Colombelli, A., Grilli, L., Minola, T., & Rasmussen, E. (2020). Innovative start-ups and policy initiatives. Research Policy, 49(10), 104027.

[48] Colombo, M., Compaño, R., Napolitano, L., Rentocchini, F. and Tuebke A. "Policy challenges in supporting entrepreneurial ventures" Industrial R&I – JRC Policy Insights, forthcoming.

[49] This and the following figures are from JRC analysis based on Dealroom data that was presented at the expert webinar "Tackling the Scale-Up Gap" on October 5th 2021. This webinar was introduced by Commissioner Gabriel and was organised by the JRC together with DG-R&I and EISMEA to better quantify the scale-up financing gap, establish what is known about the causes of the gap and its negative economic consequences and to identify how best to address the gap, see: https://publications.jrc.ec.europa.eu/repository/handle/JRC127232.

Figure 2.4: Corporate Venture Capital investment by headquarter region of *Scoreboard* parent company



JRC own compilation using the EU Industrial R&D Investment Scoreboard and Dealroom data.

Despite its increasing relevance, CVC remains small compared to other open innovation strategies available to large corporations (e.g. M&A and R&D alliances)[50] and to internal R&D investment in terms of the amount of resources it mobilises. Nevertheless, it exhibits some interesting patterns.

Table 2.10 reports a regional breakdown of the expenditure in R&D and in CVC by the DR-matched *Scoreboard* companies between 2013 and 2018[51]. Even though in every region the CVC budget is only a small fraction of total R&D spending, it is relatively much more important in the USA than in any other region. The right column of Table 2.10 reports the elasticity of CVC expenditure to R&D spending (how much R&D increases in percentage terms in response to a 1% increase in CVC spending) and shows an overall complementarity between the two variables driven mostly by Japanese and US-based *Scoreboard* companies.

Table 2.11 reports regression coefficients from a sectoral breakdown of the CVC-R&D relation for *Scoreboard* companies and shows an overall positive correlation and complementarity between CVC and R&D in *Scoreboard* companies operating in the health and ICT sectors. The financials and automotive sectors display significantly negative elasticities, suggesting that CVC can be also used to tap into new business sectors[52]. This reveals the strategic interests of top R&D investors, which are looking to complement internal innovation capabilities, enlarge their product portfolio[53], explore new lines of business and/or counteract weaknesses in internal innovation capabilitie[54] via CVC.

50 For evidence on the scale of M&A acquisitions by *Scoreboard* companies please refer to section 2.1.4.

51 The analysis is carried out on a restricted time window (2013-2018) due to the inclusion of several relevant balance sheet variables from *Scoreboard* companies (employment, capital expenditure, R&D), which leads to the loss of many observations if extended beyond the window on when the matching (with VC data) was performed.

52 R. Compaño, L. Napolitano, F. Rentocchini, C. Domnick, P. Santoleri, A. Tübke, & P. McCutcheon, Corporate Venturing for R&I: Practitioner's views and policy questions, European Commission, Seville, 2022, JRC130034.

53 MacMillan, I. C., Roberts, E. B., Livada, V., & Wang, A. Y. (2008). *Corporate venture capital (CVC) seeking innovation and strategic growth: Recent patterns in CVC mission, structure, and investment.* National Institute of Standards and Technology, US Department of Commerce.

54 Ma, S. (2020). The life cycle of corporate venture capital. *The Review of Financial Studies,* 33(1), 358-394.

Table 2.10: *Scoreboard* R&D and CVC investment by region (2013-2018)

Sector	CVC/R&D Ratio [%]	R&D-CVC elasticity
EU 27	2.4	0.36
USA	4.0	0.54 *
China	2.6	0.56
Japan	1.2	0.61 *
RoW	1.0	0.001
Total	**2.6**	**0.39 ***

Note: Coefficients in the third column are the coefficients of the R&D variables in the log-log regressions where VC investments is regressed on R&D expenditure at the company level; estimates control for capital expenditure, number of employees and sector and year fixed effects; * asterisks signal a statistically significant effect at the 10% confidence level.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table 2.11: *Scoreboard* R&D and CVC investment by sector (2013-2018)

Sector	CVC/R&D Ratio [%]	R&D-CVC elasticity
Aerospace & defence	0.003	
Automobiles & other transport	0.2	-1.10 *
Chemicals	0.1	
Energy	*0.3*	
Financials	*17.7*	-1.40 *
Health industries	*2.2*	0.25 *
ICT producers	*3.3*	0.02
ICT services	*5.6*	0.57 *
Industrials	*0.5*	-0.12
Others	2.5	-0.10
Total	**2.6**	**0.39 ***

Note: Coefficients in the third column are the coefficients of the R&D variables in the log-log regressions where VC investments is regressed on R&D expenditure at the company level; estimates control for capital expenditure, number of employees and sector and year fixed effects; * asterisks signal a statistically significant effect at the 10% confidence level.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.4 Focus on selected sub-sectors: Automotive and semiconductors

This section analyses in further detail the R&D and economic trends of companies operating in two industries for which R&D is a critical competitive factor. The EU is facing major challenges in these industrial sectors, to cope with increasing global competitiveness pressure and the forthcoming industrial green and digital transformations.

2.4.1 Automotive sector

In 2021, the automotive sector was the industry that by far invested the most in R&D, accounting for one-third of the EU's total R&D investment. Globally, EU-based companies accounted for more than 40% of this sector's total R&D investment. However, the EU's lead in this sector is being challenged by two main factors: first, the shift in power source from fossil fuels to electricity, and second, the ongoing digital transformation of the automotive industry.

Shift to electric mobility

Worldwide, policy targets to phase out fossil fuels in transport are driving the fast growing sales of electric vehicles (EVs)[55]. From 2012 to 2021, the number of electric cars sold worldwide increased from 120 000 to 16.5 million, accounting for almost 10% of global car sales in 2021.

By world region, China's market is leading the EVs uptake with 3.3 million cars sold, followed by the EU (2.3 million), and the US far behind (0.76 million). By manufacturing company, the market is led by the US company Tesla (which has a factory in China), followed by the Chinese companies BYD and SAIC. There are 4 EU companies in the list of top companies by EV sales in 2021: The German companies Volkswagen, BMW and Mercedes, and the Swedish company Volvo, which is owned by the Chinese Geely Group (see Figure 2.5).

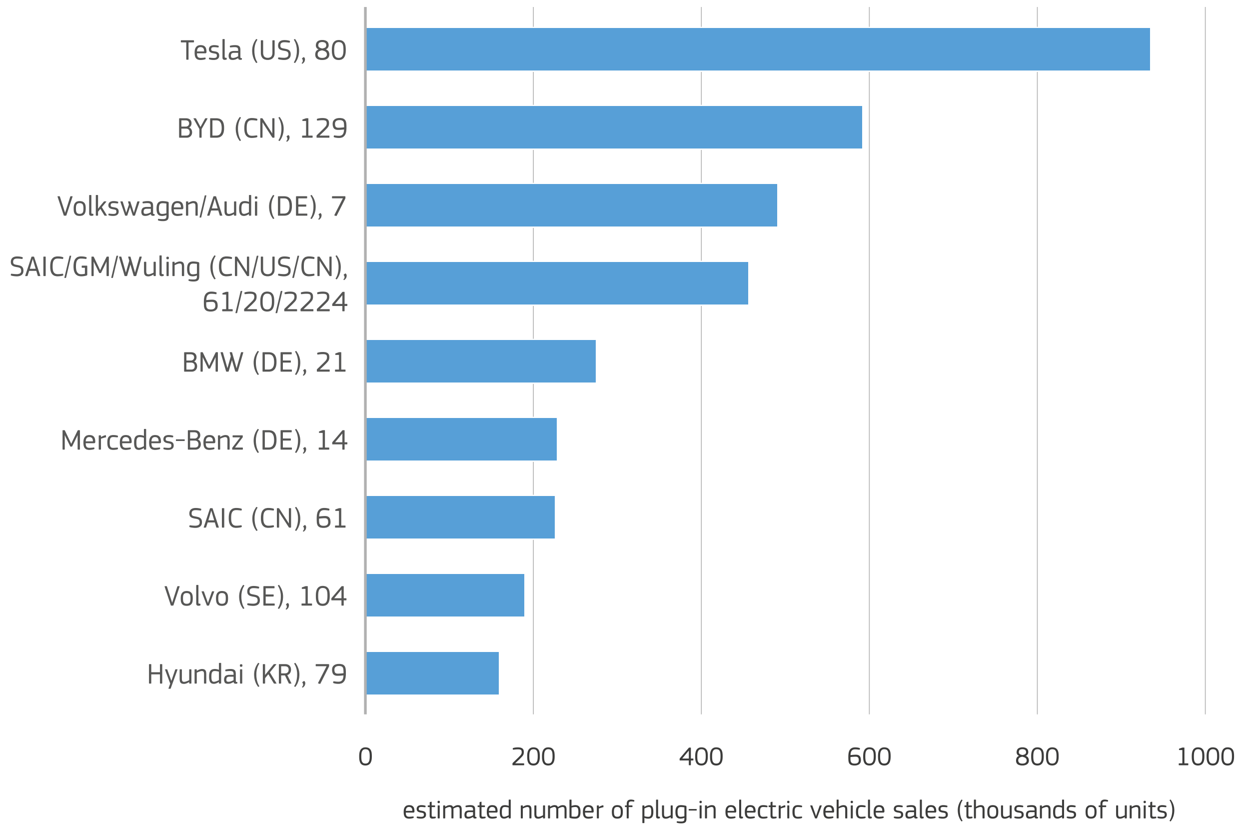
Plug-in battery electric vehicles (BEVs) now have two key components – the battery and chips/software – with other parts of the vehicle being fairly low technology which is widely available. This creates a difficult situation for the existing large car companies that have to continue to develop and improve their ranges of internal combustion engine cars while simultaneously developing a range of new battery electric vehicles. By contrast, the pure EV companies such as Tesla (and also smaller ones such as Rivian) have a laser focus solely on improving their BEVs and working on future ranges of partly and then fully autonomous vehicles.

These trends are raising new issues related to the supply of critical raw materials (e.g. cobalt, lithium and nickel for batteries), charging infrastructure and recycling. In particular, the supply chain of batteries is currently concentrated in China (producing three quarters of all lithium batteries and accounting for more than half of the processing and refining of the key battery raw materials), whereas Europe produces over one-quarter of the EVs but holds a very small share of the supply chain.

In this context, the EU launched in 2017 the European Battery Alliance aiming to develop an innovative, competitive and sustainable battery value chain in Europe.

[55] EV market figures taken from *"Global EV Outlook 2022, Securing supplies for an electric future"*, International Energy Agency, 2022.

Figure 2.5: Top companies by global sales of EVs in 2021



Note: The number after the country code indicates the position in the global *Scoreboard* ranking.
Source: Statista, https://www.statista.com/statistics/977407/global-sales-of-plugin-electric-vehicles-by-brand/, 2022.

Digital transformation

The incorporation of new ICT-based technology is making up a larger proportion of the value added in the whole automotive value chain. For many years, car companies have been using increasing numbers of semiconductor chips and more complex software to improve their vehicles and subsystems, to increase manufacturing productivity and efficiency, reach new markets and optimise supply chains. Nowadays, ICT is enabling new opportunities such as connected vehicles, autonomous driving and mobility services. Following this trend, big tech companies from the ICT industries such as Google, Amazon, Apple, Microsoft and Baidu are investing heavily in the personal mobility market.

R&D and economic trends of top R&D investors in the automotive sector

The main indicators of the automotive sector for the main world regions are summarised in Table 2.12.

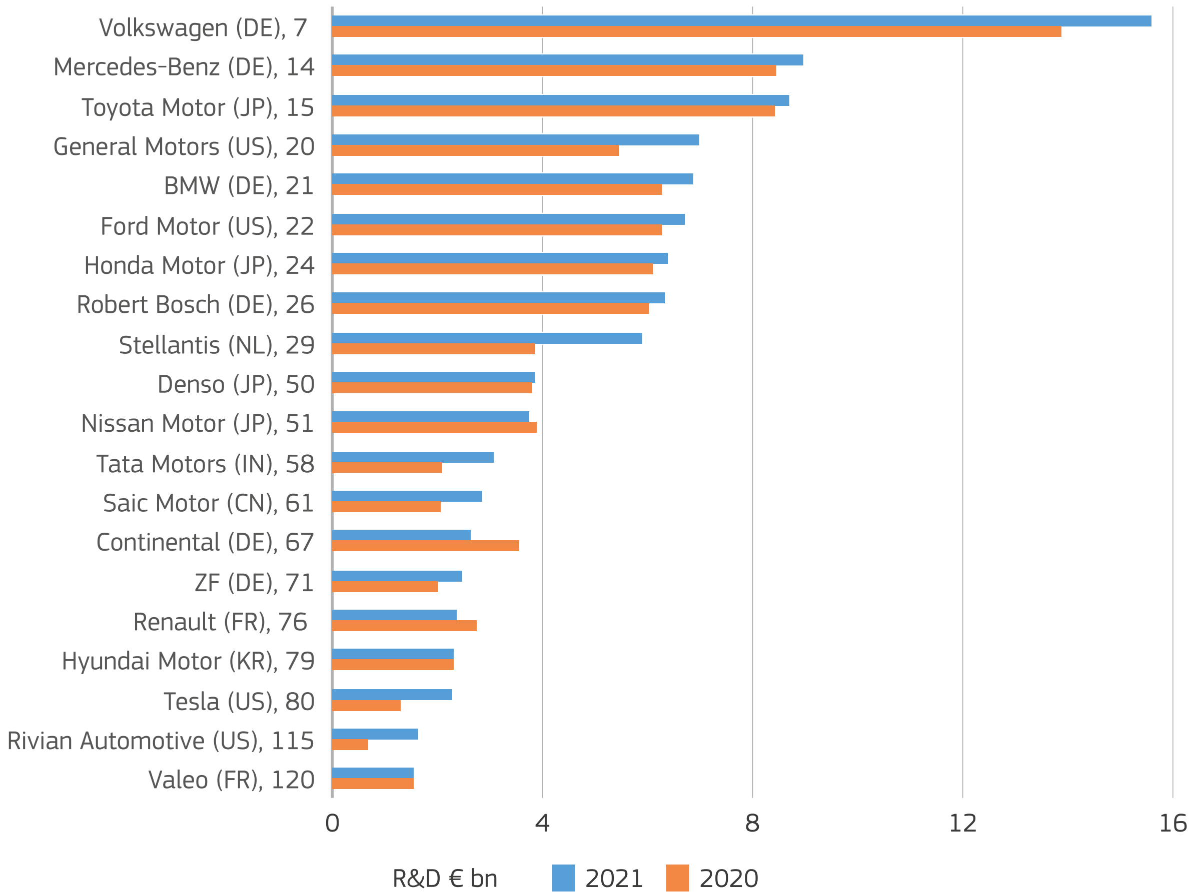
Table 2.12: Automotive R&D and financial indicators for main world regions

	EU	US	China	Japan	RoW	Total
Number of firms	34	37	54	28	27	180
R&D in 2021, EUR bn	62.6	27.6	18	33.2	11	152.4
Net Sales, EUR bn	1118.2	507.8	403.2	749.6	330.7	3109.6
R&D intensity, %	5.7	6.1	4.6	4.5	3.3	5
Capex, EUR bn	38.7	38.3	15	52.3	11.4	155.7
Capex / net sales, %	4.1	10.6	4.8	7.4	3.9	5.9
Profitability, %	9	6.1	1.8	7.3	5.6	7
Employees, million	2.9	0.8	1.1	1.7	0.5	7
Sales/employee, EUR k	352.3	445.2	291.1	413.1	205.7	357.8

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 2.6 shows the top 20 automotive companies ranked by amount of R&D investment. As in other sectors, R&D investment by company is highly concentrated: these 20 companies account for 73% of total R&D investment of the automotive sector. Unfortunately, companies do not give enough information about their R&D strategies to enable their R&D on electric vehicles and autonomous driving to be separated from conventional automotive R&D on internal combustion engine vehicles.

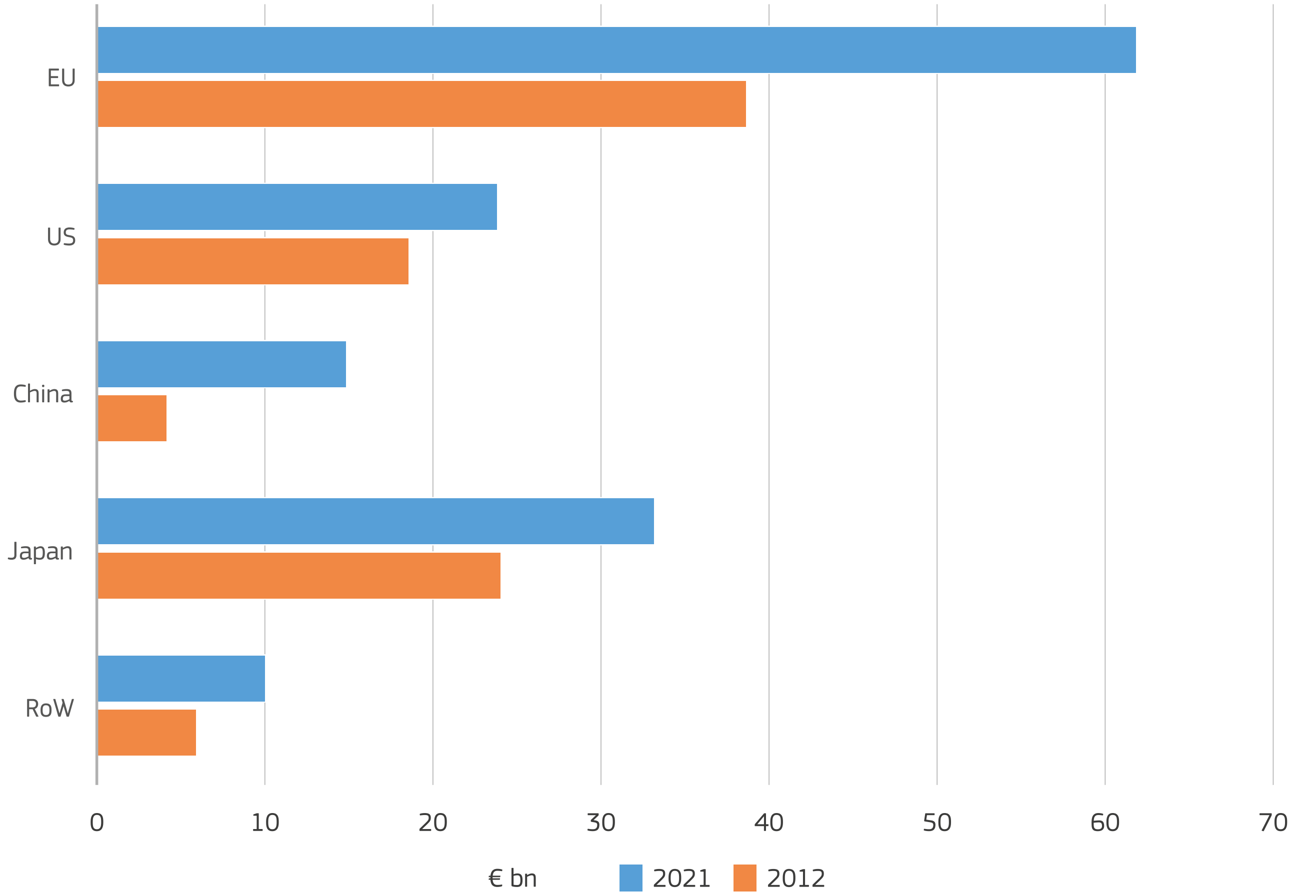
Figure 2.6: Top 20 automotive companies ranked by level of R&D investment in 2021



Note: The number after the country code indicates the position in the global *Scoreboard* ranking.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 2.7 compares the R&D investment of the automotive sector for the main regions over the past 10 years, including only those companies that have been present in the *Scoreboard* since 2012, i.e. 121 (out of 147) companies, accounting for 94% of total R&D investment of the sector in 2021.

Figure 2.7: R&D investment in the automotive sector for main world regions in 2012 and 2021



Note: Data refers to 121 companies (out of 147 in the sector) for which R&D data are available for the both years, accounting for 94.0% of R&D investment in 2021.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.4.2 Semiconductors[56]

Semiconductor chips[57] are indispensable components of electronic devices. They are enablers for the whole value chain of key industries, such as ICT, automotive, health, food, energy, and environment sectors. Moreover, chips are expected to play a central role for technological leadership[58] in space, science, artificial intelligence, electric mobility, aerospace and defence equipment.

In 1990 the chip manufacturing market was fully controlled by three regions[59]. Europe (44% market share), the US (37%) and Japan (19%). Over the past three decades, Europe and the US radically reduced their market share to 9% and 12% respectively and chip manufacturing shifted to Asia, namely to Taiwan, South Korea and China. In 2020 their market share was as follows: Taiwan 22%, South Korea 21% and China 15%.

[56] Some leading companies in the semiconductor industry operate in several sectors. For example, in the *Scoreboard*, Apple, Samsung and Qualcomm are classified in a different industrial sector.
[57] A chip is a set of electronic circuits on one small flat piece or "chip" of semiconductor material, usually silicon.
[58] The scramble for semiconductors is our era's industrial Great Game, *Financial Times*, 27/01/2022.
[59] TSMC: the Taiwanese chipmaker caught up in the tech cold war; *Financial Times*, 24/10/2022.

Over the past couple of years, the semiconductor industry attracted much policy attention worldwide due to an exceptional chip shortage, mostly because of the pandemic, that severely hurt a wide range of industries including automotive. To address this issue, a number of policy measures have been launched to improve the chip supply chain's resilience and to reduce dependence on foreign countries. In fact, no country nor any world region is able to control the entire chip-making supply chain, which involves complex design, equipment, processing technology, materials and chemicals.

At present, in the semiconductor industry, chip design is led by US companies, and manufacturing is led by companies based in Taiwan and South Korea. The EU hosts few players in two key segments of the semiconductor value chain, i.e. chip design and manufacturing.

R&D and economic trends of top R&D investors in the semiconductor industry

The main indicators of the semiconductor sector for the main world regions are summarised in Table 2.13. This table includes companies classified in the *Scoreboard* in the semiconductor sector and 3 companies classified in other sectors but showing strong activity in the semiconductor sector (Apple, Samsung and Qualcomm).

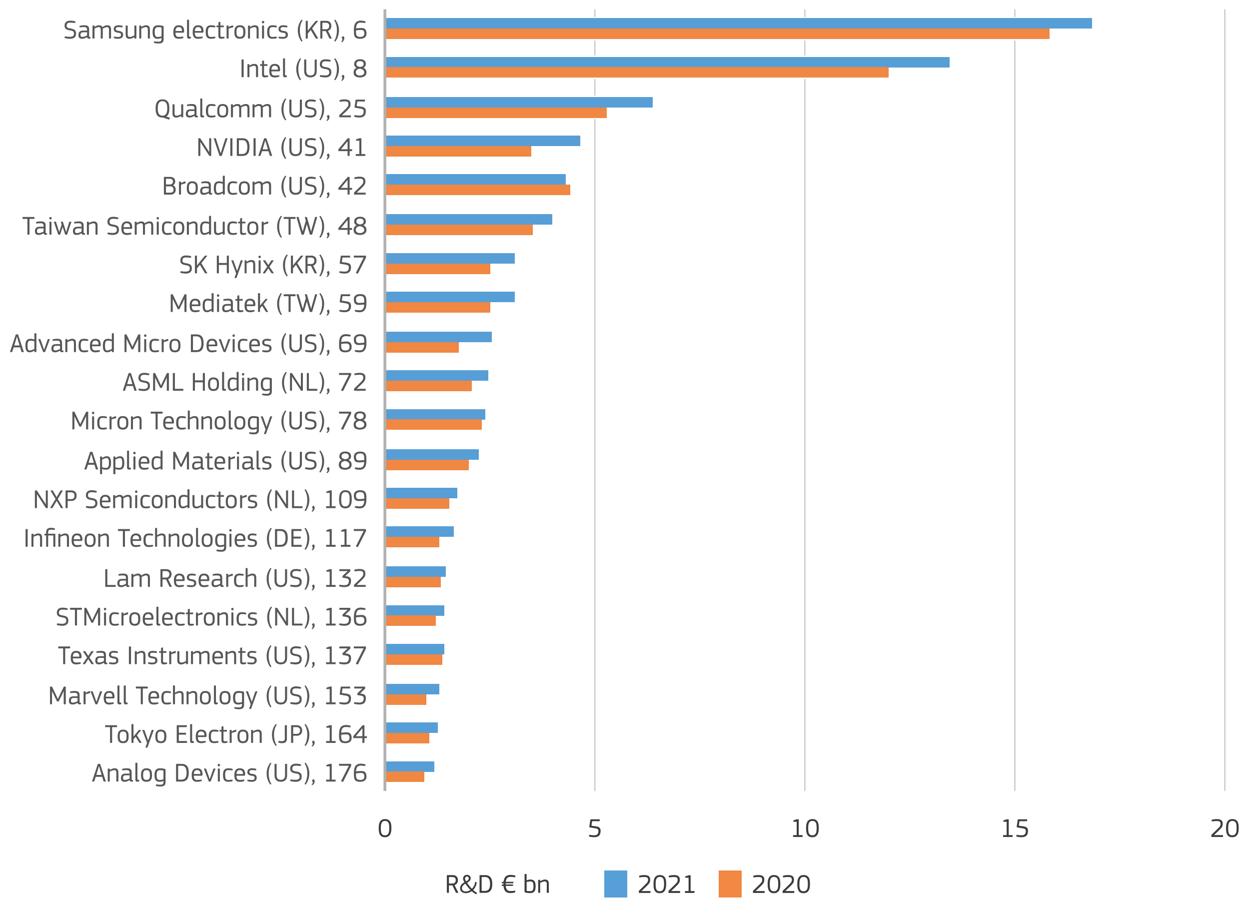
Table 2.13: Semiconductors' R&D and financial indicators for regions/countries

	EU	US	China	Japan	Taiwan	South Korea	Total
Number of firms	9	39	11	8	18	4	89
R&D in 2021, EUR bn	8.2	47.9	2.2	2.5	10.0	20.1	90.9
Net Sales, EUR bn	59.2	304.0	46.3	31.0	93.8	241.9	776.1
R&D intensity, %	13.9	15.8	4.7	8.1	10.7	8.3	11.7
Capex, EUR bn	4.9	37.5	7.8	1.8	30.6	47.3	129.9
Capex / net sales, %	8.4	12.3	16.8	5.8	32.6	19.5	16.7
Profitability, %	24.6	28.8	9.0	25.4	32.3	19.8	24.8

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 2.8 shows the top 20 semiconductor companies ranked by volume of R&D investment. As in other sectors, R&D investment is highly concentrated, these 20 companies account for 85% of total R&D of the semiconductor sector.

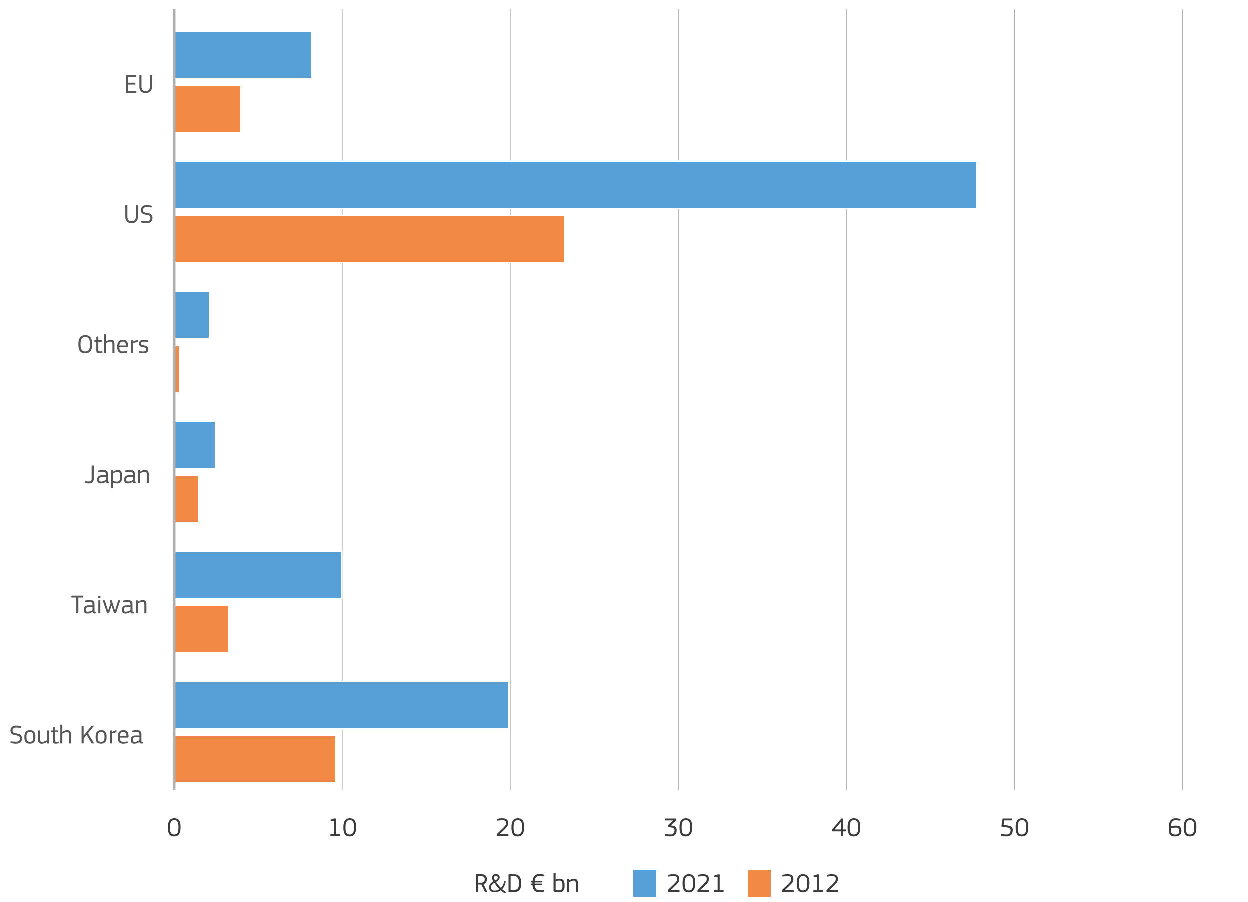
Figure 2.8: Top 20 Semiconductors companies ranked by volume of R&D investment in 2021



Note: The number after the country code indicates the position in the global *Scoreboard* ranking.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 2.9 compares the R&D investment of the semiconductor sector for the main regions over the past 10 years, including only those companies that have been present in the *Scoreboard* since 2012, i.e. 88 (out of 90) companies, accounting for 99.8% of total R&D investment in 2021.

Figure 2.9: R&D investment in the semiconductors sector in 2012 and 2021 for regions/countries



Note: Data refers to 87 companies (out of 89 in the sector) for which R&D data are available for the both years, accounting for 99.8% of the R&D in 2021.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

2.5 Key points

- The ICT services sector is led by the US whose R&D in this sector has more than tripled over the last 10 years. China is in second place but with less than one quarter of the US's R&D, even though its R&D in this sector has increased by almost ten times over the decade. The EU has just over half of the R&D of China with Japan in fourth place with around two-thirds of EU R&D.

- The biotech sector is also led by the US with over two-and-a-half times the R&D of the EU in second place. Japan is in third place with less than half of the EU's R&D and China follows with around half the R&D of Japan. The US is particularly strong in biotechnology and several US pharmaceutical companies have enhanced their pipelines of new drugs by acquiring biotech companies.

- The ICT producers' sector is again led by the US with more than twice the R&D of China. The EU has around two-thirds of China's R&D in this sector with Japan around two-thirds of the EU's.

- The automotive sector is led by the EU with nearly twice the R&D of Japan. The US has around two-thirds the R&D of Japan with China following with about half of Japan's R&D.

- Overall, the EU companies lead the automotive sector. They have much larger R&D investment, larger sales, larger profitability and more employees than their competitors. There are 9 EU companies among the top 20 companies by R&D investment, and 4 EU companies among the top 9 companies by EV sales.

- Japanese companies are still the sector's second R&D investor but over the past 10 years their number in the *Scoreboard* decreased significantly and their volume of R&D increased much less than that of their EU counterparts.

- Compared with the 2012 *Scoreboard*, in 2021 the automotive sector includes less EU companies, the same number of US companies and many more Chinese companies. Some of the new companies such as Tesla and Rivian only operate in the EV market.

- Over the past 10 years, the automotive companies' R&D intensity has grown worldwide, but more rapidly for the US and Chinese companies. Consequently, in 2021, the US and Chinese companies reduced significantly their R&D intensity gap with the EU in the automotive sector.

- The shift to electric mobility and the digitalisation of the automotive industry increases competition, with the arrival of new pure EV automotive companies and players from ICT industries. This is challenging the leadership of the EU, which needs to react, taking the new business opportunities and overcoming the barriers arising in the reshaped value chain of the automotive industry.

- The US companies dominates the semiconductor sector, especially in the high R&D-intensive segment of chip design. They have the largest number of companies and their R&D investment and net sales are larger than those of the other world regions together (6 times more R&D investment and 5 times more sales than their EU counterparts). There are 11 US companies among the top 20 companies by R&D investment, and 4 EU companies.

- Over the past 10 years, R&D investment in semiconductors has increased significantly across all world regions but especially in China: the Chinese companies' R&D investment multiplied by seven in this period. However, in 2021, Chinese companies' R&D investment was still much lower than that of their US, South Korean, Taiwanese and EU counterparts.

- The average R&D intensity of the EU companies is larger than that of Chinese, Japanese, Korean and Taiwanese companies, suggesting they operate in the high R&D-intensive segment of the semiconductor value chain.

- Semiconductor manufacturing is very capital intensive as can be seen from the very high capital investments of the US, Taiwan and South Korea. The advent of 5G and other demands mean that TSMC alone announced in January 2022 that it would make capital investments of USD 40 bn to USD 44 bn during 2022. This illustrates the scale of investment needed to remain world class in this industry.

- Semiconductors is a strategic sector where EU companies are underrepresented in key segments of the value chain, i.e. chip design and manufacturing. There is a need to stimulate the creation and scale-up of more EU companies, identifying the most promising and critical technologies for development in the EU, and attracting investment in selected high value-added segments of the supply chain. In this context, the EU launched in 2022 the European Chips Act aiming to increase resilience to supply chains disruptions and to increase its global share in manufacturing.

3 SCOREBOARD DYNAMICS BETWEEN 2012 AND 2022

This chapter describes the dynamics of the *Scoreboard* between 2012 and 2022 in terms of changes in the number of companies and R&D invested. The approach is geographic and sectoral, and the focus is on the four main investor regions (the US, the EU, Japan and China) as well as the three major R&D investor sectors, namely ICT, health and automotive. The chapter describes more general decade long trends and it provides an analysis of the dynamics between the two end years of the period under scrutiny. It encompasses an assessment of the top 10 and top 50 R&D investors worldwide, of rank changes in the common set of *Scoreboard* 2012 and 2022 (1228 companies), and of the companies entering and exiting these two *Scoreboards.*

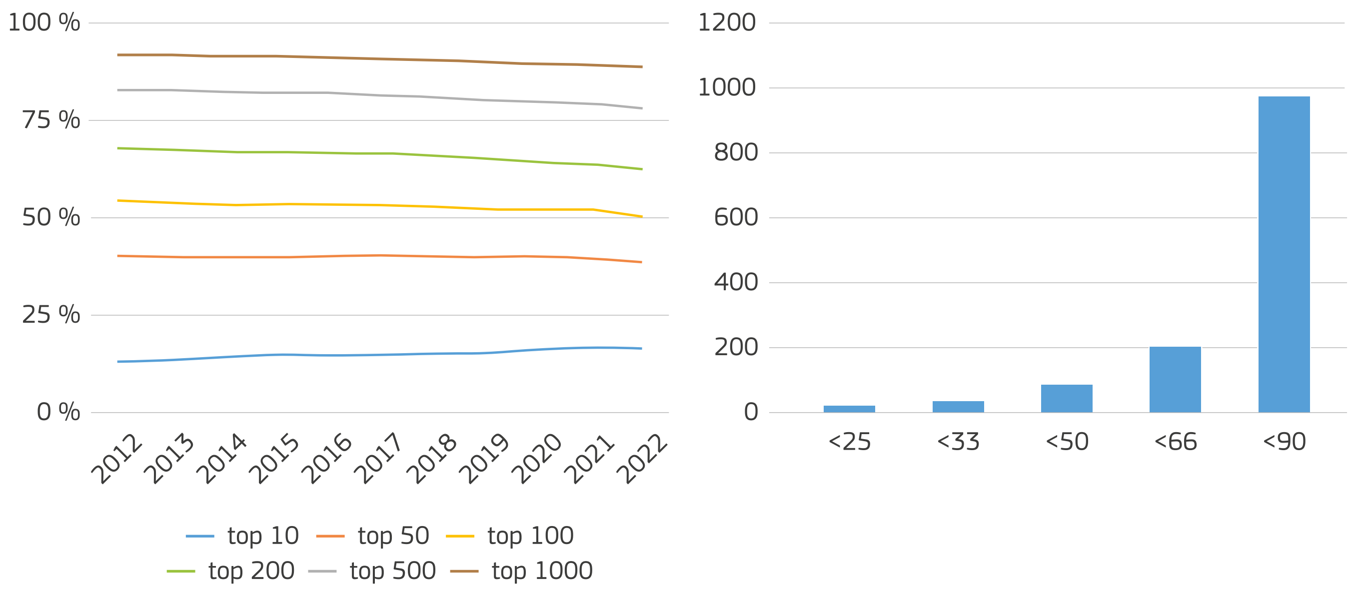
3.1 General R&D trends over 10 years in the main geographical regions and industrial sectors

Concentration[60] of the number of companies and R&D investments

Throughout the last decade, the EU Industrial R&D Investment *Scoreboard* has been weighted towards the largest companies in the sample. The top 50 companies invest around 40% of the total R&D of all 2500 companies. Below the top 50 the concentration in terms of R&D investment starts to decrease, with the top 100 companies investing in R&D somewhat more than half of the total 2500 *Scoreboard* companies. The top 500 firms invest 80% of the total R&D (Figure 3.1, left). In terms of number of companies, a mere 85 firms invest half of the total and the first 200 companies about two-thirds.

[60] Defined as the cumulative share of R&D investment across companies

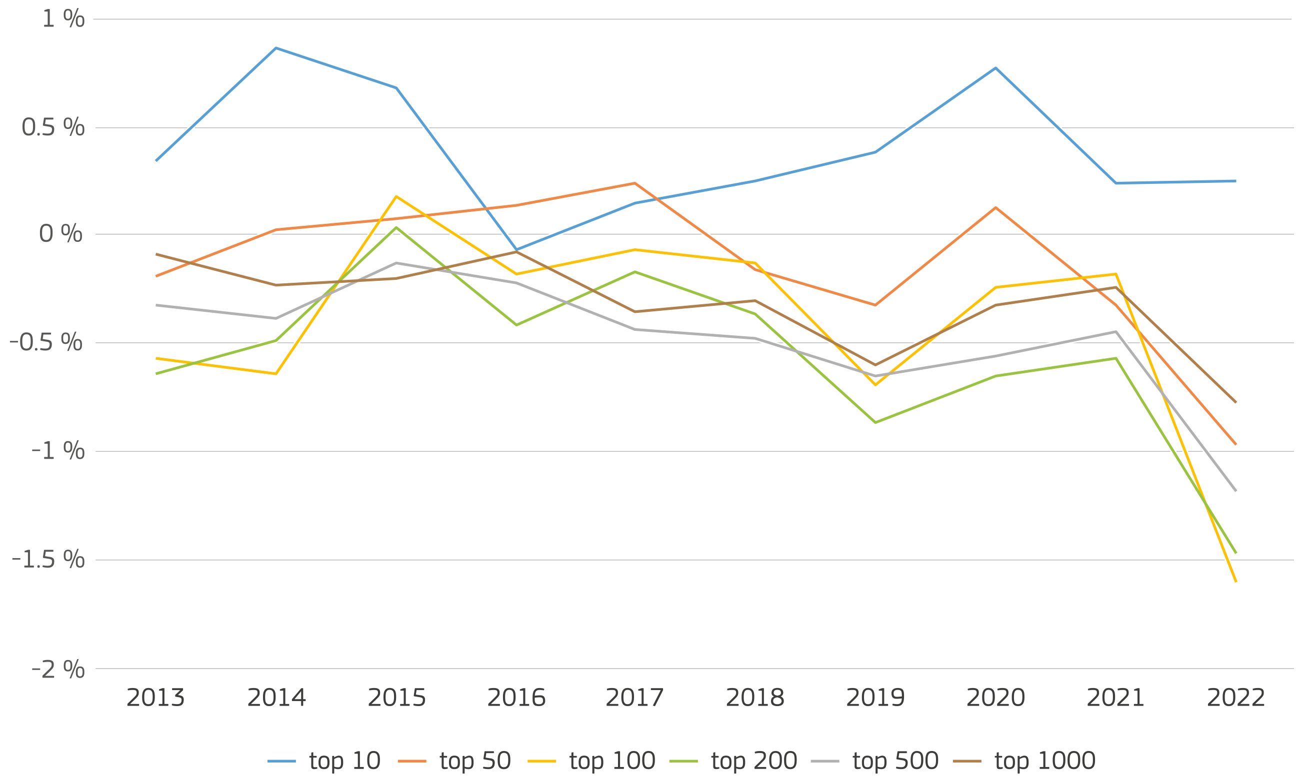
Figure 3.1: Concentration total R&D investment in *Scoreboards* 2012-2022



Note: Left panel: Share of R&D invested by the top k (k=10, 50,...) R&D investing companies *Scoreboards* 2012-2022; Right Panel: Number of companies accounting for 25%, 33%,... of the total R&D investments in *Scoreboards* 2012-2022, average
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The differences in the cumulative shares of R&D investment of the first k companies (k ranging from 1 to 2500) from one year to another over the analysed period are minor. The significant skewness of the distribution is clearly visible also from the 10-year average shares (Figure A 1 in Annex 3), showing that global R&D is concentrated in a rather limited number of companies. However, apart from the top 10, the concentration seems to have slightly decreased over time, which, together with the overall significant increase of the R&D expenditures points towards some decrease of the concentration (Figure 3.2, Table A 1).

Figure 3.2: Year-on-year changes in the cumulated shares of R&D investment in SB2012-2022



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Number of companies – main geographical regions

The largest share of the top 2500 R&D investors was headquartered in the US throughout the whole period. They are also the most numerous in almost every quintile group, as well as in the top 10, top 50 and top 100 (see Figure 3.3). The number of EU companies decreased overall by a net[61] 13 companies on average per year. While in the top 500 the decrease was only marginal (1.2 companies on average per year), the number of EU companies in the lowest quintile group almost halved, from 103 companies in 2012 down to 56 by 2022. The main reason behind this are mergers and company reorganisations, as well as R&D investment being too low to reach the threshold of the 2500, implying relatively low growth amongst small up-and-coming companies (Table 3.1).

[61] The difference between the number of companies entering and exiting the *Scoreboard.*

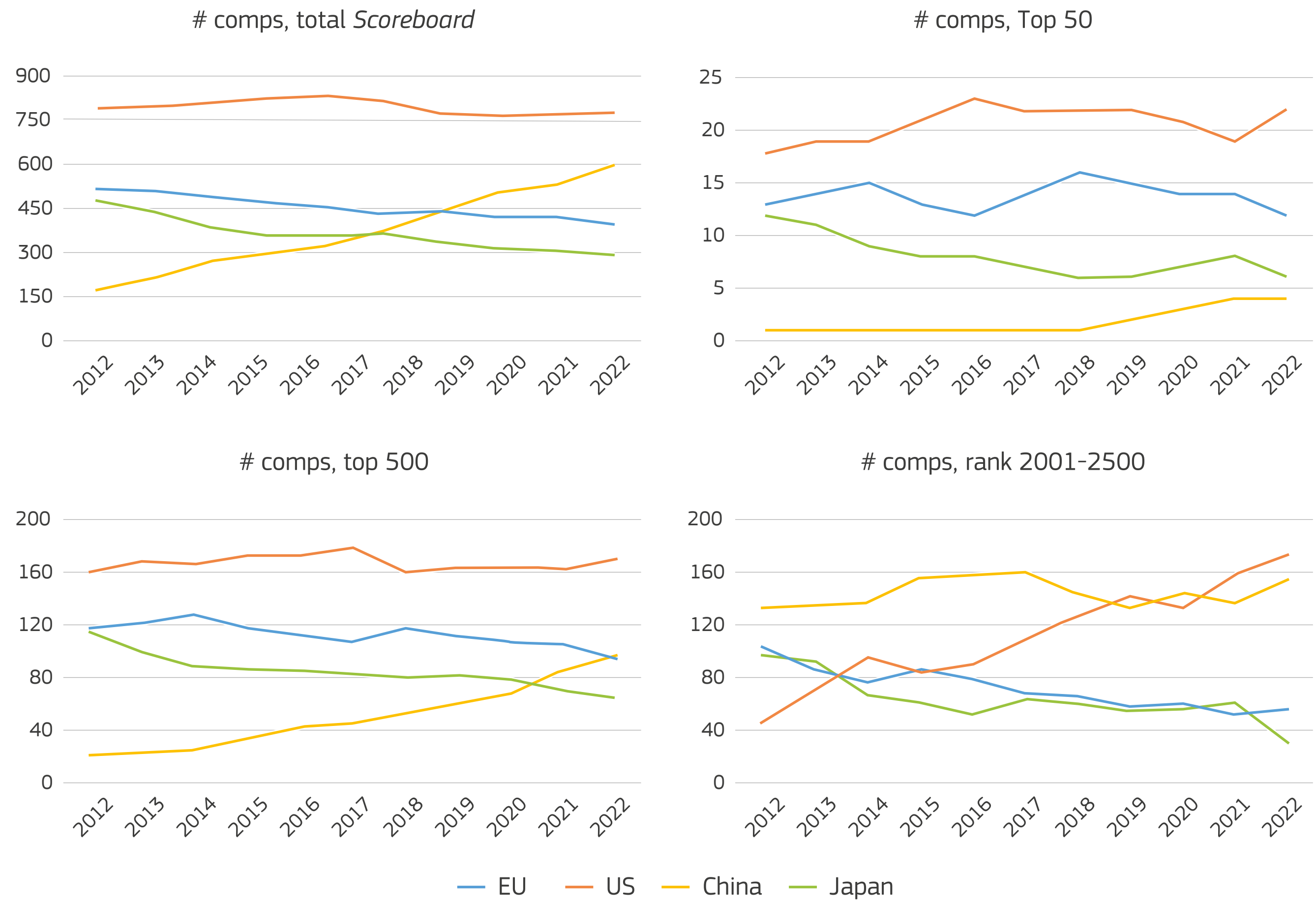
Table 3.1: Main reasons for EU companies exiting the *Scoreboard*

Number of companies	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
M&A, ownership*	9	12	20	8	15	7	6	6	10	8
Too low R&D	0	16	4	6	2	2	1	0	2	3
Liquidation	2	3	1	1	0	0	0	0	1	
Other**	6	4	0	4	8	2	2	3	5	7
Total	17	35	25	19	25	11	9	9	18	18

*: Reorganisations mainly, HQ change, name change
**: Mainly data related, such as still undisclosed data at the cut-off date
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The main increase in the number of Chinese companies took place in the lower quintiles as well as in the ranks 101-500). The increase in their number in the top 100 is also large (5 times), and in 2022 there were 16 Chinese companies in this group. Of the four main regions, Japan lost the largest number of companies in the *Scoreboard*, on average 18 companies exited every year. They lost ground in every quintile as well as in the top 10, 50 and 100 (Figure 3.3 and Figure A 2 in Annex 3). A more detailed analysis on sectors is provided in Section 3.3.

Figure 3.3: Main changes in the number of companies by country/region



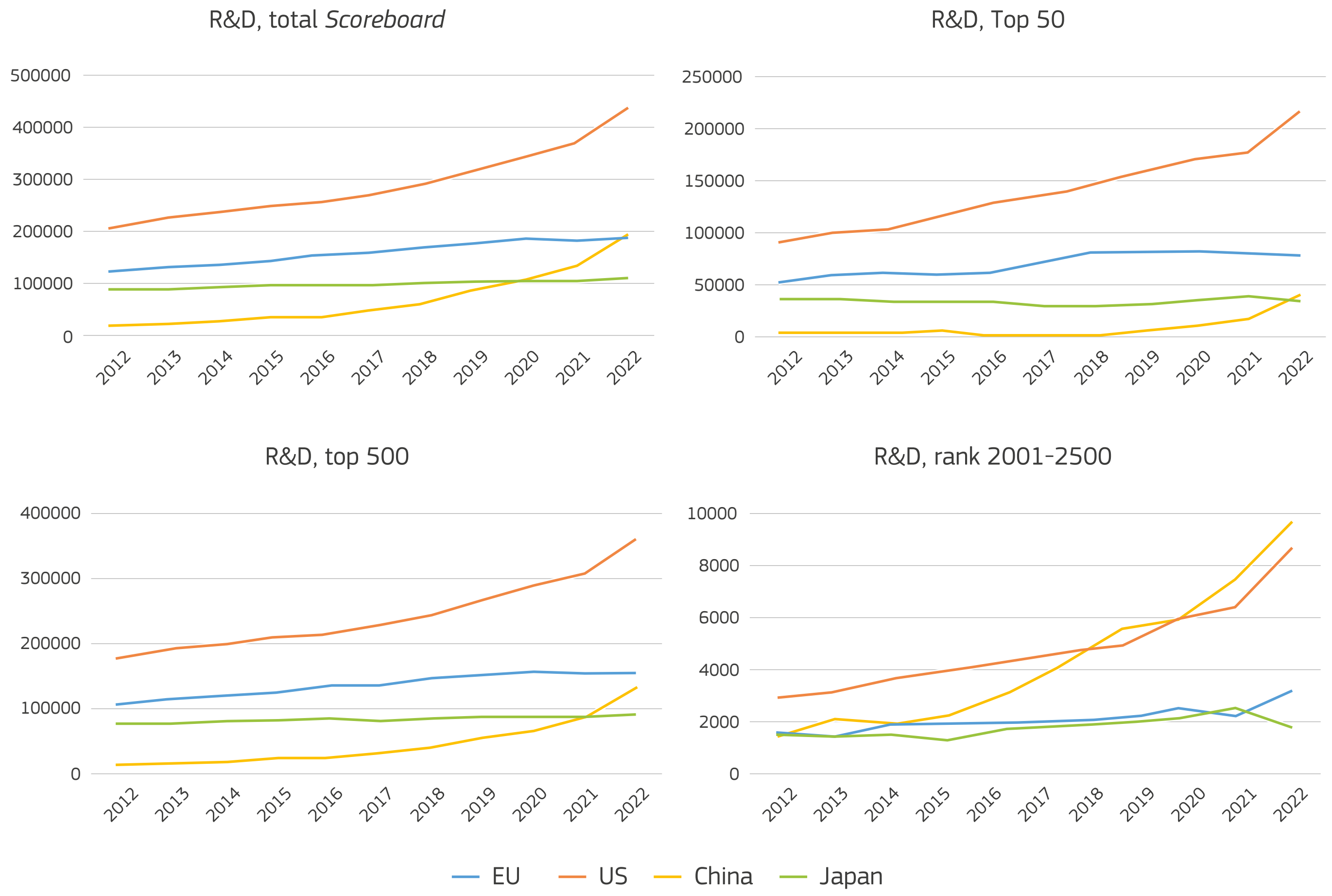
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

R&D investment – main geographical regions

The US is by far the largest R&D investor of the last decade, both overall and in every quintile groups, except for the lowest quintile where it was overtaken by China in 2018. This means that the largest percentage of the cohort of the 500 smallest R&D investors just reaching the *Scoreboard* threshold is nowadays from China. EU headquartered companies have been strongly represented in the top 50 and top 100, but are overtaken by China for the 101-500 ranks onward. The 10-year compound annual growth rate (CAGR) of R&D investment of EU companies in the *Scoreboard* (4.3%) is moderate, and below that of the entire *Scoreboard* (7.2%), the US (7.5%), and China (25%) – with the latter having invested massively in R&D and overtook the EU in 2022, being now the second largest R&D investing region after the US. Chinese R&D has significantly increased overall in the *Scoreboard*[62], only in the top quintile the increase was somewhat smaller. The growth of in Chinese companies' R&D investment in the top 50 is impressive (CAGR of 29%), but their main increase is in the group of the top 51-100 companies[63]. Japanese companies dropped out of the top 10 in 2016/2017, and Japanese R&D investment seems to have been almost stagnating overall (Figure 3.4).

[62] Especially since 2018, which may to some extent stem from a certain improvement of the data disclosure – see methodological annex for further details
[63] This group already has a much lower share in total R&D than the top 50; see Figure 3.1.

Figure 3.4: Main changes in the number of companies by country/region



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

3.2 Now and then: Top rankings in the 2012 and 2022 *Scoreboards*

Top 10

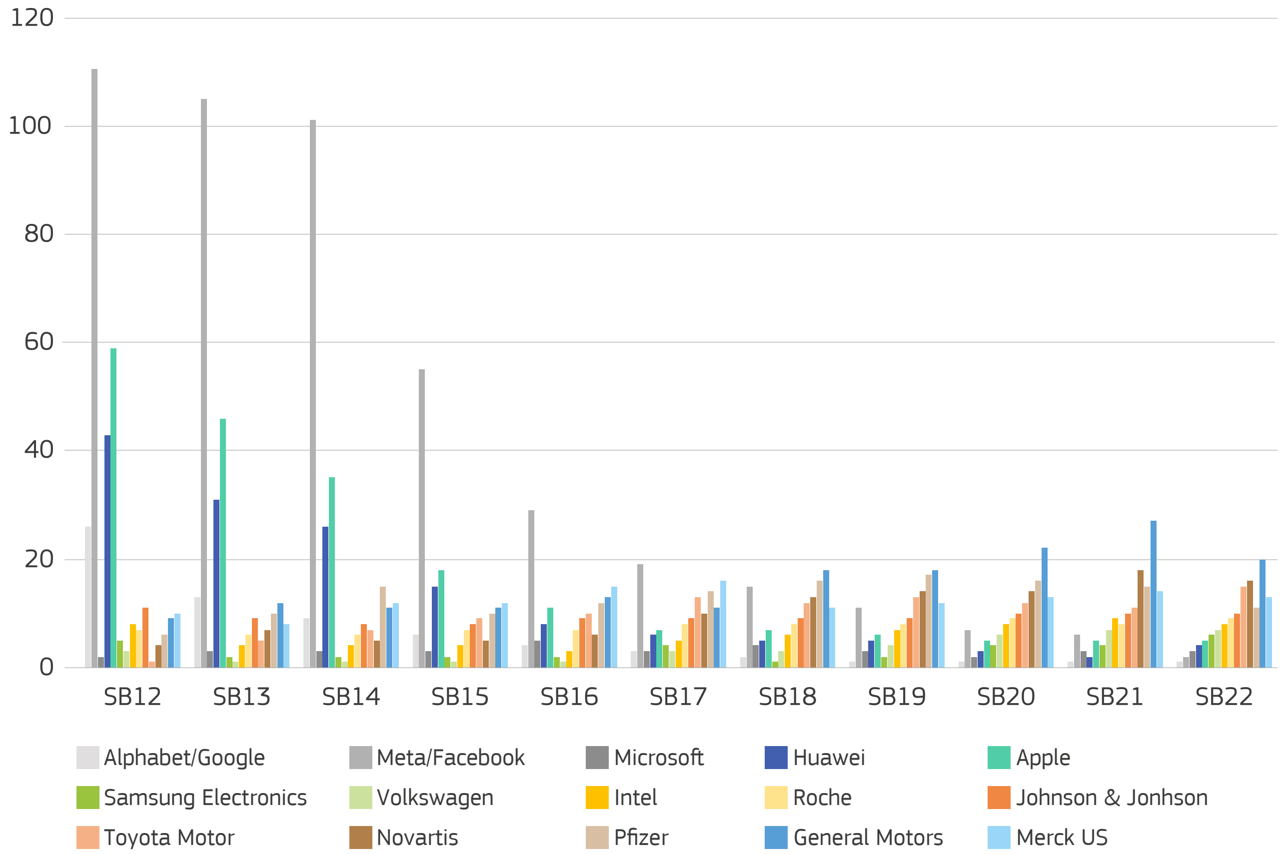
15 different companies appear in the top 10 of both the 2012 and the 2022 *Scoreboard*. At first sight, this shows a rather high turnover[64], with 5 new companies in the top 10 in 2022. However, apart from Facebook/Meta the same 9 companies have populated the top 10 since the *Scoreboard* 2017 (Figure 3.5). Furthermore, their investment share of the 2 500 companies is rather stable and has even increased slightly, as seen in Figure 3.2. This points to a stability in R&D investments of the key R&D investors. Their total R&D investment was EUR 182.2 billion in *Scoreboard* 2012, which represents a compound average growth rate (CAGR) of 9.3% since 2012, higher than that of the entire *Scoreboard*, which was 7.2% (Table 3.1). The highest CAGR was registered by Facebook/Meta (52%), followed by Apple (25%), Huawei (20%), and Alphabet (20%). Acquisitions made by these companies played a significant role in this impres-

[64] The number of companies that are no longer present in the group in a certain year compared to a previous year.

sive growth[65]. The other companies of the top 10 had single digit R&D growth.

Facebook/Meta, Apple and Huawei have seen the greatest improvements of their rankings during the assessed period, with Meta encountering the sharpest increase in its ranking, starting with a jump from the 297th position to 105 in the 2013 *Scoreboard* and to rank 55 in 2015 from the 101st rank of the previous year (Figure 3.5).

Figure 3.5: Changes in the rankings of the *Scoreboard* 2022 top 10 companies, 2012-2022



*: Facebook/Meta ranked 297 in 2012. Lowest rank is 110 for a better readability.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

As previously mentioned, the average annual growth rate of R&D investment by the 2500 *Scoreboard* companies was 7.2%, which resulted in a close to doubling of the total R&D investment since 2012, reaching EUR 1 094 billion in the 2022 *Scoreboard*. About one fifth (19.6%) of the overall increase came from the top 10 investors in the 2022 *Scoreboard*. The 16.7% R&D investment share of the top 10 in 2022 is rather high and has increased since over the past 10 years (13.7%)[66].

[65] https://tracxn.com/d/acquisitions/acquisitionsbyApple
https://en.wikipedia.org/wiki/List_of_mergers_and_acquisitions_by_Apple
https://www.titlemax.com/discovery-center/lifestyle/everything-facebook-owns-mergers-and-acquisitions-from-the-past-15-years/
https://en.wikipedia.org/wiki/List_of_mergers_and_acquisitions_by_Meta_Platforms
https://en.wikipedia.org/wiki/List_of_mergers_and_acquisitions_by_Alphabet

[66] 12.8%, using the original SB2012 series. Note: for intertemporal comparisons of the 2012 and 2022 figures we used the R&D investment series of the 2012 *Scoreboard* expressed in original currency and applied the 2022 euro exchange rates.

In the top 10 of the 2012 *Scoreboard* the US was present with 5 companies, followed by Switzerland with 2, as well as South Korea, Japan, and Germany with one company each. By 2022, the US dominance continued (6 companies), one of the Swiss companies (Novartis) dropped out together with Toyota, the only Japanese company in the top 10. One Chinese company (Huawei) got into the group; South Korea and the EU are represented with one company each. Sector-wise the ICT sectors (producers and services) dominate with 7 companies out of 10, accounting for 77% of the total of the top 10 R&D investment. This is a radical change compared to 10 years ago, when the amount of R&D investment of top 10 was more evenly distributed among the health (41%), ICT (32%) and automotive (27%) sectors (Table 3.2)[67].

Table 3.2: Top 10 investors in R&D in 2012 and 2022, EUR million

Rank 2022	Rank 2012	Company	Country	Sector	R&D 2022	R&D 2012*	CAGR %
1	26	Alphabet	US	ICT services	27 867	4 558	19.8
2	297	Meta	US	ICT services	21 768	343	51.5
3	2	Microsoft	US	ICT services	21 642	8 662	9.6
4	43	Huawei	CN	ICT producers	19 534	3 122	20.1
5	59	Apple	US	ICT producers	19 348	2 145	24.6
6	5	Samsung Electronics	KR	ICT producers	16 813	7 604	8.3
7	3	Volkswagen	DE	Automobiles & o.t.	15 583	7 203	8.0
8	8	Intel	US	ICT producers	13 412	7 372	6.2
9	7	Roche	CH	Health industries	13 261	7 810	5.4
10	11	Johnson & Johnson	US	Health industries	12 991	6 664	6.9
15	1	Toyota Motor	JP	Automobiles & o.t.	8 691	6 029	3.7
16	4	Novartis	CH	Health industries	7 983	7 998	0.0
11	6	Pfizer	US	Health industries	10 239	7 775	2.8
20	9	General Motors	US	Automobiles & o.t.	6 975	7 173	-0.3
13	10	Merck US	US	Health industries	9 134	6 957	2.8
Total Top 10					182 219	74 584	9.3
Total Top 2500					**1 093 860**	**545 757**	**7.2**
Share Of Top 10 In Total Top 2500, %					**16.7**	**13.7**	

*: Recalculated figure using 2022 national currency exchange rates to euro (see Table A 1 in Annex 2)
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[67] Note that Amazon is not included in the 2022 top 10. This is because Amazon accounts do not separate its R&D and content investments so its R&D cannot be included. However, we estimate that Amazon invests more than Alphabet in R&D so it would be at #1 were it to be included. This addition would increase the top 10's R&D and the US share of R&D, and it would mean J&J dropping out of the 2022 top 10 and the number of ICT companies accounting for 8 of the top 10.

Top 50

As stated earlier (Figure 3.1, left) the top 50 is the group of companies in the *Scoreboard* that accounts for the largest average share of R&D investment for the key sectors (i.e. automotive, ICT, health), i.e. around 40% of total R&D investment. These 50 companies may therefore be considered the backbone of the *Scoreboard* (Figure 3.6).

14 companies (i.e. 28% of the total) in the top 50 are new in 2022 compared to 2012. Out of the entrants, 11 companies were already in the *Scoreboard* in 2012, all of them in the top 500 with one exception. The remaining three companies, i.e. China State Construction (CN), Abbvie (CN) and Stellantis (EU), were not in the *Scoreboard* previously under these names. However, two of the predecessors of Stellantis (Fiat and Peugeot) as well as one of Abbvie (Abbot) were already included also in 2012, in or close to the top 50 (Abbot ranked 35^{th}, Peugeot 45^{th}, and Fiat 52^{nd}). This turnover does not seem to be high over such a long time span, which again highlights the persistence in the top 50.

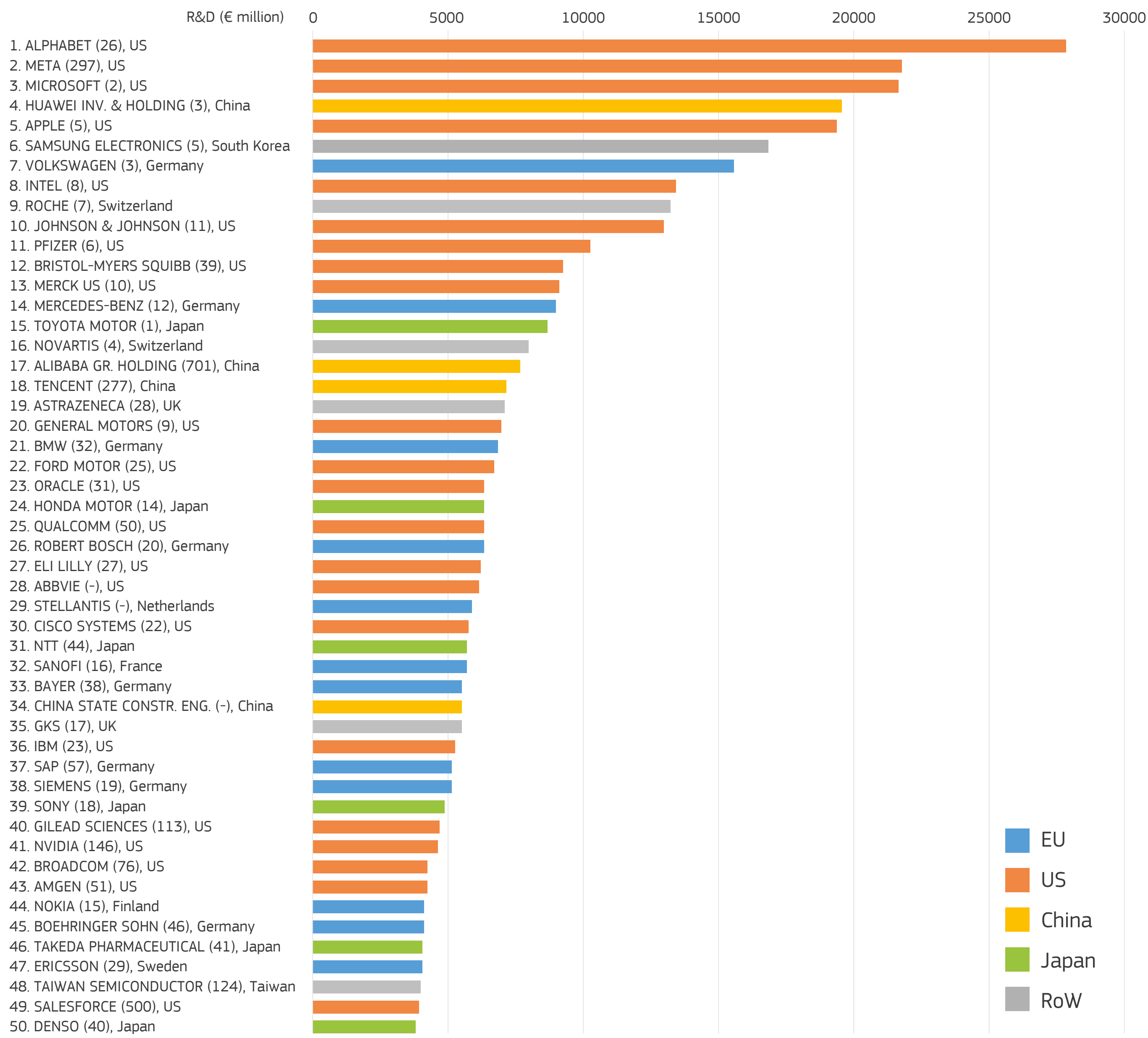
Among the 14 entrants, the ICT sectors dominate with 9 companies. They are followed by health (3) as well as construction and automotive with one each. The share of ICT companies R&D in the total top 50 increased significantly to 52% in 2022, from 36% in 2012. Although increasing in terms of number, the R&D share of health companies in the top 50 decreased by 5 percentage points from 32% in 2012. Likewise, the automotive sector dropped by 5 percentage points from its level of 23% in 2012.

Region wise, similarly to the top 10, the top 50 is dominated by US companies, mainly ICT firms, but also from the health sector, in line the strength of these two sectors in the US economy. Their share in the top 50 is lower than in the top 10, stressing that US tech companies are top ranked in the *Scoreboard*. The US presence has strengthened also in the health sector: while its 6 companies in 2012 accounted for 47% of the health industry R&D, in 2022 the number of companies increased to 8 and they invested 54% of the total health R&D of the *Scoreboard*. (Table 3.2).

The main exiting companies are from Japan, their number in the top 50 of the 2022 *Scoreboard* halved compared to 2012. They exited mainly from the ICT sector and the 'others' category, the latter due to the dropout of Panasonic (leisure goods), and Toshiba (general industrials). The Japanese R&D in the top 50 group fell by EUR 4 billion.

There are currently 12 EU companies in the top 50, which is one company less than 10 years ago (Airbus, ranked 60 in 2022). Apart from Airbus, and Peugeot (see Stellantis case) it was only Alcatel-Lucent that exited the *Scoreboard* in 2017, but only as a brand. It has de facto remained in the top 50 as a result of the takeover by Nokia. The other EU headquartered companies present in 2012 are still there also in 2022. The remarkable stability of the EU presence can be observed also on the sectoral level: there is the same number of companies in each of the key sectors in 2022 as in the *Scoreboard* 2012. Moreover, with the exception of SAP (ranked 57^{th} in *Scoreboard* 2012) and Stellantis (already discussed) every EU company that is in the top 50 in *Scoreboard* 2022 was also in the top 50 10 years ago. However, the ranks of EU companies in this group worsened, mainly due to the previously mentioned strong US presence in the top half. The EU is still the second largest R&D investor of the group of 50 behind the US. However, the average growth of EU R&D investments in the group is moderate (CAGR of 4%), less than half of the US growth (9%) or that of the total *Scoreboard* (7.2%). The growth of EU R&D investment is driven mainly by the automotive sector (CAGR 7%).

Figure 3.6: Top 50 investors in R&D in 2022 (rank 2012 in parentheses), EUR million



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Although China is now number 2 after the US in the *Scoreboard* with respect to companies and R&D, its presence in the top 50 with only 4 companies is still modest. However, it seems that its investments have expanded rapidly, it has already overtaken Japan. Its presence is increasing, mainly in the two ICT sectors (Figure 3.6 and Table 3.3).

Table 3.3: Top 50 investors in R&D in *Scoreboard* 2012 and 2022 by region and by sector

	Number of companies						R&D investment*						
	EU	US	JP	CN	Row	Total	EU	US	JP	CN	Row	Total	Total, %
2012													
Automotive	5	2	4	0	0	11	23 081	11 852	15 663	0	0	50 597	23%
Health industries	3	6	1	0	4	14	10 356	32 865	2 179	0	24 343	69 744	32%
ICT producers	4	4	2	1	2	13	14 886	17 735	5 569	3 122	11 101	52 412	24%
ICT services	0	4	2	0	0	6	0	22 033	3 914	0	0	25 947	12%
Others	1	2	3	0	0	6	3 249	7 229	9 966	0	0	20 444	9%
Total	13	18	12	1	6	50	51 572	91 715	37 291	3 122	35 444	219 143	
2022													
Automotive	5	2	3	0	0	10	43 643	13 685	18 910	0	0	76 239	18%
Health industries	3	8	1	0	4	16	15 331	63 005	4 065	0	33 855	116 256	27%
ICT producers	3	6	0	1	2	12	13 323	53 815	0	19 534	20 790	107 462	25%
ICT services	1	6	1	2	0	10	5 168	86 842	5 732	14 878	0	112 620	27%
Others	0	0	1	1	0	2	0	0	4 902	5 509	0	10 411	2%
Total	12	22	6	4	6	50	77 465	217 348	33 609	39 921	54 645	422 988	
						CAGR	**4%**	**9%**	**-1%**	**29%**	**4%**	**7%**	

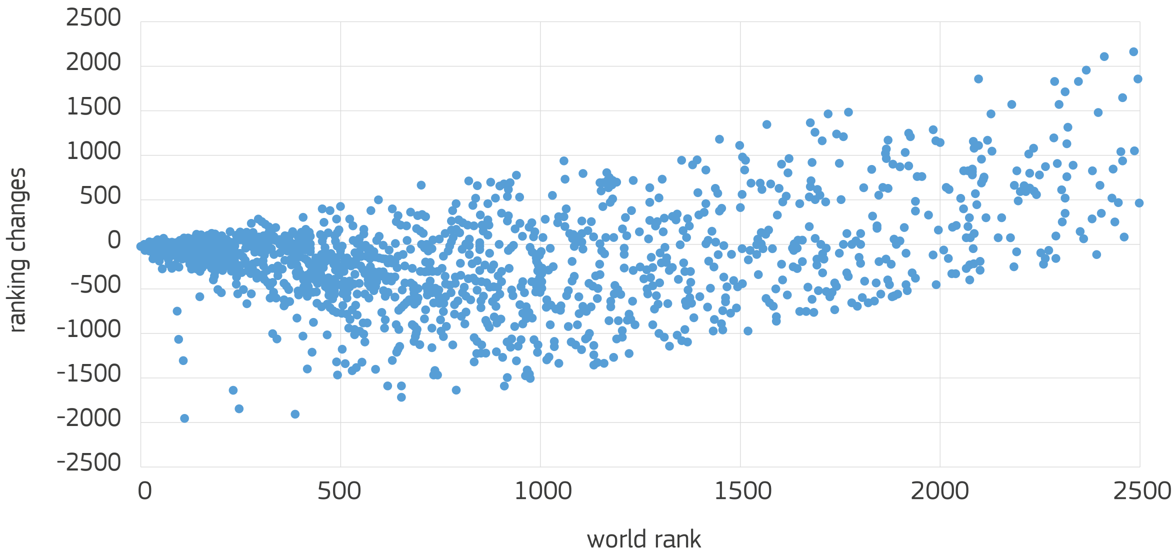
* For R&D for 2012 figures were recalculated using 2022 national currency exchange rates to euro
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

3.3 Now and then: ranking changes, entry and exit

Ranking changes

Of the top 2500 investors in R&D in the 2022 *Scoreboard*, the same 1228 companies appear in both the 2012 and 2022 *Scoreboards*. These companies invested a total of EUR 843.6 billion in R&D in 2021, i.e. 77.1% of the total 2022 *Scoreboard*. The volatility of the ranking change increases towards the lower ranks of the first quintile, then it becomes more stable (Figure 3.7). This illustrates the logical fact that while a change of a certain magnitude in the R&D expenditure of the top 500 companies tends to induce a smaller change in their rankings, in the four lower quintiles[68] even a small change can trigger a rather large change in the ranking position. In other words, companies in the four lower quintiles invest significantly less in R&D than their higher ranked counterparts and therefore have larger effects in terms of ranking change, i.e. higher impact of an extra euro of R&D investment on the ranking change[69].

Figure 3.7: Ranking change between 2012 and 2022



Note: Horizontal: ranking in 2012, vertical change in ranking between 2012 and 2022
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

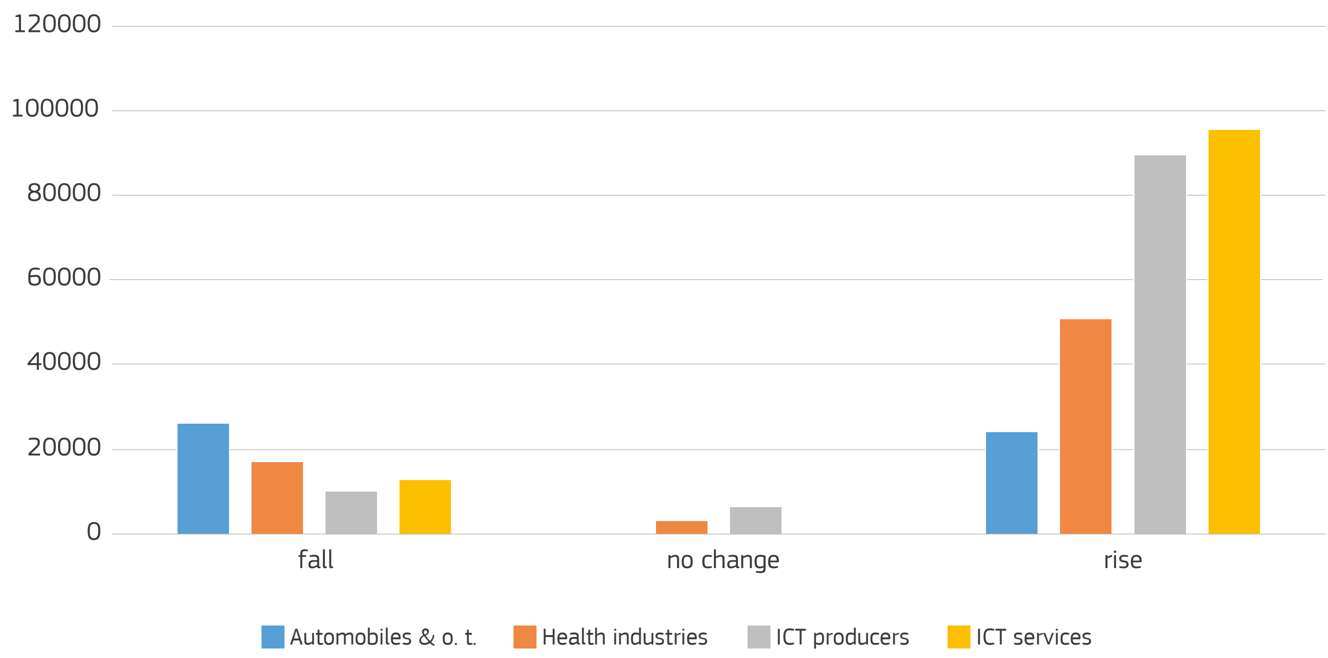
Another way to look at the dynamics is to observe the scatterplots of the 2012 and 2022 rankings (Figure Figure A 4). In the top quintile, the scatterplot of 2012 and 2022 rankings shows less volatility and a certain degree of concentration around the 45-degree line[70] meaning thus fewer and smaller changes in the ranking positions. In the lower quintiles the ranking changes are rather scattered, meaning that the probability that a company significantly changes its rank as a result of an additional amount of R&D invested is much higher in the bottom 80% of the companies. The graph on the right of Figure A 4 shows that a significant share of the common set has not managed in 10 years to enter the top quintile from any position between 501 and 2500. Indeed, there were altogether 63 companies entering the top 500 in 2022 compared to 2012. A possible future research avenue, beyond the scope of the present analysis, would be to understand why these

[68] And especially as of the 1000th position onwards.
[69] In financial terms, while the companies ranked 500-2500 in the 2022 *Scoreboard* invested between EUR 50 and 360 million in R&D in 2021, the top quintile, except for the top 50, invested between EUR 360 million and EUR 3.7 billion. This represents a six-fold difference for the bottom 2000 companies and a more than nine-fold difference for the group of companies ranked 51 to 500.
[70] The 45-degree line indicates no change in the rank.

companies have never increased their R&D investment to levels that would have made them top 500 R&D investors worldwide. The 21% share (159 out of 751) of EU companies in this group of companies adds to the interest in researching them.

Over a 10 year period it is to be expected that each industrial sector has a positive contribution to R&D, and that the increase of their R&D investment has kept the companies in the common set of 1228, regardless of their rank changes. In the top 1000[71] the ICT services sector has contributed the most to the R&D increase[72], companies improving their ranking in this sector invested more than double on average per company than similar companies in automobiles or health sectors (Figure 3.8 Top 1000, common set, 2012-2022 changes Figure 3.8, and Figure A5 in Annex 3). Out of the key sectors, the automotive sector has contributed the least and it is the only sector in the top 1000 where more companies worsened their positions than those that improved.

Figure 3.8: Top 1000, common set, 2012-2022 changes



n° of companies	Fall	N° change	Rise	Total
Automotive	41	1	28	41
Health	36	2	59	36
ICT producers	63	1	83	63
ICT services	22	0	55	22

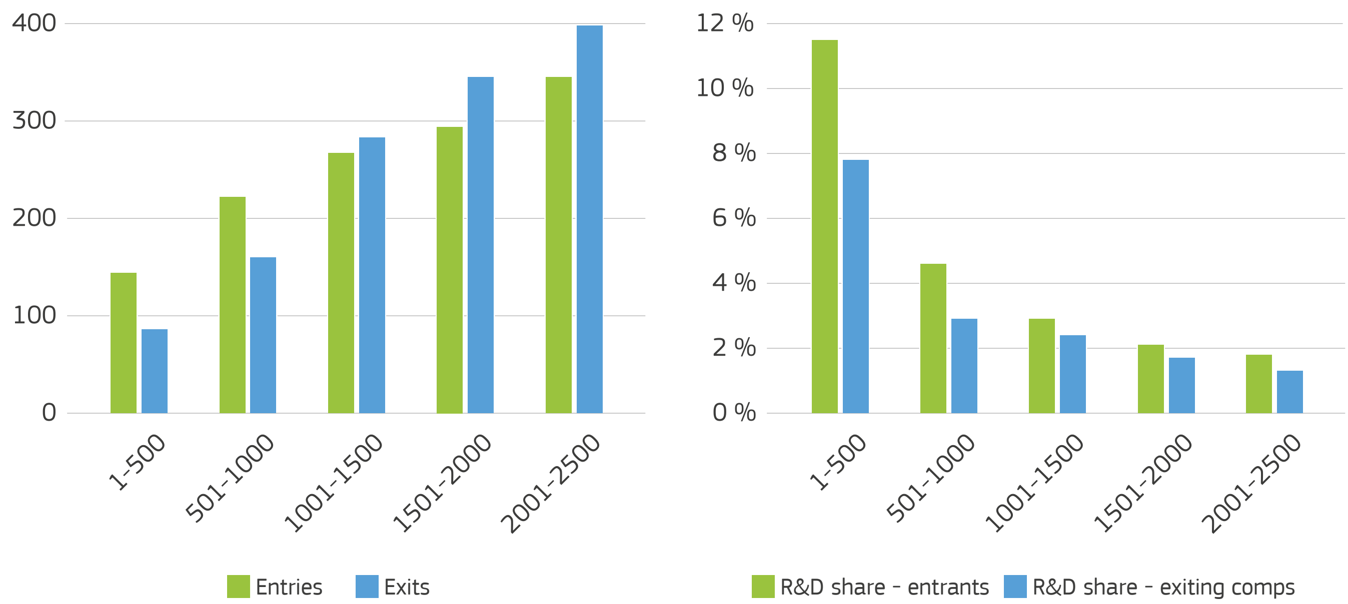
Note: Top Panel: Average R&D of companies improving (rise) and worsening (fall) their ranking; right panel: Changes in R&D in the main sectors of activity by ranking change type
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

71 The top 1000 accounts for about 88% of R&D of the total *Scoreboard* (the top 500 for 80%). In the three lower quintiles, changes in the ranks are linked to fairly low R&D figures and changes in the rank positions of these companies may have less relevance.
72 Mergers and acquisitions may have played an important role in the increases of the ICT services R&D investments.

Entry/exit

A total of 1272 companies entered or exited[73] the ranking between the 2012 and 2022 *Scoreboards* (Figure 3.9). The larger numbers towards the bottom cohorts indicate the increasing volatility of the tail, i.e. the turnover of companies is higher in the lowest ranks. Besides, more companies entered newly the top two quintiles than exited, because of substantial growth in R&D amongst smaller companies. The R&D shares on the right panel of Figure 3.9 reflect this development: the highest shares are those of entrants in the top two quintiles, and they are higher than those of the companies exiting these cohorts. While new entrants' R&D investments account for ca. 23% of the total R&D invested in the *Scoreboard* 2022, 16% of the *Scoreboard* 2012 R&D[74] has been lost via the exiting companies. Since the total R&D in the 2022 *Scoreboard* is about double that of 2012, the entrants have clearly added significantly to the amount of R&D investment. This can be quantified to about 30% of the total R&D in the *Scoreboard* 2012 (or 15% of 2022). It is important to note that many exits have been due to takeovers and mergers so that the R&D of the exiting company is still in the *Scoreboard* but now assigned to the acquirer. M&A is common in the health and ICT sectors.

Figure 3.9: **Entries and exits between** ***Scoreboard*** **2012 and 2022 per quintile; number of firms and R&D**



Note: Left: Number of entering/exiting companies between *Scoreboard* 2022 and 2012 per quintile. Right: R&D share in total *Scoreboard* R&D (2012 for exiting, and 2022 for entering companies) of companies from the left per quintile
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[73] An entry means a company that is present in the ranking in a certain year (here: 2022) but absent from it in the reference year (here: 2012). An exit means a company that is present in the reference year but no longer in the other year (here: 2022). The number of entries on the level of the *Scoreboard* corresponds to the number of exits. However, in the quintile group the two are not necessarily equal, as the exit does not mean exiting the quintile, but disappearing from the full list of 2500 companies.

[74] Expressed in 2022 exchange rates.

Concerning geographical regions and sectors of activity, the main turnover (i.e. entry/exit) development is the increase of Chinese presence in terms of the number of companies present practically in each sector, as well as a significant and overall increase in the R&D investment (Table 3.4). China's strategy of investing in key technology sectors is clearly seen in the *Scoreboards*, via their massive investments in the automotive, health and ICT sectors. The US entrants' investment is still by far the largest in ICT services and health industries (the latter mainly in biotech and pharma), and its massive reduction of R&D investment in the ICT producers sector reflects its strategy of outsourcing a part of its R&D activity. A significant share of Chinese growth in this sector may stem from this process. For the EU, in contrast, apart from automotive, the increase in R&D in the key sectors is relatively modest. It is important to mention that the Rest of the world (RoW) figure hides the big increase in the importance of Taiwan for IT hardware R&D and production. New entrants from Taiwan in this sector invested EUR 1.4 billion in 2021.

Table 3.4: Net entries* to *Scoreboard* 2022 by region and sector, and net R&D changes

	Number of companies						R&D, EUR m					
Sector	**EU**	**JP**	**CN**	**US**	**Row**	**Total**	**EU**	**JP**	**CN**	**US**	**Row**	**Total**
Aerospace & Defence	-3	-1	4	-6	-4	-10	-248	-16	395	-510	348	-31
Automobiles & other transport	-10	-24	35	0	-2	-1	3 855	-552	6 177	2 566	1 146	13 191
Chemicals	-6	-27	29	-17	-12	-33	92	-604	3 465	-1 594	-472	887
Construction	-12	-17	24	-3	-3	-11	961	-336	11 811	-112	116	12 440
Energy	-8	-8	16	-3	-7	-10	538	-136	2 654	-206	101	2 951
Financial	-10	0	12	1	2	5	358	0	2 014	2 625	469	5 466
Health industries	-18	-13	79	129	3	180	4 573	-114	11 204	28 520	2 815	46 998
ICT producers	-24	-53	99	-110	-54	-142	-2 616	-1 375	19 080	-9 204	-1 458	4 427
ICT services	-13	-9	65	74	-12	105	722	1 317	12 808	31 208	3 722	49 778
Industrials	-35	-52	63	-20	-24	-68	-1 741	-1 142	10 910	176	936	9 138
Others	-24	-43	74	-9	-13	-15	438	-970	16 315	1 934	-407	17 311
Total	-163	-247	500	36	-126	0	6 932	-3 928	96 833	55 404	7 316	162 557

* Difference in the number of companies that entered the 2022 *Scoreboard* and exited the 2012 *Scoreboard*.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

3.4 Now and then: World regions and sectors – comparison between the 2012 and 2022 *Scoreboards*

We compare company trends (number, volume of R&D investment) between the *Scoreboard* editions of 2012 and 2022 by main competing geographical region (China, US, EU, Japan) and by sector of activity. As we have previously seen, the automotive sector, ICT producers, ICT services and health industries are the four key industries that dominate the *Scoreboard*. Altogether, they account for around 73% (in 2012) to 78% (in 2022) of total R&D investment by the top 2 500 investors. In both years, the key sectors had the most companies in the top 100[75]. The number of ICT services companies increased more than any other sector in the top 100, followed by health firms. ICT firms tend to be higher ranked, particularly in ICT services (Figure 3.10).

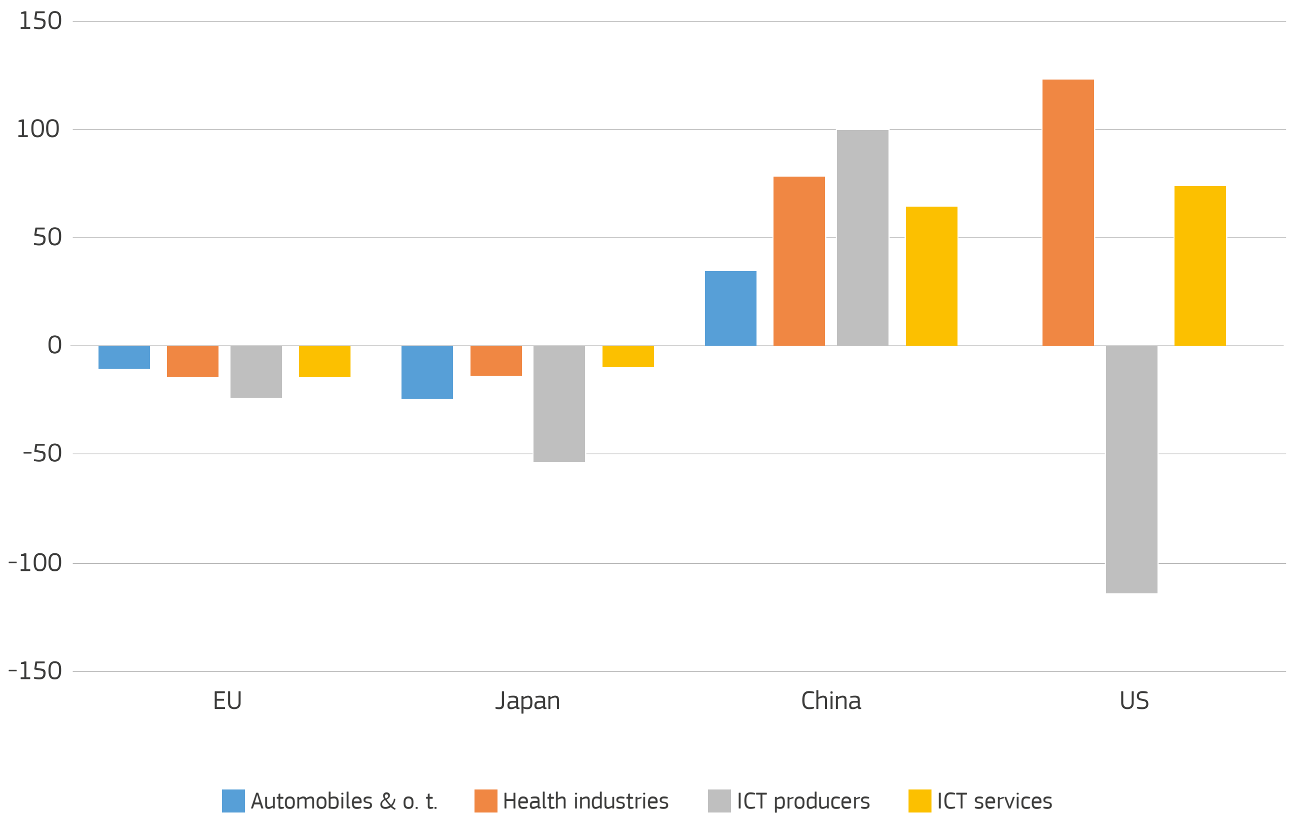
Figure 3.10: Number of companies by sector in the top 100 in *Scoreboard* 2012 and 2022

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[75] Although the present analysis does not focus primarily on the top 100 companies, this category shows most visibly the change in the number of companies per sector.

One of the most important development in the global R&D ranking is that more and more positions are being taken up by high-tech companies, mainly from the US and China, at the expense of more traditional manufacturing sectors, mainly from the EU and Japan. Chinese presence has significantly increased in the *Scoreboard*, with the addition of 503 companies between 2012 and 2022 (Table A1, Annex 3). The US presence increased in health industries and ICT services, thanks mainly to its sustained investment in information technology and pharmaceuticals. The US has a clear global lead in biotechnology. However, it stagnated in the automotive sector and decreased in ICT producers sector because of its massive outsourcing of computer hardware R&D, mainly to Taiwan, China, and South Korea. The number of EU headquartered companies slightly decreased in the key sectors[76]. Japanese companies are fewer in the 2022 *Scoreboard* than in 2012, with the largest decrease in the ICT producers sector (Figure 3.11).

Figure 3.11: Main changes between *Scoreboard* 2012 and 2022 in key sectors by country/region, number of companies



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[76] Although it is decreasing, the net decrease in the key sectors is only 61 companies between 2012 and 2022, i.e. six companies per year.

Between the 2012 and the 2022 *Scoreboards* the R&D investment of the 4 main competing regions in the *Scoreboard's* 4 key industries were the ones that increased R&D the most globally, particularly in the US and China (Table 3.5)[77]. The main difference between the regions is that while the R&D investment of the EU, Japan and US mainly targeted the key sectors, Chinese R&D investments increased somewhat more evenly across industrial sectors. Chinese investment also increased significantly in the construction, energy and industrials as it strengthened its position as a base for lower cost manufacturing. While the share of R&D of the four key sectors in the former 3 regions ranges between 87% and 99%, in China it is only 61%. Similarly to new entrants (see Table 3.3, above), the RoW figure of the changes for ICT producers includes the major increase of the R&D of Taiwanese ICT hardware production companies. These companies more than doubled their R&D investment, accounting for about 57% of the RoW-total[78]. Taiwan Semiconductors Manufacturing (TSMC) alone produces some 50% of the world's chips[79] and 90% of the advanced chips[80]. This company increased its R&D by EUR 2.9 billion between the 2012 and 2022 *Scoreboards* (i.e. 2011 and 2021).

Table 3.5: Change of R&D by country/region and sector between 2012* and 2022, EUR million

R&D invested by sector	Change between SB2022 and SB2012					
	EU	JP	CN	US	RoW	Total
Aerospace & Defence	-1 260	-16	587	-26	-134	-849
Automobiles & o.t. (key)	**2 6271**	**9 804**	**15 020**	**7 513**	**5 658**	**64 266**
Chemicals	990	1 388	3 690	-1 928	743	4 883
Construction	1 457	162	22 020	-82	582	24 139
Energy	1 185	-143	4 101	-1 164	-962	3 018
Financial	3 233	0	2 014	2 954	1 628	9 829
Health industries (key)	**19 294**	**4 962**	**13 385**	**68 287**	**14 896**	**120 824**
ICT producers (key)	**5 441**	**569**	**45 055**	**40 469**	**19 694**	**111 229**
ICT services (key)	**7 333**	**4 062**	**33 351**	**108 363**	**7 299**	**160 408**
Industrials	1 027	-358	17 684	-1 481	1 381	18 254
Others	1 688	1 765	18 313	4 421	5 915	32 102
Total	**66 660**	**22 197**	**175 221**	**227 325**	**56 700**	**548 103**
Key sectors - total	58 339	19 398	106 811	224 632	47 547	456 727
Key sectors - %	88%	87%	61%	99%	84%	83%

***:** Scoreboard 2012 figures recalculated with the Scoreboard 2022 exchange rates.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[77] Note that especially for China the previously mentioned improvement in coverage may be somewhat stronger. However, China's massive technological investments of the last 10-20 years is well documented in the literature.

[78] Taiwanese companies of this sector increased their R&D investment to EUR 22.3 billion in the *Scoreboard* 2022 from around EUR 10 billion[78] in 2012, meaning an increase of EUR 11.3 billion out of the EUR 19.7 billion (i.e. 57%) total increase of this sector for the RoW companies.

[79] https://www.cnbc.com/2021/03/16/2-charts-show-how-much-the-world-depends-on-taiwan-for-semiconductors.html – website last accessed on 8 November, 2022.

[80] https://www.stimson.org/2022/semiconductors-and-taiwans-silicon-shield/ – website last accessed on 8 November, 2022.

The EU's R&D investment has been highly concentrated in the automotive sector and rather low in ICT in the last decade compared to the *Scoreboard* average structure of number of companies (Table A 4, Annex 3) and of R&D invested (Table 3.6).

The most notable changes between the 2012 and the 2022 *Scoreboards* are:

- An increase in the share of R&D investment in health industries and ICT services, and a decrease in the share of R&D investment by ICT producers across the board and in the four competing regions, with some significant individual increases (e.g. health in China and ICT services in the US);
- The automotive sector R&D was by far the most significant for both the EU and Japan and its importance increased over the last ten years. Its share in the total R&D invested by companies headquartered in these regions is around 30% (Japan) and 32.5% (the EU). These shares are more than double of their *Scoreboard* average counterparts;
- A significant share of Chinese *Scoreboard* companies invests in construction, industrials, and energy sector, the latter's share experiencing a huge decrease, although it is still somewhat higher than the *Scoreboard* average.

Table 3.6: Change of R&D by country/region and sector between 2012* and 2022, EUR million

SB Sectors	SB average		EU		Japan		China		US	
	2012	2022	2012	2022	2012	2022	2012	2022	2012	2022
Aerospace & Defence	3.4%	1.6%	6.0%	3.3%	0.0%	0.0%	0.0%	0.3%	3.6%	1.7%
Automobiles & other transport	16.2%	13.9%	28.8%	32.5%	25.5%	29.2%	14.6%	49.2%	9.5%	6.3%
Chemicals	3.7%	2.3%	3.5%	2.8%	7.1%	6.9%	0.5%	1.9%	3.1%	1.1%
Construction	1.2%	2.8%	1.2%	1.5%	1.3%	1.2%	13.2%	12.6%	0.3%	0.1%
Energy	3.0%	1.8%	3.5%	2.9%	1.2%	0.9%	13.0%	3.5%	1.7%	0.6%
Financial	1.7%	1.8%	3.1%	3.7%	0.0%	0.0%	0.0%	1.0%	0.3%	0.8%
Health industries	21.0%	21.5%	15.3%	20.0%	11.3%	13.5%	1.9%	7.0%	26.2%	28.2%
ICT producers	24.8%	22.6%	18.3%	14.8%	22.3%	18.4%	33.7%	26.6%	26.8%	22.2%
ICT services	10.2%	19.8%	5.9%	7.7%	5.9%	8.3%	6.7%	17.7%	17.5%	33.1%
Industrials	6.7%	5.0%	8.3%	6.0%	10.0%	7.8%	12.8%	10.4%	4.6%	1.9%
Others	8.0%	6.9%	6.1%	4.9%	15.3%	13.9%	3.5%	9.7%	6.4%	4.1%

Note: **Orange** = lower than *Scoreboard* average, **blue** = higher than *Scoreboard* average
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

3.5 Keys points

- The importance of the top 50 corporate R&D investors is shown by the relative stability in terms of sample composition and their large share of global R&D investment throughout the last decade. In this group of companies, the EU has a strong and stable presence in terms of number of companies; until this year, the EU companies have been the second largest R&D investors behind the US. However, the average growth rate of R&D investment of the EU companies over the past 10 years lags behind that of the top 50.

- A significant share of companies present in the *Scoreboard* nowadays has not managed to enter the top 500 from any position between 501 and 2500 in the past 10 years.

- The number of EU companies decreased by a net amount of 13 companies per year on average during the last decade. While in the top 500 the decrease was only marginal, in the lowest quintile group the number of EU companies have almost halved, from 103 companies in 2012 down to 56 by 2022. The main reasons behind these changes are mergers and company reorganisations as well as R&D being too low to reach the *Scoreboard* threshold suggesting a relatively low growth amongst small up-and-coming companies.

- The share of R&D investment in health and ICT services in the total *Scoreboard* has increased in every major investor region at the expense of ICT producers. Some sectoral increases are rather significant, such as health R&D share in China and ICT services in the US.

- The automotive sector R&D was by far the most significant for both the EU and Japan and its importance increased over the last 10 years. Its share in the total R&D invested by companies headquartered in these regions is around 30% (Japan) and 32.5% (the EU). These shares are more than double than the share of the automotive on the level of the entire *Scoreboard*.

- A significant share of Chinese *Scoreboard* companies are in the construction, industrials, and energy sectors, with the latter experiencing a strongly declining R&D share, although it is still somewhat higher than the share of the energy sector on the level of the entire *Scoreboard*.

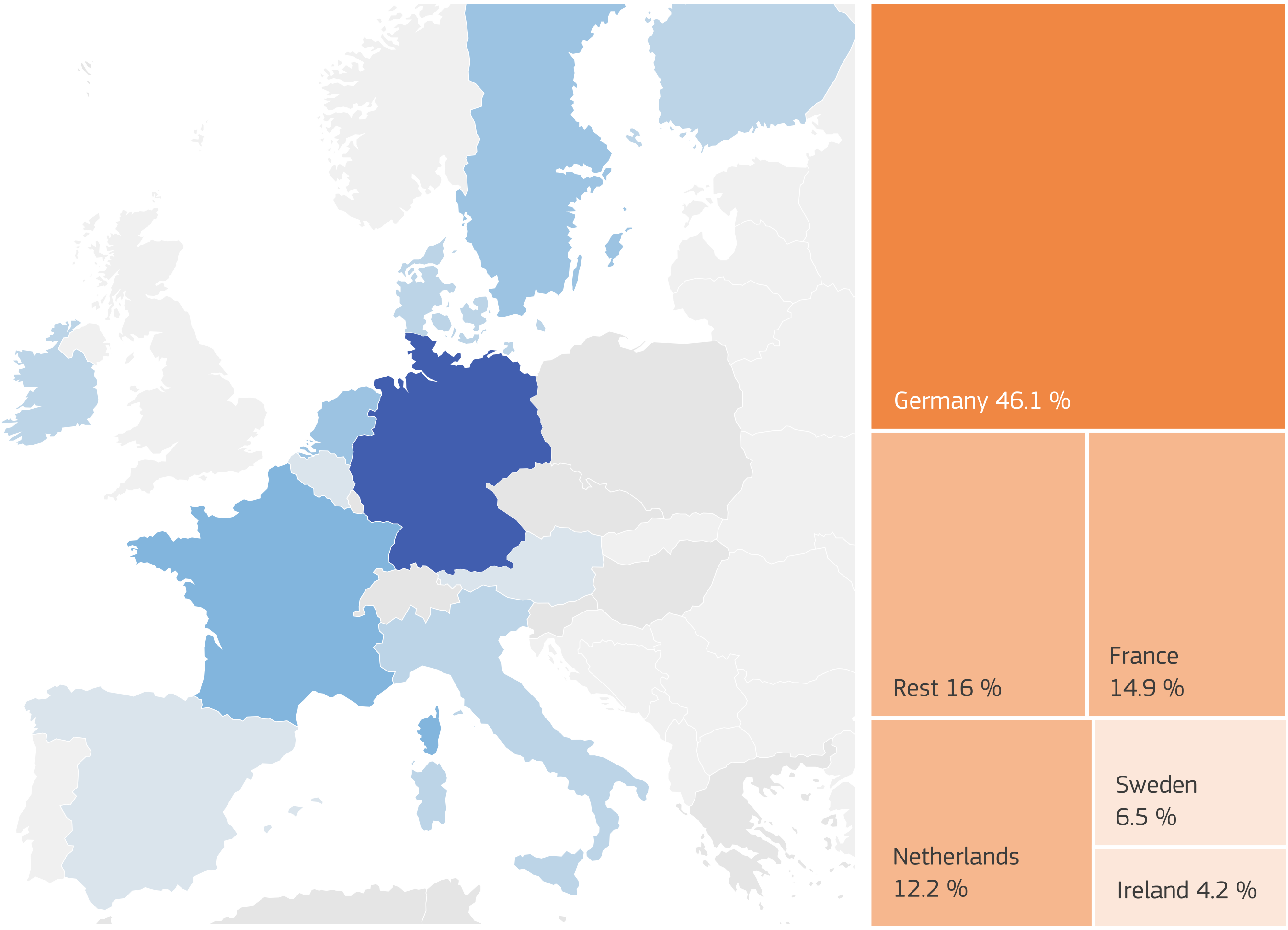
4 A CLOSER LOOK AT THE EU

This chapter provides a more detailed description of the private R&D investment across EU countries, based on data of the 1000 companies headquartered in the EU with the highest R&D investments. This includes the 361 EU headquartered companies in the global 2500. 639 additional companies spent between EUR 48.7 million (the threshold to get into the top 2500 ranking) and EUR 3.1 million in 2021. The threshold to enter the EU1000 sample increased by around 50% compared to the 2021 *Scoreboard* (which was EUR 2 million), mainly as the result of the economic recovery after the COVID-19 pandemic. This chapter is structured as follows: Section 4.1 gives a country overview, Section 4.2 provides a look at the sectors, Section 4.3 presents details on the three largest R&D sectors in the extended sample, and the final Section 4.4 gives a closer look at the top 5 R&D investing countries in the EU-27.

4.1 Top 1000 EU R&D investors – country overview

The geographical distribution of the EU1000 companies is presented in figure 4.1. Overall, the EU1000 companies are located in 19 Member States and invested EUR 202.9 billion in R&D in 2021. The 639 companies from the extended group add EUR 10.1 billion to the EUR 192.8 billion of the core 361 companies (5% of the total R&D investment by the EU1000).

Figure 4.1: Total R&D Investment by the EU1000 – Map / Treemap of the distribution of R&D investment



Note: Map - colour darkness proportional to R&D investment in 2021 by companies headquartered in the country.
Treemap – Top 5 countries representing 84% of R&D in the EU1000 sample, the remaining 14 countries are responsible for 16% of the total.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table 4.1 presents the distribution of R&D by Member State for the EU1000 firms. The top three countries in terms of R&D investment by the EU1000 sample, Germany, France, and Netherlands, represent together 50.1% of the companies with headquarters there and 73.3% of R&D investments. However, also Member States without representation in the EU1000 do have R&D investing firms but their investment either does not reach the threshold of EUR 3.1 million, they are affiliates, headquartered in other countries or not publicly listed.

Table 4.1: R&D by Member State in the EU1000 sample

Country	Companies (core/extended)	R&D (EUR m)	Share of companies	Share of R&D
Belgium	34 (12/22)	3 480.06	3.4%	1.72%
Czechia	1 (0/1)	21.84	0.1%	0.01%
Denmark	66 (25/41)	7 804.46	6.6%	3.85%
Germany	285 (114/171)	93 620.49	28.5%	46.15%
Ireland	42 (24/18)	8 575.12	4.2%	4.23%
Greece	7 (0/7)	40.18	0.7%	0.02%
Spain	27 (12/15)	4 698.73	2.7%	2.32%
France	149 (57/92)	30 306	14.9%	14.94%
Italy	45 (20/25)	5 689.19	4.5%	2.80%
Luxembourg	25 (3/22)	1 678.75	2.5%	0.83%
Hungary	1 (1/0)	165.37	0.1%	0.08%
Malta	1 (1/0)	62.62	0.1%	0.03%
Netherlands	66 (38/28)	24 755.13	6.6%	12.2%
Austria	38 (13/25)	2 446.48	3.8%	1.21%
Poland	3 (0/3)	78.72	0.3%	0.04%
Portugal	5 (2/3)	228.87	0.5%	0.11%
Slovenia	1 (1/0)	154.55	0.1%	0.08%
Finland	52 (12/40)	5 946.95	5.2%	2.93%
Sweden	152 (26/126)	13 112.85	15.2%	6.46%
Total	1000 (361/639)	202 866.4	100.0%	100.0%

Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

4.2 Top 1000 EU R&D investors – sectoral overview

The distribution R&D investment of the EU1000 companies across sectors is shown in Table 4.2. The largest sector in terms of R&D is of course automobiles and other transport, which is responsible for over 31% of R&D in the sample, followed by the health industries. From the 1000 companies, 170 are SMEs with less than 250 employees; in each sector, there is at least one SME that belongs to the 1000 largest R&D investors, and in both health industries and ICT services 2 SMEs belong to the EU core group, and one firm in construction as well. In sum, there are only few more SMEs in the extended EU sample than the US has SMEs in the global top 2500 R&D investors (156); in Europe, each 5 SMEs in the top 2500 come from the UK and Switzerland.

Table 4.2: R&D by sector in the EU1000 sample

	Countries	Core group	Extended group	SMEs	R&D, EUR m	Share of R&D
Aerospace & defence	7	10	5	1	6 432.8	3.2%
Automobiles & other transport	10	34	26	3	63 193	31.1%
Chemicals	9	16	21	2	5 624.6	2.8%
Construction	12	9	29	2	3 371.8	1.7%
Energy	15	26	12	2	5 794.5	2.9%
Financial	12	22	48	4	7 845	3.9%
Health industries	14	68	128	98	40 508.4	19.9%
ICT producers	12	42	74	16	29 717.8	14.7%
ICT services	14	30	78	21	15 955.5	7.9%
Industrials	12	57	95	3	13 171.7	6.4%
Others	16	47	123	18	11 251.3	5.6%

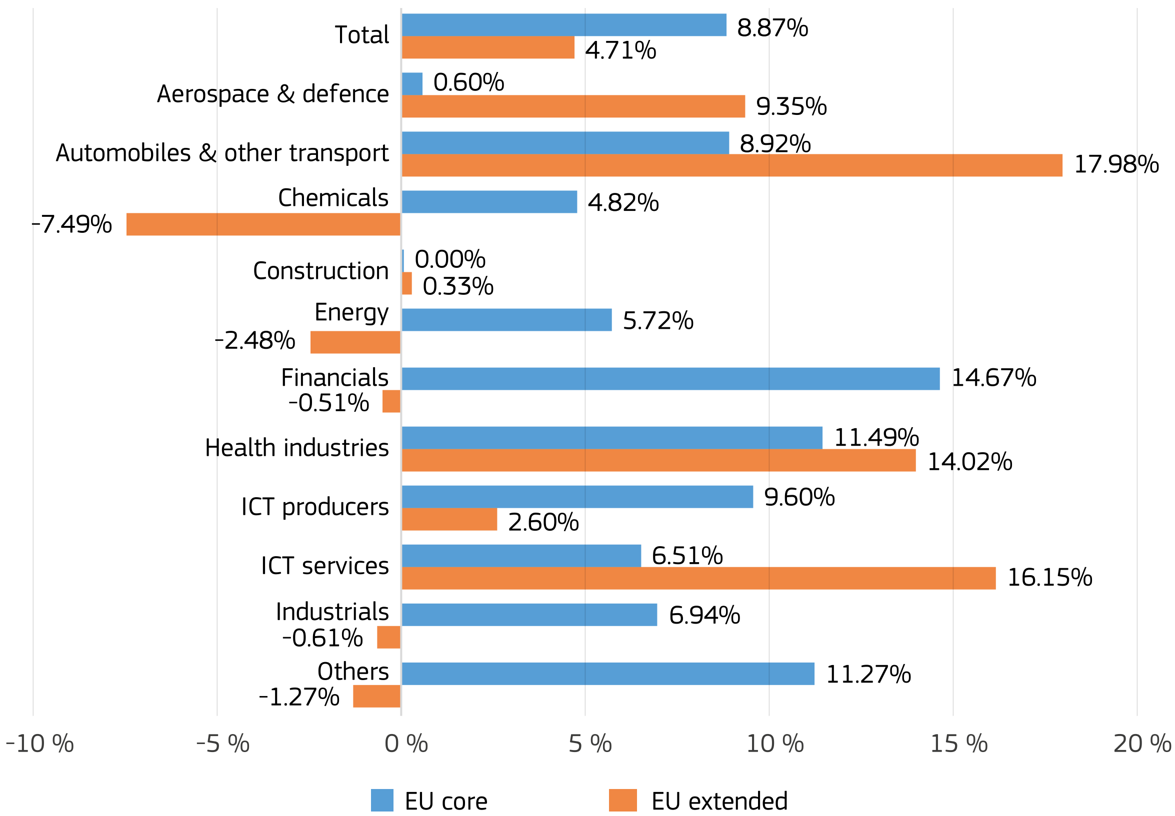
Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 4.2 displays the growth of R&D investment across sectors for the core and the extended group. Overall, the R&D investment of the core companies increased by 8.87%, significantly higher than for the extended group (4.71%) but six percentage points lower than the growth of total R&D investment by the top 2500. In sum, the core group spent EUR 15.69 billion more on R&D in 2021 than in the previous year – an amount that exceeds the total R&D of the remaining 639 companies by 50%.

The growth rates of R&D investment vary considerably across sectors and also between the two groups. The core companies in aerospace and defence report only a marginal increase of 0.6% after the massive decline of 22.6% in 2020 - the total R&D investment by these ten companies in 2021 therefore remains almost EUR 1.8 billion below the level of 2019. In contrast, the extended group companies continue their positive growth trajectory from the past year with an increase of 9.35%, but their total R&D amounts to only EUR 74 million.

In the chemicals sector, the growth of R&D investment in the core group was strong enough to reach the 2019 level, while in the extended group the decline observed in 2020 continued in a similar magnitude. While the companies in construction raised their R&D investment only by little (if at all), a dynamic development is observed for the other sectors. Particularly positive is the development of the core companies in the financial and energy sector – however, these sectors, as aerospace and defence, comprise only small shares of total R&D of the EU1000 companies (compare Table 4.2, Figure 4.3)

Figure 4.2 : 1-year R&D growth rates by sector- EU core vs EU extended group



Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The most significant increase for the total R&D investment of the EU1000 comes from the companies in automobiles and other transport – the core group invested over EUR 5 billion more in 2021 and thereby slightly surpassed the R&D investment of 2019, and the extended group companies report the largest relative increase in R&D investment across all sectors. Given the high weight of this sector in the EU (31.3% of the total R&D in the EU1000), this development is a significant driver of the EU total.

The core firms in health industries continue their expansion, and also the extended group companies significantly raised their R&D investment after the decline in 2020 (-5.3%). Overall, the 68 EU health companies in the core group spent EUR 38.5 billion on

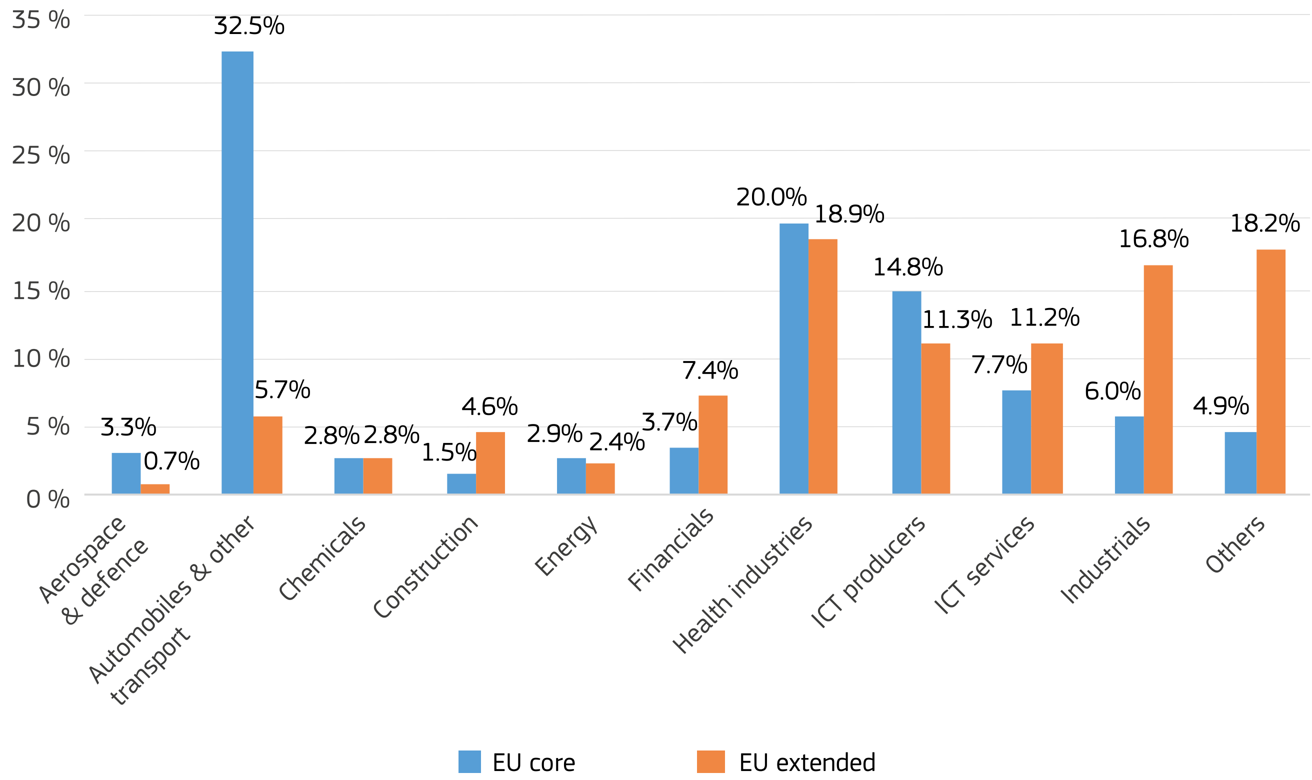
R&D in 2021, the second most important R&D sector in the EU. This positive development is to a large extent determined by the European companies in biotechnology and pharmaceuticals that developed vaccines and treatments against COVID-19; overall, the sector's R&D investment increased by EUR 4 billion compared to 2020 (plus EUR 6 billion compared to 2019).

For the ICT producers and ICT services, both groups raised their R&D investment in the previous year, but while the core group of ICT producers expanded almost three times more than the extended group, the extended group of ICT services increased their R&D much stronger than the core group. Overall, this implies for ICT producers that they slightly surpassed the level of R&D in 2019 (after the reduction in 2020), while for ICT services, which continued its expansion form 2020, the 2021 R&D investment exceeds the 2019 level by EUR 2.2 billion.

Finally, the core companies in industrials and the group "others" both increased their R&D investment in 2021. However, for the industrial core companies, this increase was not enough to reach the R&D investment from the year 2019, while the core companies in "others" continued their expansion path. The companies of the extended group in these two sectors reduced their R&D in 2021 compared to 2020 and thereby perpetuate the negative development of the past year, albeit at a slower pace.

Figure 4.3 displays the distribution of R&D across sectors for the core and extended group of the EU headquartered SB companies. The R&D investment distribution across sectors between the core and the extended sample firms differs considerably. While in the core group, the automobile and other transport sector dominates the distribution, the

Figure 4.3 : R&D share by sector - core EU vs extended EU



Note: "Core" refers to the 361 companies in the global top 2500, "extended" refers to the additional 639 companies that form the EU1000 R&D investors. The percentages are the shares of R&D by sector of the core (blue bars) and extended (orange bars) groups.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

extended group distribution has more weight in the high-tech sectors health industries, ICT services and ICT producers, as well as in "others" and industrials. Taken together, ICT services and ICT producers constitute the largest sector in the extended sample with 22.5% of R&D investment.

The extended group shares of R&D in ICT services and industrials are higher than the corresponding ones of the core group. The largest share of R&D in the extended sample is attributed to companies in health industries – with 18.9% of the total the sector ranks first, followed by "others" with 18.2%. Bearing in mind the small amount of R&D the extended group represents, the analysis of the sectoral distribution of R&D in the extended group can give insights into the role of small R&D investors in important high-tech sectors where the EU lags behind its competitors.

4.3 Top 3 Sectors in the Extended Group

The three largest sectors in term of R&D investment in the extended group of the EU1000 are health industries, the group of "others" and industrials; these three sectors comprise 346 of the 639 extended group companies and EUR 5.44 billion of the total of EUR 10.1 billion R&D investment of this group (54.1% of companies, 53.9% of R&D). The analysis of these sectors of the extended sample of R&D investors in the EU allows obtaining a deeper understanding of the most important sectors beyond the well-known top R&D investors.

Table 4.3 displays how the number of firms and the R&D investment of the three sectors is distributed across EU Member States, as well the growth rate of R&D investment of those firms compared to 2020. The companies in the sectors health industries and "others" come from 11 Member States, and from 15 for industrials. While the companies in health increased their R&D investment considerably (see above), the companies in the other two sectors reduced their R&D (compare Figure 4.2). It is important to note that the growth rates in R&D investment by country and sector can be driven by actions of a few firms.

75% of the companies in health industries are SMEs with less than 250 employees, while this share is only 3.2% for industrials, and 14.6% for "others". Out of all 170 SMEs in the EU1000, 96 are in the extended group in the health sector. In health industries, France, Sweden and the Netherlands are by far leading in terms of R&D investment and number of companies; overall, 60 Swedish companies are SMEs, and 29 of them in the health sector, France has 40 SMEs with 28 being in health. The growth of R&D investment in this high-tech sector and the large number of SMEs is an encouraging sign of a deepening of this important sector in the EU.

The group "others" contains a heterogeneous set of firms: 69 of the 123 companies are in high- or medium-high tech segments[81], in particular in fields such as leisure goods, (business) support services or personal goods. The small decrease in R&D compared to 2020 is the results of reduced investment of several larger firms in this group, while the majority of firms increased their R&D relative to the previous year. There are 18 SMEs in this group and they spread proportionally across the different fields of activity.

The third largest sector of the EU extended sample in terms of R&D is industrials that contains firms in medium-high (74 firms) and low-tech (21 firms) segments. While the companies in the medium-high tech segments increased their R&D investment compared to the previous year, those in low-tech decreased it, leading to an overall reduction in this sector.

[81] We follow the OECD technology classification based on R&D intensity: Galindo-Rueda, F. and F. Verger (2016), 'OECD Taxonomy of Economic Activities Based on R&D Intensity', OECD Science, Technology and Industry Working Papers, No 2016/04, OECD Publishing, Paris, https://doi.org/10.1787/5jlv73sqqp8r-en.

Table 4.3: EU extended group – Top 3 sectors: Country overview

	Health industries			Others			Industrials		
	n	R&D, EUR m	1-year R&D growth (%)	n	R&D, EUR m	1-year R&D growth (%)	n	R&D, EUR m	1-year R&D growth (%)
Belgium	7	128.61	2.98	4	46.15	29.87	4	65.11	-2.81
Denmark	9	131.56	31.89	7	140.88	-9.72	3	86.93	7.13
Germany	13	170.91	-12.91	36	564.40	-7.21	32	599.88	3.18
Ireland	7	65.93	-16.58	5	62.98	12.56	0		
Greece	0			1	6.58	15.10	0		
Spain	4	50.06	12.87	2	11.66	11.74	2	29.30	-0.46
France	33	532.80	8.50	12	187.12	-1.07	12	217.58	-15.69
Italy	4	63.23	14.86	6	84.37	12.39	5	146.62	7.34
Luxembourg	0			4	64.41	1.52	6	91.80	4.85
Netherlands	11	315.96	60.53	4	70.50	3.64	4	105.33	11.49
Austria	3	17.11	3.57	5	88.51	14.02	3	39.11	7.35
Poland	0			2	52.11	-52.13	0		
Portugal	0			1	16.47	34.50	0		
Finland	3	31.64	20.27	12	160.00	16.93	6	95.35	-9.08
Sweden	34	401.92	16.54	22	284.39	10.40	18	221.08	-4.68
Total	**128**	**1 909.73**	**14.02**	**123**	**1 840.51**	**-1.27**	**96**	**1 698.09**	**-0.61**

Note: Health industries comprise the subsectors pharmaceuticals & biotechnology and health care equipment & services; Industrials comprise general industrials, industrial engineering, industrial transportation, industrial metals & mining, and the sector "others" contains leisure goods, household goods & home construction, forestry & paper, support services, food producers, general retailers, personal goods, food & drug retailers, media, travel & leisure, tobacco, mining, and beverages.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Even if the R&D investment of the selected three sectors is similar, the remaining financial indicators displayed in Table 4.4 show how different they are. The companies in health so far serve only a small market in terms of net sales, and relating this to their R&D investment results in an R&D intensity close to 100%; aggregate profits are negative for this group as 96 out of the 128 companies marked a loss in 2021. At the same time, capital expenditures increased by 18.39%, employment by close to 14% and market capitalisation by almost 60%. The strong development of this SME dominated nascent group of R&D intensive companies in the extended sample of the EU1000 is a positive sign for a growing biotechnology and pharmaceutical sector in the EU.

Table 4.4: EU extended group – Top 3 sectors: Financial indicators

	Health industries	Others	Industrials
Net sales (EUR m)	11 054	196 609	291 790
One-year change	10.47%	10.54%	21.23%
R&D intensity	99.95%	2.30%	2.28%
Operating profits (EUR m)	-665	8 924	27 291
One-year change	29.58%	456.69%	141.14%
Profitability	-6.02%	4.54%	9.34%
Capex (EUR m)	568	7 622	10 064
One-year change	18.39%	8.50%	16.87%
Capex/net sales	5.14%	3.87%	3.45%
Employment	44 400	740 469	1 231 303
One-year change	13.89%	0.12%	3.31%
R&D per employee, EUR	42 774	2 522	1 387
Market capitalisation (EUR m)	59 156	187 002	249 766
One-year change	58.36%	38.71%	51.15%

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Very much in contrast are the figures for industrials. Net sales of the EU extended group industrial companies amounted to over EUR 291 billion in 2021, a strong increase of 21% compared to 2020 that mainly relates to effects connected to COVID-19 and the economic recovery process, in particular for transport and logistics services. As an example, the net sales of Deutsche Post (industrial transportation) increased from EUR 63.3 billion in 2019 to EUR 81.7 billion in 2021; another example is the Danish logistics provider DSV that doubled its net sales since 2019 to EUR 24.5 billion. Also the companies in industrial metals and mining saw both their net sales and profits increase with the economic upswing and the demand- and supply-driven price increases of their products in 2021. A positive development is also the growth in employment of this labour-intensive sector – over 1.2 million people work for these 96 companies.

The companies collected in the group "others" also recovered from the COVID-19 pandemic, but developed in a less positive way than industrials. The at first sight almost unrealistic increase of profits by 456% is a result of the sector composition: The sector "others" encompasses the large travel providers such as Lufthansa or TUI that made significant losses in 2020 due to COVID-19 which could be reduced in 2021 but profits remained negative. Similarly, related leisure good providers such as Samsonite recorded massive losses in 2020 that were recovered in 2021. Also, producers of food and beverages, tobacco and forestry and paper recorded increased net sales and profits in 2021 and in many instances, the 2021 values exceeded those for 2019.

Combining the ICT services and ICT producers sector into one ICT sector, these 152 companies cover 22.5% (EUR 2.2 billion) of the R&D investment of the extended group and thereby constitute the largest R&D investing sector in this group. Their combined R&D investment grew by 8.9% relative to the previous year and is thus in line with the EU1000 sample. The top 5 countries in the ICT sector, Germany (50 firms), France (27), Sweden (27), Finland (14) and Denmark (8) headquarter 82% of the companies as well as of R&D investment. Here again an already familiar pattern emerges: Germany has the largest number of companies and the highest R&D investment (EUR 676 million), and Sweden has the most SMEs (13 out of 27 companies).

4.4 Country Focus – Top 5 EU Countries

Table 4.5 presents the main financial indicators for the companies headquartered in the top 5 countries in terms of R&D investment in the EU1000 sample. The number of companies in the top 1000 per country changed slightly: Germany lost 9 companies, Netherlands gained 3, Ireland gained 2, and Sweden and France each gained one company compared to 2020.

Companies headquartered in Germany are by far the largest R&D investors: as an example, the German automotive and other transport sector invested EUR 45.79 billion in R&D in 2021, while in France - the number two R&D investor in the EU-27 – all companies in the ranking together spent EUR 30.3 billion. With this value, France is the only country of this selection in which the level of R&D investment in 2021 is below its pre-COVID value (EUR 34.07 billion, see *Scoreboard* 2020).

Table 4.5: Main economic indicators for the EU1000 – Top 5 Member States

	Germany	France	Netherlands	Sweden	Ireland
Companies	285	149	66	152	42
R&D investment (EUR m)	93 620	30 306	24 755	13 112	8 575
One-year change	7.99%	2.67%	21.93%	5.62%	10.46%
Net sales (EUR m)	2 174 800	1 176 955	563 486	250 006	252 865
One-year change	14.07%	17.07%	24.81%	8.70%	11.28%
R&D intensity	4.87%	7.51%	6.03%	5.94%	4.08%
Operating profits (EUR m)	171 452	115 211	66 545	39 242	33 311
One-year change	219.53%	97.15%	185.52%	53.33%	67.30%
Profitability	7.88%	9.79%	11.81%	15.3%	13.17%
Capex (EUR m)	111 453	83 158	21 167	10 139	8 320
One-year change	1.93%	8.69%	-12.03%	30.34	-3.49%
Capex/net sales	5.12%	7.07%	3.76%	4.06%	3.29%
Employment	6 891 788	4 173 099	1 387 693	871 984	1 387 693
One-year change	-0.92%	-3.84%	9.91%	4.56%	10.27%
R&D per employee, EUR	13 5848	7 262	15 495	15 037	6 179
Market capitalisation (EUR m)	1 632 977	1 464 341	902 013	455 060	847 367
One-year change	29.65%	30.72%	61.64%	38.14%	37.61%

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The most striking figure in Table 4.5 is the strong increase of R&D investment in the Netherlands by 21.94% – almost 40% of the increase is linked to Stellantis, which raised its R&D in 2021 by over EUR 2 billion. Also, Curevac (mRNA therapies, COVID-19 vaccine development) raised its R&D from EUR 87.5 million to EUR 722.5 million. The influence of the registration of the Stellantis headquarter in the Netherlands is visibile also in the other indicators: the close to EUR 4 billion reduction of capital expenditures (CAPEX) and the increase in market capitalisation by EUR 12 billion drive the overall strong decline in CAPEX and the strong increase in market capitalisation for the Netherlands. The same holds for employment – the almost 10% increase compared to 2020 is driven by the merger of Stellantis; with this bookkeeping transfer it increased employment by 100 000 full time equivalents. Overall, if Stellantis had not registered its headquarter in the Netherlands, R&D investment in Netherlands would have still grown by over 14%, and employment by around 3% (compare Chapter 2).

The second noticeable observation is the increase in profits in all five countries, and in particular in Germany and the Netherlands. The total profits of the German R&D investors increased by 219% compared to 2020, those of the Dutch companies by 185%. While an increase in profits is observed for all selected countries and is natural after the strong contraction due to COVID-19, the German numbers require a more detailed look (compare also section 4.3).

The German car producers realized massive profits in 2021: Mercedes-Benz profits increased from EUR 7 billion in 2020 to EUR 28 billion in 2021; from this, EUR 12.4 billion profit was gained solely from discontinued operations that comprised the profit from the spin-off and hive-down of the former Daimler Trucks & Buses segment. Volkswagen doubled its profits from EUR 9 billion to EUR 18 billion, and BMW almost tripled it from EUR 4.8 billion to EUR 13.4 billion. Not only the German luxury car producers had a golden year 2021, also companies such as Rheinmetall AG, Deutsche Bank, Deutsche Telekom, Deutsche Post, BASF and Infineon saw massive increases in profits that partly by far exceeded any of the past ten years. Last but not least, the German COVID-19 vaccine developer BioNTech earned profits of EUR 14.9 billion in 2021 after a loss of EUR 82 million in 2020. Nevertheless, the profitability of the German top R&D investors was considerably lower than of the companies in the other economies presented in Table 4.5.

A closer look at France reveals why the aggregate R&D investment is below the 2019 level, even if more French companies are in the EU1000 than in 2019, when UK companies were still included in the *Scoreboard*. For 4 out of the 5 largest French R&D investors Sanofi, Renault, Valeo, Schneider and Faurecia, the R&D investment in 2021 was considerably lower than in 2019 (except for Schneider). The large French aerospace and defence sector raised its R&D by 3.12%, but the automotive sector reduced its investment by over 5%. Even if R&D investment in France is not as concentrated as in Germany with the all-dominating automotive sector, the growth in R&D investment by 87 out of the 149 firms in 2021 was not enough to reach the aggregate of 2019.

As mentioned above, the group of French firms in the top 1000 contains many companies from the health sector (41), and 28 of them are SMEs. The health sector is a driving force for the increase in net sales of the French companies, even if many of these companies were not yet profitable, their market capitalisation increased in 2021.

Sweden, the third largest R&D investing country in the EU-27, has three large R&D investors that spent over EUR 1 billion in R&D; at the same time the largest number of SMEs in the EU1000 is located in Sweden. While in aggregate, the Swedish companies show the lowest growth rates in terms of net sales and operating profits, they have the largest increase in capital expenditures of the 5 countries. Vattenfall (energy) and Volvo (automobiles) are the companies that drive the increase of almost 18%. Also SSAB, the largest steel manufacturer in Scandinavia, contributed significantly to the increase in profits and market capitalisation. Many of the small Swedish companies in health industries significantly increased their R&D compared to 2020 (and also relative to 2019), but given their relatively low amounts this has only a minor effect on aggregate R&D investment in Sweden.

With 10.46%, Ireland experienced the second largest increase in R&D investment of the 5 top R&D investing countries in the EU-27. Strong and quantitatively important contributions to R&D growth came from companies in health industries, i.e. Medtronic (which is responsible for over a quarter of Irish R&D in the SB), Jazz Pharmaceuticals or Horizon Pharma, but also Accenture raised its R&D investment by over EUR 200 million compared to 2020. Market capitalisation of the 42 companies increased by over 38% since 2020 – this is mainly the result of Johnson Controls (American Irish-domiciled multinational conglomerate for equipment, controls and services for energy efficiency of buildings) that witnessed a EUR 20 billion increase in market capitalisation to currently over EUR 47 billion. Finally, the strong growth in employment of the Irish top R&D investors of 10.27% relates almost entirely to Accenture that increased its number of employees from 506 000 to 624 000, worldwide.

4.5 Key points

- In 2021, the largest 1000 corporate R&D investors in the EU spent EUR 202.8 billion on R&D; 95% of this amount was invested by the 361 companies that belong to the group of the global top 2500 R&D investors. In addition, 639 companies that spent between EUR 48.7 million (the threshold to get into the top 2500 ranking) and EUR 3.1 million in 2021, are included in the EU1000. The threshold to enter the EU1000 sample increased by around 50% compared to the 2021 *Scoreboard*, mainly as the result of the economic recovery from COVID-19.

- The sample of the EU1000 displays the large variety of innovative companies in the EU-27. The traditional stronghold of EU corporate R&D lies in the automotive sector, 31.2% of the total corporate R&D was realised in this sector. On the other end of the scale, the *Scoreboard* identifies a significant number of smaller R&D investors in important and fast-growing high-tech sectors such as health or ICT.

- Both, the largest R&D investors and the smaller ones increased their R&D investment in 2021 compared to the previous year. The 361 EU companies that are also in the top 2500 raised their R&D by 8.87%, while the additional 639 companies increased their R&D by only 4.71%. Along with the recovery from COVID-19 in terms of R&D investment, also profits, sales and employment developed favourably in 2021.

- The pace of growth of the EU1000 aggregate R&D investment was again slower than for the other world major R&D investing regions - the US and China. The analysis of the top EU1000 R&D investors revealed that policy support for this heterogeneous group of companies, spanning from very large global corporations to high-tech SMEs, requires a broad mix of policies, ranging from investments into specific technologies (e.g. EU Battery Alliance) to scale-up support for small, growing firms.

5 PATENTING TRENDS IN GREEN AND CIRCULAR ECONOMY TECHNOLOGIES

The 2021 EU Industrial R&D Investment Scoreboard provided an update on general patenting trends in climate change mitigation technologies (CCMTs), also referred to as 'green' patents, and an extensive analysis of green inventions for energy-intensive industries (EII). This year's chapter continues the review on general trends in CCMTs and focuses on patenting trends in the circular economy, one of the main building blocks of the European Green Deal[82]. The chapter provides an analysis of circular economy technologies (CETs) for the EU, a comparison with other major economies, and insights on the performance of EU *Scoreboard* companies and their subsidiaries in comparison with the leading R&D investors of other major economies.

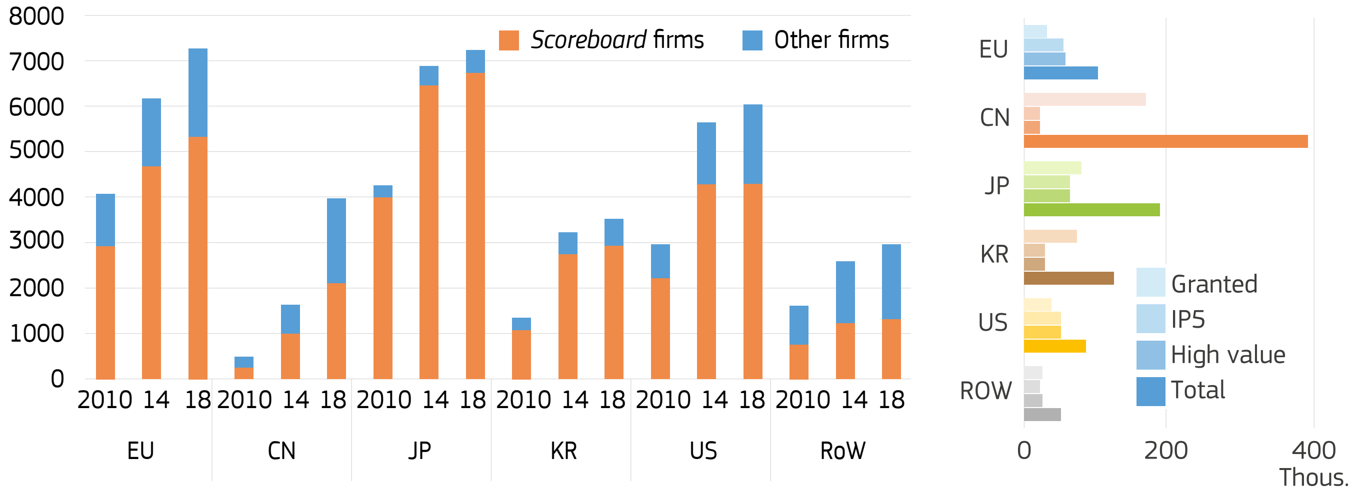
We identify the CETs through CCMT patent classes[83] and aggregate them into industry groups. Table 5.2 in Box 5.1 shows the industries analysed and the concordance of codes used in the analysis. Section 5.1 provides an update on trends in CCMTs. Section 5.2 presents an analysis of global trends in CET inventions, provides further insights on the patenting activity of EU Member states, and examines the activity of global and EU *Scoreboard* companies.

5.1 Update on overall trends in CCMTs

The global share of green inventions has increased consistently to 9% of all filings in 2018, driven by very high numbers of Chinese inventions patented domestically. Globally, green high-value inventions have a share of 10% of all high-value patent filings in 2018. At 58%, the US and the EU have the highest shares of high value patents (patents filed at several patent offices, indicating international protection) among their green patents. The EU and the US also have a more diverse contribution to green innovation from applicants beyond the *Scoreboard*. By contrast, most of the high-value green filings in Japan and South Korea come from *Scoreboard* investors (Figure 5.1). The *Scoreboard* companies have a share of around 73% of green high-value inventions in 2018. Overall, the EU is among the leaders in high-value green inventions, having caught up with Japan. However, Japan remains in the lead in high-value green inventions by *Scoreboard* companies.

[82] Factsheets on the European Green Deal: https://ec.europa.eu/info/publications/factsheets-european-green-deal_en
[83] Section Y02 of the CPC classification. https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions

Figure 5.1: Trends in high-value green inventions: *Scoreboard* firms and other applicants



Note: On the left: trend of annual fillings of high-value green inventions for major economies for the years 2010, 2014 and 2018.
On the right: Green inventions in the period 2010-2018: total number of inventions, high-value inventions, IP5 inventions and granted inventions for major economies.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Box 5.1: Methodology

Patenting trends are produced following the methodology developed by the JRC[84] to derive indicators on global inventions in clean energy technologies[85]. Patent data are retrieved from PATSTAT 2022 Spring Edition. As data are not as complete from 2019 onwards, the analysis relies on 2018 annual figures to compare across major economies and to compute the specialisation index.

The analysis is restricted to Climate Change Mitigation Technologies (CCMTs)[86]. CCMTs – referred to as green technologies in the context of this study - are identified through the Y02 and Y04 schemes of the Cooperative Patent Classification (CPC).

[84] JRC publications:
- Pasimeni, F., Fiorini, A., and Georgakaki, A. (2021). International landscape of the inventive activity on climate change mitigation technologies. A patent analysis. Energy Strategy Reviews, 36, 100677. https://doi.org/10.1016/j.esr.2021.100677
- Pasimeni, F. and Georgakaki, A. (2020). Patent-Based Indicators: Main Concepts and Data Availability. JRC121685, https://setis.ec.europa.eu/patent-based-indicators-main-concepts-and-data-availability_en
- Pasimeni, F., Fiorini, A., and Georgakaki, A. (2019). Assessing private R&D spending in Europe for climate change mitigation technologies via patent data. World Patent Information, 59, 101927. https://doi.org/10.1016/j.wpi.2019.101927
- Pasimeni, F. (2019). SQL query to increase data accuracy and completeness in PATSTAT. World Patent Information, 57, 1-7. https://doi.org/10.1016/j.wpi.2019.02.001
- Fiorini, A., Georgakaki, A., Pasimeni, F. and Tzimas, E. (2017). Monitoring R&I in Low-Carbon Energy Technologies. EUR 28446 EN, Publications Office of the European Union, Luxembourg. ISBN 978-92-79-65591-3, https://doi.org/10.2760/434051

[85] SETIS Research & Innovation data: https://setis.ec.europa.eu/publications/setis-research-innovation-data

[86] CPC classification: https://www.cooperativepatentclassification.org/cpcSchemeAndDefinitions

Table B 5.1: Y02 and Y04 schemes of the CPC classes

CCMT	Y scheme	Y02 and Y04 description
Adaptation	Y02A	Technologies for adaptation to climate change
Buildings	Y02B	CCMTs related to buildings
CCS	Y02C	Carbon capture storage (CCS), sequestration or disposal of greenhouse gases
ICT	Y02D	CCMTs related to information and communication technology (ICT)
Energy	Y02E	Reduction of greenhouse gas emissions, related to energy generation, transmission or distribution
Production	Y02P	CCMTs in the production or processing of goods
Transport	Y02T	CCMTs related to transportation
Waste	Y02W	CCMTs related to wastewater treatment or waste management
Systems	Y04S	Systems integrating technologies related to power network operation, communication or information technologies, i.e. smart grids

The JRC methodology uses patent families as a proxy for inventions. Patent families include all documents relevant to a distinct invention, including patent applications to multiple jurisdictions as well as those following regional, national and international routes. Statistics are produced based on applicants only (as the owners of the patent and, thus, directly financing R&D activities) and considering different categories of applicants, namely companies, universities and government non-profit organisations. In case of multiple documents per invention, and when more than one applicant or technology code is associated with an application, fractional counting is used to proportion effort between applicants or technological areas, thus preventing multiple counting. An invention is considered of high-value when it contains patent applications to more than one office, as this entails longer processes and higher costs and thus indicates a higher expectation of the prospects in international markets[87, 88]. Within a patent family, only patent applications protected in more than one office and in one of the largest five offices are considered as IP5[89]. High-value considers all countries separately, while IP5 requires at least one application to the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the National Intellectual Property Administration of the People's Republic of China (CNIPA) or the United States Patent and Trademark Office (USPTO). A granted invention only sums fractional counts of the patent family related to granted patent applications.

Fractional counting is also used to quantify international collaborations in patenting activity. Co-inventions are calculated based on a matrix of all combinations among co-applicants, for inventions that have been produced by at least two entities resident in two different countries. Shares of co-inventions in the same country are not considered.

87 Dechezleprêtre, A., et al., (2011). Invention and transfer of climate change–mitigation technologies: a global analysis. *Review of environmental economics and policy.*
88 Dechezleprêtre· A· et al.· (2015). Invention and International Diffusion of Water Conservation and Availability Technologies. *OECD Environment Working Papers· Nº 82.*
89 Daiko· T· et al.· (2017). World top R&D investors: industrial property strategies in the digital economy· Publications Office. https://data·europa·eu/doi/10.2760/837796

The analysis of EU *Scoreboard* companies focuses on the companies headquartered in the EU. The portfolio of inventions of these companies includes the inventions produced by all subsidiaries, irrespective of their location. The matching of subsidiaries to applicant names in PATSTAT currently covers 60% of the *Scoreboard* companies, which however account for 97% of R&D investments.

The selection of CCMTs relevant to Circular Economy Technologies (CETs) is done using relevant codes from the CPC classification shown in Table B 5.2, focusing on reuse and recycling aspects of inventive activities. Patent classes are aggregated as construction, chemicals & plastics, fertilisers, glass, metals, pulp & paper, food, fuel from waste, textiles, batteries & fuel cells, electrics & electronics, packaging, vehicles and wastewater & sludge. Chemicals & plastics, fertilisers, glass, metals and pulp & paper are the subgroups of EII. To facilitate the illustration of results, in certain instances we group textiles, batteries & fuel cells, electrics & electronics, packaging, vehicles and wastewater & sludge in the "other" category due to low levels of patent applications in corresponding technology classes.

Table B 5.2 : Concordance of circular economy technologies and CPC classes

Industry		**Technology**	
Level 1	**Level 2**	**Y02 scheme codes**	**Description**
Construction	Construction	Y02W 30/58; Y02W 30/78; Y02W 30/91	Construction, demolition, wood and furniture recycling, and the use of waste
EII	Chemicals & Plastics	Y02P 20/143; Y02P 20/582; Y02P 20/584; Y02W 30/52; Y02W 30/62; Y02W 30/74	Plastics and chemicals recycling, and the use of recycled materials
	Fertilisers	Y02A 40/20; Y02W 30/40	Fertilizers of biological origin, and the use of waste or refuse in fertilisers
	Glass	Y02W 30/60	Glass recycling
	Metals	Y02P 10/20; Y02W 30/50	Reuse, recycle and recovery of metals
	Pulp & Paper	Y02W 30/64	Paper recycling
Food	Food	Y02P 60/87	Re-use of by-products of food processing for fodder production
Fuel from Waste	Fuel from Waste	Y02E 50/30	Fuel from waste, e.g. synthetic alcohol or diesel
Other	Textiles	Y02W 30/66	Disintegrating fibre-containing textile articles to obtain fibres for re-use
	Batteries & Fuel Cells	Y02W 30/84	Recycling of batteries or fuel cells
	Electrics & Electronics	Y02W 30/82	Recycling of waste of electrical or electronic equipment
	Packaging	Y02W 30/80	Packaging reuse or recycling, e.g. of multilayer packaging
	Vehicles	Y02W 30/56	Solid waste management of vehicles
	Wastewater & Sludge	Y02W 10/40	Valorisation of by-products of wastewater, sewage or sludge processing

Note: Technology descriptions adapted from the Y02 scheme descriptions of the CPC.

Table 5.1 shows the specialisation index[90] for the nine sub-classes of green technologies in major economies and changes over the period 2010-2018. Green sub-classes (in rows) relate to the patent classification of CCMT (Table B 5.1 in Box 5.1). In 2018, the EU had the highest specialisation index in all green technologies and the strongest increase in specialisation over the reference period among major economies. The EU has a positive specialisation index in every sub-class except for the green technologies related to ICT, and has experienced an increase in its specialisation in every technological category except for adaptation technologies.

Table 5.1: Specialisation index in CCMT by technological categories and major economies (2018)

CCMT	EU		CN		JP		KR		US		RoW	
	Index	Change	Index	Change	Index	Change	Index	Change	Index	Change	Index	Change
Adaptation	0.1	0.0	-0.3	0.0	-0.5	▲ 0.1	-0.1	▲ 0.3	0.4	▼ -0.2	0.6	▲ 0.1
Buildings	0.2	▲ 0.1	0.1	▲ 0.2	-0.1	▼ -0.1	-0.1	▼ -0.4	-0.2	▲ 0.1	0.1	▼ -0.1
CCS	0.3	▲ 0.1	-0.6	▲ 0.2	-0.4	▲ 0.1	0.1	▲ 0.5	0.4	▼ -0.3	0.3	0.0
ITC	-0.5	0.0	0.8	▼ -0.5	-0.5	▼ -0.5	0.7	0.0	0.3	▲ 0.1	-0.2	▼ -0.3
Energy	0.1	▲ 0.1	-0.1	▲ 0.2	0.2	▲ 0.1	0.9	▲ 0.4	-0.4	▼ -0.3	-0.3	▼ -0.1
Production	0.2	▲ 0.2	-0.2	▲ 0.1	0.0	▲ 0.0	0.1	▼ -0.1	0.0	▲ 0.0	-0.1	▼ -0.1
Transport	0.6	▲ 0.3	-0.7	▲ 0.1	0.1	▼ -0.1	-0.2	▲ 0.2	0.1	▲ 0.1	-0.3	▲ 0.3
Waste	0.5	▲ 0.2	-0.2	▲ 0.0	0.0	▲ 0.0	-0.4	▼ -0.1	-0.1	▼ -0.2	0.5	▲ 0.2
Systems	0.2	▲ 0.3	-0.3	▲ 0.2	0.0	▲ 0.0	0.0	▼ -0.5	0.2	▼ -0.1	0.2	0.0

Note: Based on high-value inventions.
For each economy, the index in 2018 is listed in the 1st column and the change with respect to 2010 is listed in the 2nd column.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

The matrix in Figure 5.2 shows the dispersion of the nine sub-classes of green technologies across the *Scoreboard* industries. Green sub-classes (in columns) relate to the patent classification of climate change mitigation technologies (Table 1 in Box 1). In the period 2010-2019, ICT producers lead in green inventions with a share of 30% of green inventions, followed by automobiles & transport inventions. Not surprisingly, ICT producers have the major share of green inventions related to ICT (76%). Similarly, the *Scoreboard* companies in automobiles & other transport industry have the major share of green inventions related to Transport. Energy and transport are the technology areas that dominate green inventions with shares of 33% and 28%, respectively.

[90] The share of inventions in the area of interest among all inventions within a country's portfolio, compared to the respective global average share.

Figure 5.2: Matrix of patent applications of the *Scoreboard* companies' green inventions (2010-2019)

	Adaptation	Buildings	CCS	ICT	Energy	Production	Transport	Waste	Systems	
Aerospace & Defence	2%	2%	3%	1%	2%	4%	15%	2%	2%	6%
Automobiles & other transport	15%	8%	5%	2%	18%	8%	56%	5%	9%	25%
Chemicals	14%	1%	24%	0%	9%	10%	1%	18%	1%	6%
Health Industries	27%	1%	4%	1%	3%	3%	0%	4%	1%	3%
ICT producers	15%	46%	16%	76%	32%	33%	8%	17%	42%	30%
ICT services	2%	2%	1%	11%	2%	2%	0%	1%	10%	2%
Industrials	13%	15%	26%	2%	19%	25%	15%	19%	19%	17%
Others	12%	23%	20%	8%	16%	15%	3%	35%	17%	12%
	4%	7%	1%	9%	33%	14%	28%	1%	1%	100%

Note: Share of high-value green inventions labelled simultaneously with CPC codes related to technologies (rows) and ICB industries (columns).
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

5.2 Patenting trends in Circular Economy Technologies

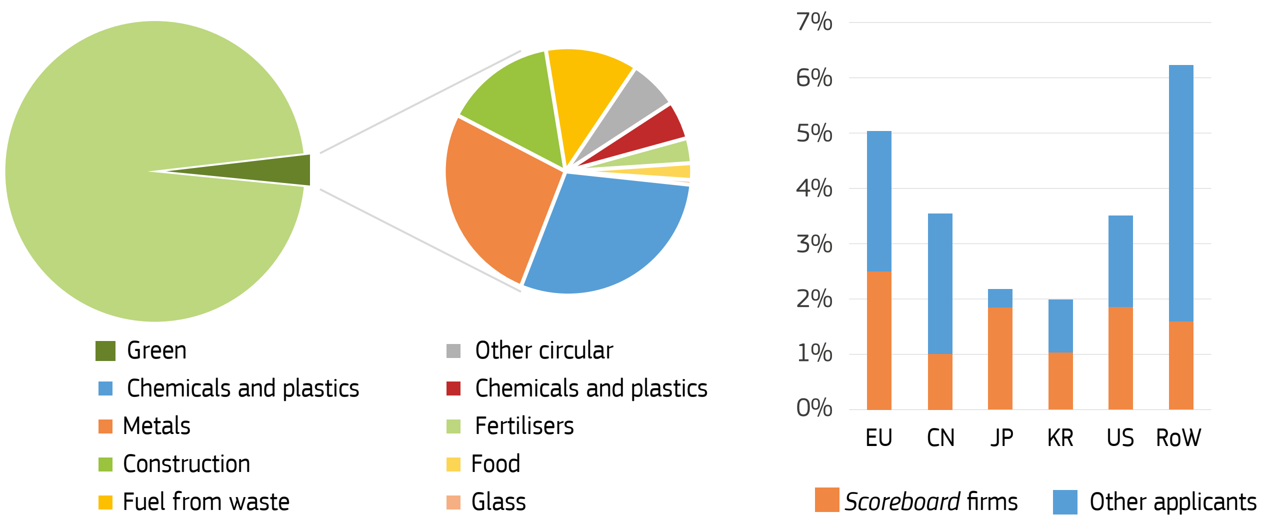
The innovative capacity of the leading EU companies in CETs is crucial to remaining competitive and leading the global transition towards a circular economy. In 2015, the EU announced the First Circular Economy Action Plan to transform the EU economy by creating new business opportunities and remaining competitive in the transition towards a circular economy[91]. The New Circular Economy Action Plan was adopted in 2020[92] and is one of the main building blocks of the European Green Deal. The plan is designed to reduce the use of natural resources by recycling and reducing waste, to create sustainable growth and jobs, and to lead global efforts on the circular economy.

The current section presents, using high-value patent statistics, the state of play in CETs for the EU in comparison with other major economies. It also provides insights on the performance of the EU *Scoreboard* companies and their subsidiaries alongside the leading R&D investors of other major economies, as these companies are the applicants of around 49% of the CET patents.

Global trends

Globally, patenting activity in CETs accounts for only about 4% of total green inventions between 2010 and 2019 (Figure 5.3). The share is the highest for the EU (5%), followed by China (4%) and the US (4%). The share of CETs in green inventions is around 2% in Japan and South Korea.

Figure 5.3: Share of CETs over green inventions in major economies. (2010-2019)

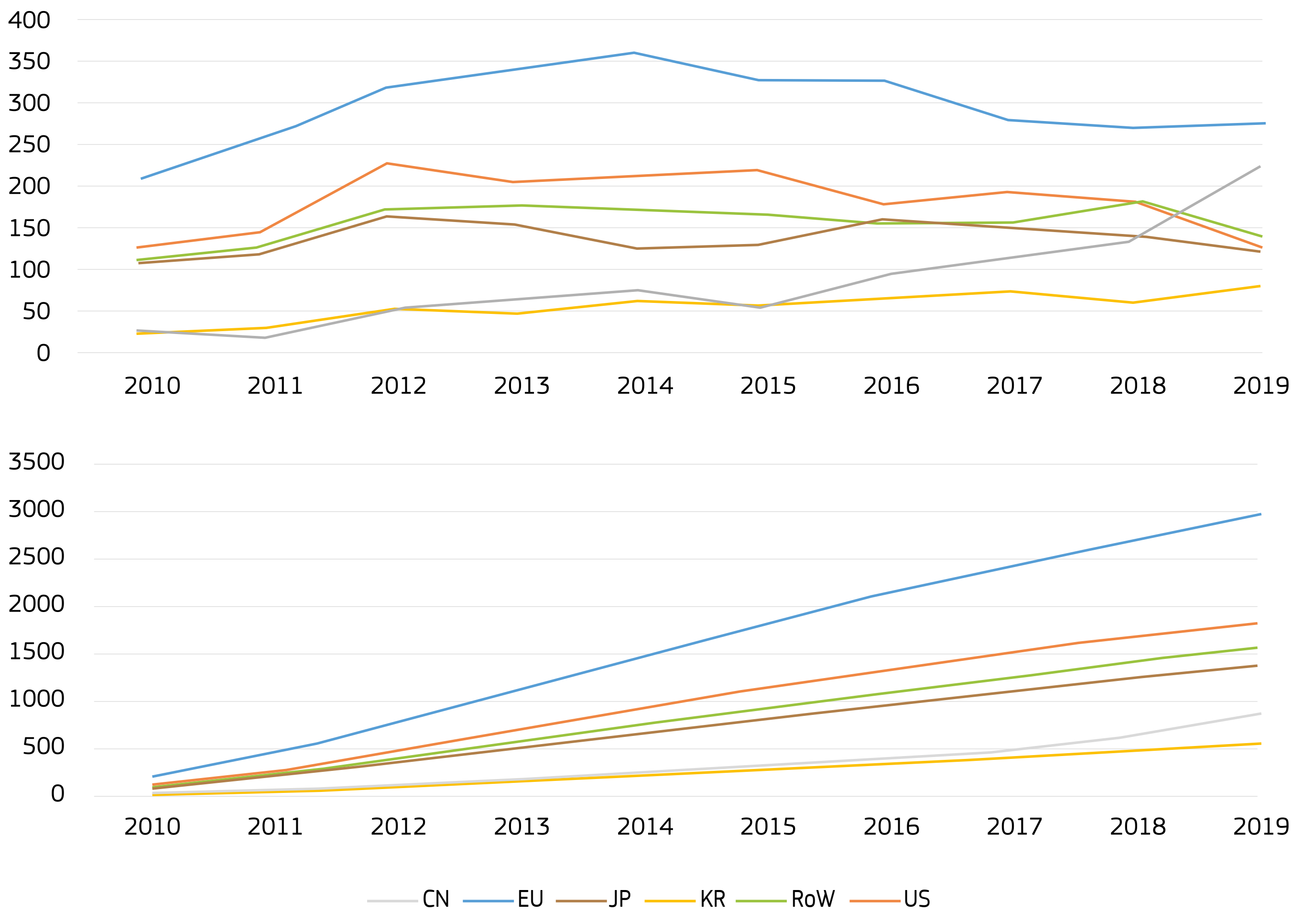


Note: On the left: Share of CETs in green inventions and the split of share by industrial categories for circular economy technologies.
On the right: Share of CETs in green inventions for major economies and the split of share between the *Scoreboard* firms and other applicants.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[91] Press release: https://ec.europa.eu/commission/presscorner/detail/en/IP_15_6203
[92] European Commission, Directorate-General for Communication, Circular economy action plan : for a cleaner and more competitive Europe, Publications Office of the European Union, 2020, https://data.europa.eu/doi/10.2779/05068

Between 2010 and 2019, the EU is the leader in CET inventions, both in absolute terms and as a share of overall green inventions (Figure 5.4). During this period, the EU's share of CETs in green inventions remains between 28% and 37%, despite a decreasing patenting trend between 2014 and 2018. The US is the second largest economy in terms of CET patenting activity, with a share fluctuating from 18% to 23%. In the US, similarly to the EU, there has been a decline in annual inventions after 2015. China had the highest growth rate over the same period; starting from a much lower level of activity, annual CET inventions more than quadrupled until 2018 and the latest figures for 2019 indicate an increase of more than seven times with respect to 2010.

Figure 5.4: High-value inventions in CETs in major economies (2010-2019[93])



Note: Top: Yearly high-value CET inventions. Bottom: Cumulative trend of high-value CET inventions.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG RTD.

In the period 2010-2019, CET inventions are concentrated in chemicals & plastics (29%), metals (27%), construction (15%) and fuel from waste (12%) as shown in Figure 5.3. The involvement of *Scoreboard* companies in CET inventions is lower than their contribution to green inventions. The *Scoreboard* companies are responsible for around 50% of the CET patents in the EU, South Korea and the US, and around 25% in China in the period 2010-2019. Similar to the trend in green inventions, the share of the *Scoreboard*

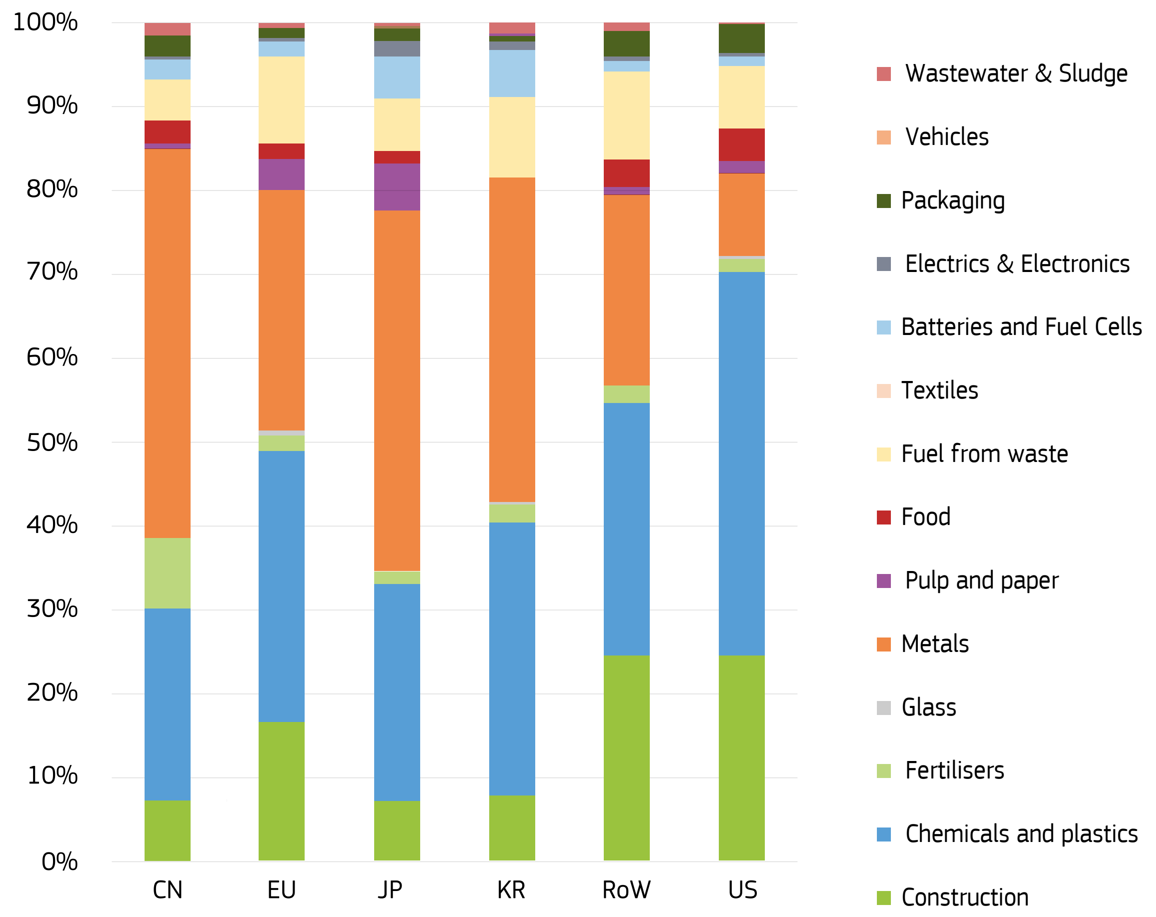
[93] Data not as complete for 2019.

companies in CET inventions remains high (around 85%) in Japan. The public sector and universities are together responsible for 15% of global CET inventions.

Figure 5.5 provides a breakdown of the CET patent filings of major economies. The distribution varies across economies. The largest industrial categories are chemicals & plastics, metals, construction and fuel from waste, while in China there is more focus on fertilisers. For the EU and the US, the chemicals & plastics category accounts for the largest share in their portfolio. The metals category comes top in Asian economies followed by chemicals & plastics, the two major subcategories of EIIs. Construction is the second largest category of CET inventions in the US (22%) but comes third or fourth in the portfolios of other economies. In China, CETs in fertilisers account for 8%, the highest share among major economies.

For all of the economies except for the US, the CET patent portfolio is largely composed of the two major subcategories of EIIs: Chemicals & plastics and metals industries. Construction comes third for the EU, with a share in its CET portfolio second only to the US. CET inventions related to fuel from waste are the fourth largest category in the EU's portfolio; the EU has the highest portfolio share for this category (11%).

Figure 5.5: Industrial distribution of CET inventions in major economies (2010-2019)



Note: Industrial categories are aggregated at Level 2 categories of Table B 5.2.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Among major economies in 2018, the EU is the only economy with a positive specialisation index[94] in most of the industrial categories for CETs except for those related to packaging (Table 5.2). Nine industrial categories have seen an increase in specialisation since 2010, the strongest of which is glass, one of the EII subcategories. Among the major economies, the EU leads the specialisation in CETs related to construction, chemicals & plastics, glass, food, fuel from waste, textiles and wastewater & sludge. China is leading in metals and has seen a substantial increase in specialisation in textiles since 2010. Japan leads in the pulp & paper and electrics & electronics industries, and is highly specialised in vehicles. South Korea leads in batteries & fuel cells as well as vehicles, and has experienced a positive trend in its specialisation in all industries except for packaging. The US leads in specialisation in CETs in packaging and has increased its specialisation in pulp & paper.

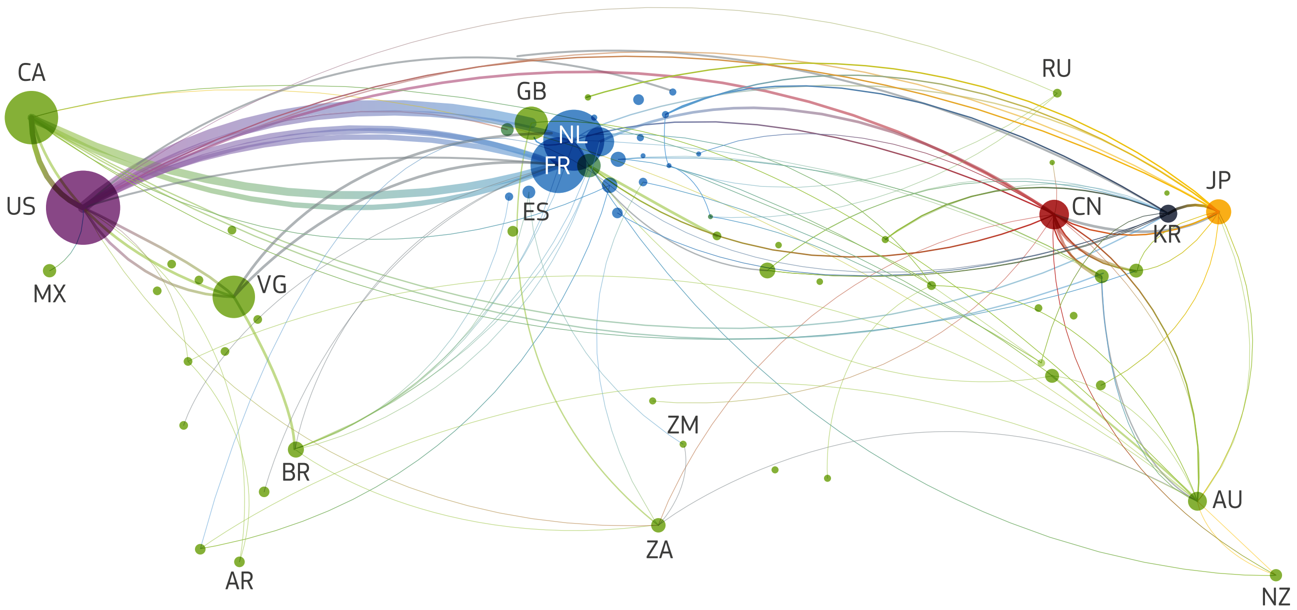
Table 5.2: Specialisation index in circular economy technologies (2018)

	EU		CN		JP		KR		US		RoW	
Industry	**Index**	**Change**	**Index**	**Change**	**Index**	**Change**	**Index**	**Change**	**Index**	**Change**	**Index**	**Change**
Construction	0.6	0.1	-0.4	0.1	-0.5	0.1	-0.3	0.1	-0.1	-0.4	1.1	0.7
Chemicals & Plastics	0.6	0.3	-0.4	-0.4	-0.5	-0.2	-0.5	0.2	0.3	0.0	0.3	0.4
Fertilisers	0.3	-0.2	-0.1	-1.1	-0.7	0.0	0.3	0.7	-0.3	-0.2	1.3	0.9
Glass	4.2	3.9	-1.0	0.0			-0.1	0.0	-0.1	-0.7		
Metals	0.0	-0.1	0.4	0.2	-0.3	0.0	-0.2	0.1	-0.4	0.0	0.8	-0.3
Pulp & Paper	0.3	-0.5	-0.8	0.2	1.4	1.5	-1.0	0.0	-0.2	0.5	-1.0	-1.8
Food	0.5	0.7	0.0	-0.9	-0.8	-0.4	-0.8	0.2	0.4	-0.6	0.8	0.6
Fuel from Waste	1.3	0.6	-0.6	0.1	-0.6	-0.1	0.0	0.4	-0.2	-0.3	0.3	0.1
Textiles	1.3	0.3	0.8	1.8			1.0				-0.3	
Batteries & Fuel Cells	0.2	0.5	-0.2	-0.2	0.0	-0.7	0.8	0.7	-0.5	-0.6	0.3	1.2
Electrics & Electronics	1.3	1.1	-0.4	-3.0	1.4	0.9	-1.0	0.0	-0.9	-0.4	-0.1	-1.1
Packaging	-0.1	-0.2	-0.8	0.2	-0.6	0.0	-0.6	0.0	1.0	0.3	1.1	0.3
Vehicles			-0.1		2.1		2.3					
Wastewater & Sludge	0.6	0.1	0.2	-0.9	-0.7	-1.1	0.3	1.3	-0.9	-0.5	1.6	

Note: Specialisation index in circular economy technologies by industrial categories and major economies. For each economy, the index in 2018 is listed in the 1st column and the change with respect to 2010 is listed in the 2nd column.
Data is not available for glass, textiles and vehicles for all years/countries, as the codes are not widely assigned.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[94] The share of CET inventions among other technologies within a country's portfolio, compared to the global average share.

Figure 5.6: Collaboration network in CETs inventions (2010-2019)

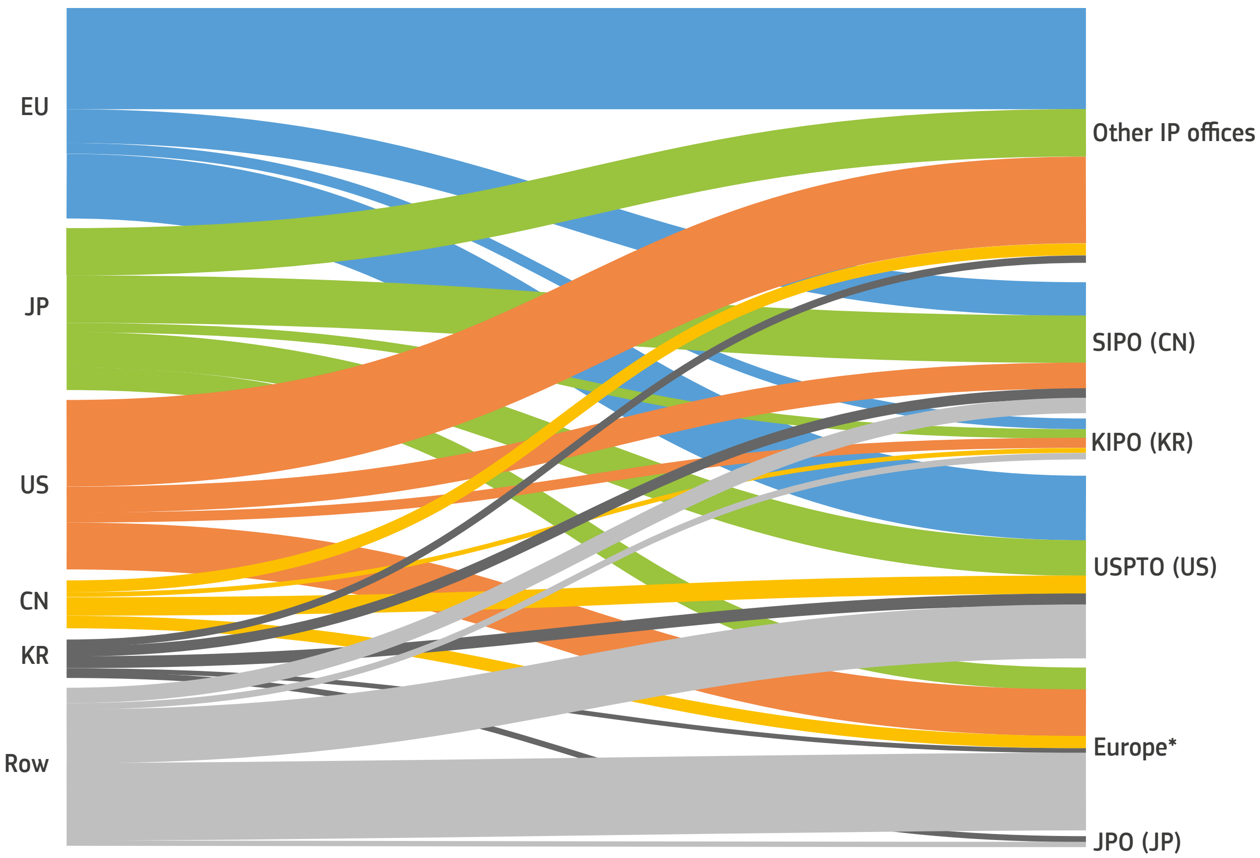


Note: Collaborations are identified through the countries of co-applicants of patents.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

At country level, the US has the highest number of international collaborations (Figure 5.6) on CET inventions in the period 2010-2019, however, the EU taken as a whole would surpass this. The Netherlands and France are the leading EU countries when it comes to international collaboration, and second and third in the world, after the US. The US has the highest number of countries involved in its international alliances, with 43 in total, including 13 EU Member States. The Netherlands and France are the primary partners in US-EU CET patent applications. Patent applicants in EU Member States primarily construct alliances with US applicants, followed by other Member States. China and Japan collaborate with 18 and 20 other countries respectively. Among EU Member States, patent applicants in France, Germany, Italy and Netherlands collaborate with counterparts in China. Applicants in Austria, Denmark, Finland, Germany, Italy and Latvia have formed alliances with counterparts in Japan.

Figure 5.7 shows that the US (23%) and the EU (20%) are the most targeted economies for international CET inventions, followed by China (16%). As with the general trend in overall green inventions, Japan attracts only a small share of international applications. As mentioned in the previous *Scoreboard*, the strong industry and technology base in Japan, coupled with very specific regulations, tend to make it a rather difficult and insular market for foreign technology providers. EU applicants tend to favour the US, with a share of 28% of its non-European applications, followed by China, with a share of 14%. The rest of the world (RoW) and the US applicants target European jurisdictions as their first foreign destination. Among the major economies in Asia, China and South Korea file their foreign patent applications primarily in the US, whereas Japanese applicants primarily target China.

Figure 5.7: International flow of CET inventions by major economies (2010-2019)

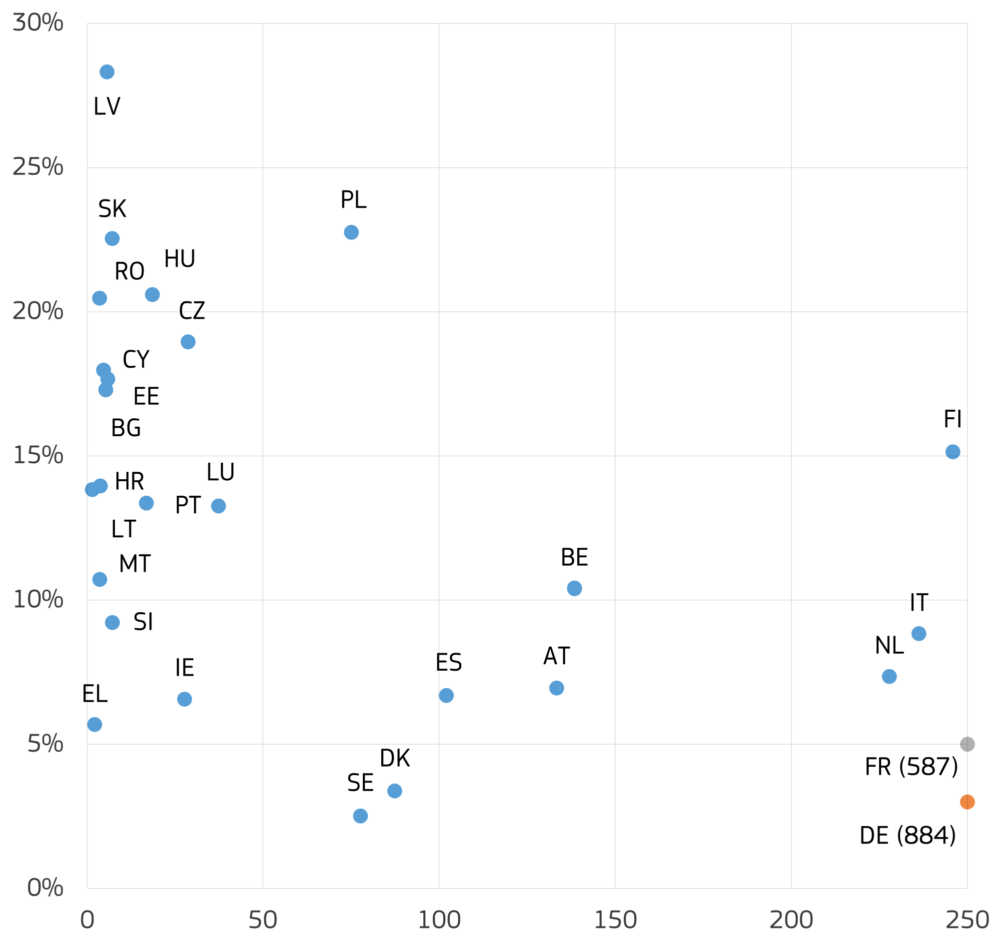


Note: Country of applicant (left) and foreign authorities targeted for protection (right).
* Europe: EPO and national IP offices of EPO members.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Trends in the EU Member States

In line with overall green invention levels, over the period 2010-2019, Germany and France have by far the highest number of CET inventions. However, these represent only 3% and 5% of the overall green inventions produced by German and French applicants, respectively (Figure 5.8). Among the countries with a high number of inventions, Finland has the highest share of CET inventions in its green patent portfolio at 15%. On the left side of Figure 5.8, Latvia, Slovakia, Hungary and Romania are the four countries with the highest shares of CET inventions in their green patent portfolios, at above 20%.

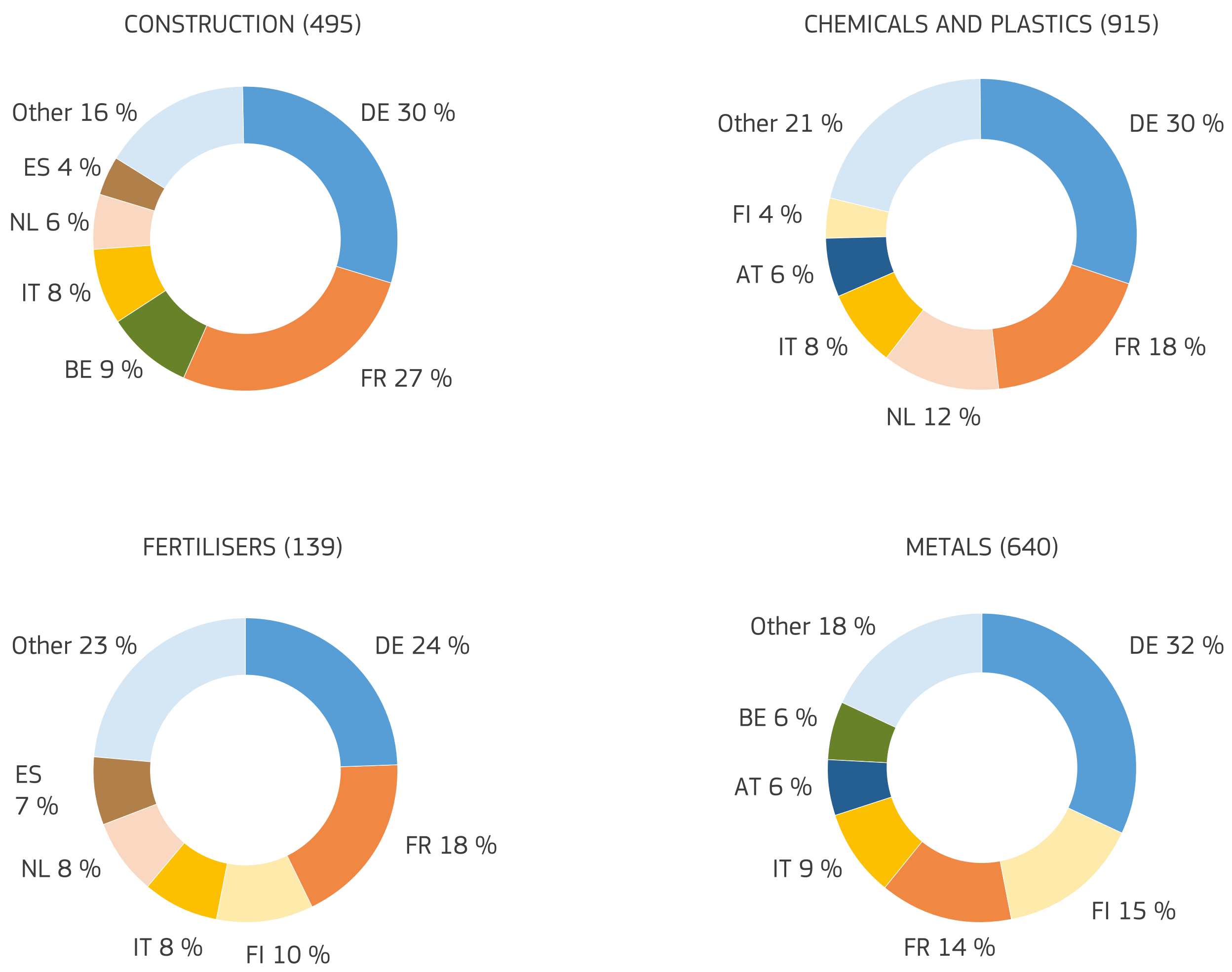
Figure 5.8: Inventive activity in CETs of the EU Member States (2010-2019)



Note: Number of CET inventions (horizontal axis), and share of CET inventions over green inventions (vertical axis).
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

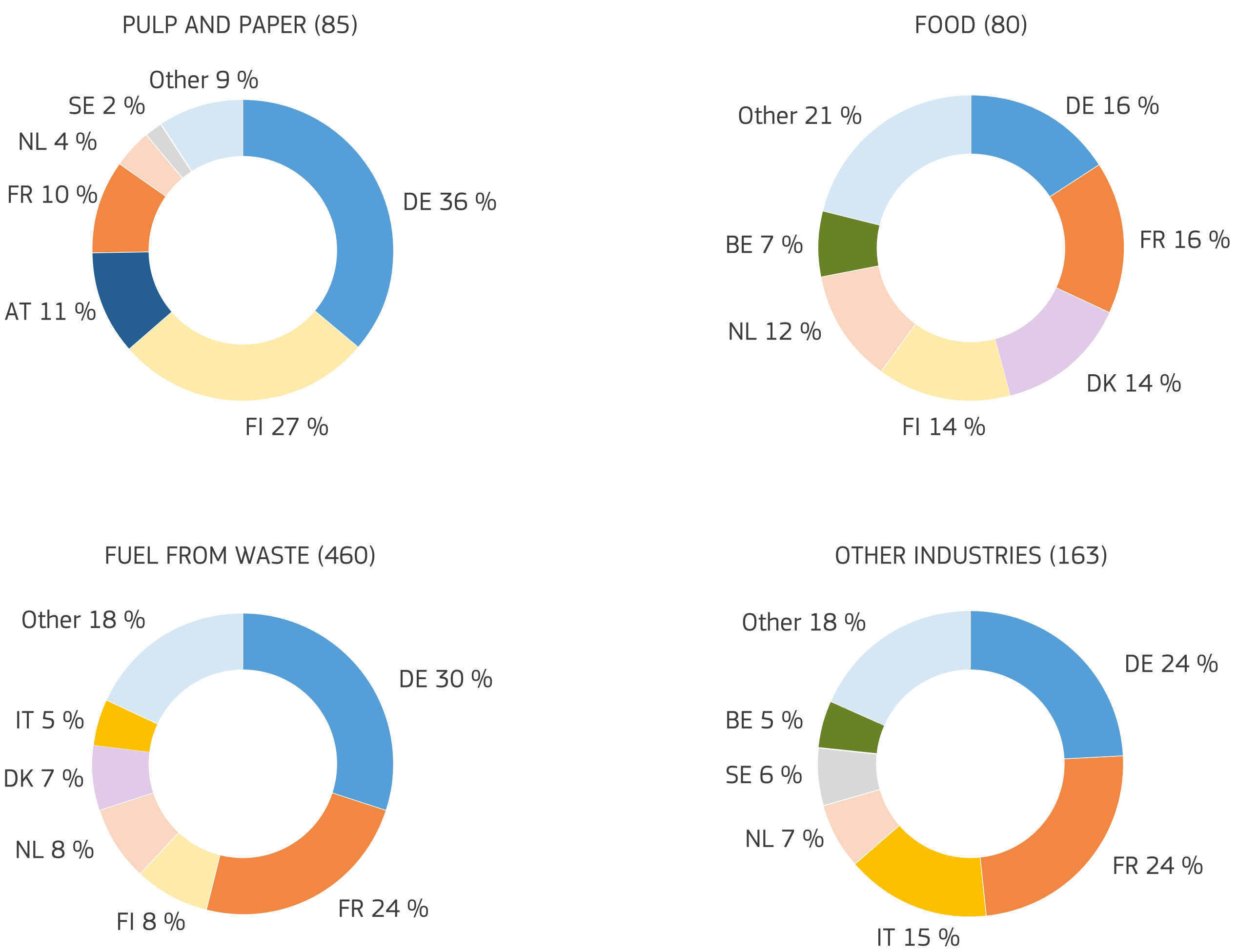
In accordance with Figure 5.8, Germany and France always rank among the top five inventing countries in each of the industrial subcategories for CETs (Figure 5.9). Germany is first in all of the eight subcategories, and followed by France except for metals and pulp & paper categories. Finland has the second highest share in EII categories related to metals and pulp & paper. Other EU Member States that appear among the top five countries by industry are the Netherlands in all categories except metals; Italy in construction, chemicals & plastics, fertilisers, metals and others; Austria in chemicals & plastics, metals and pulp & paper; Denmark in food and fuel from waste; Belgium in construction and Sweden in others.

Figure 5.9: Share of CET inventions per industry and EU Member State (2010-2019)



Note: Total number of CET inventions in the EU for each industrial category is given in parenthesis.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure 5.9: Share of CET inventions per industry and EU Member State (2010-2019)



Note: Total number of CET inventions in the EU for each industrial category is given in parenthesis.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

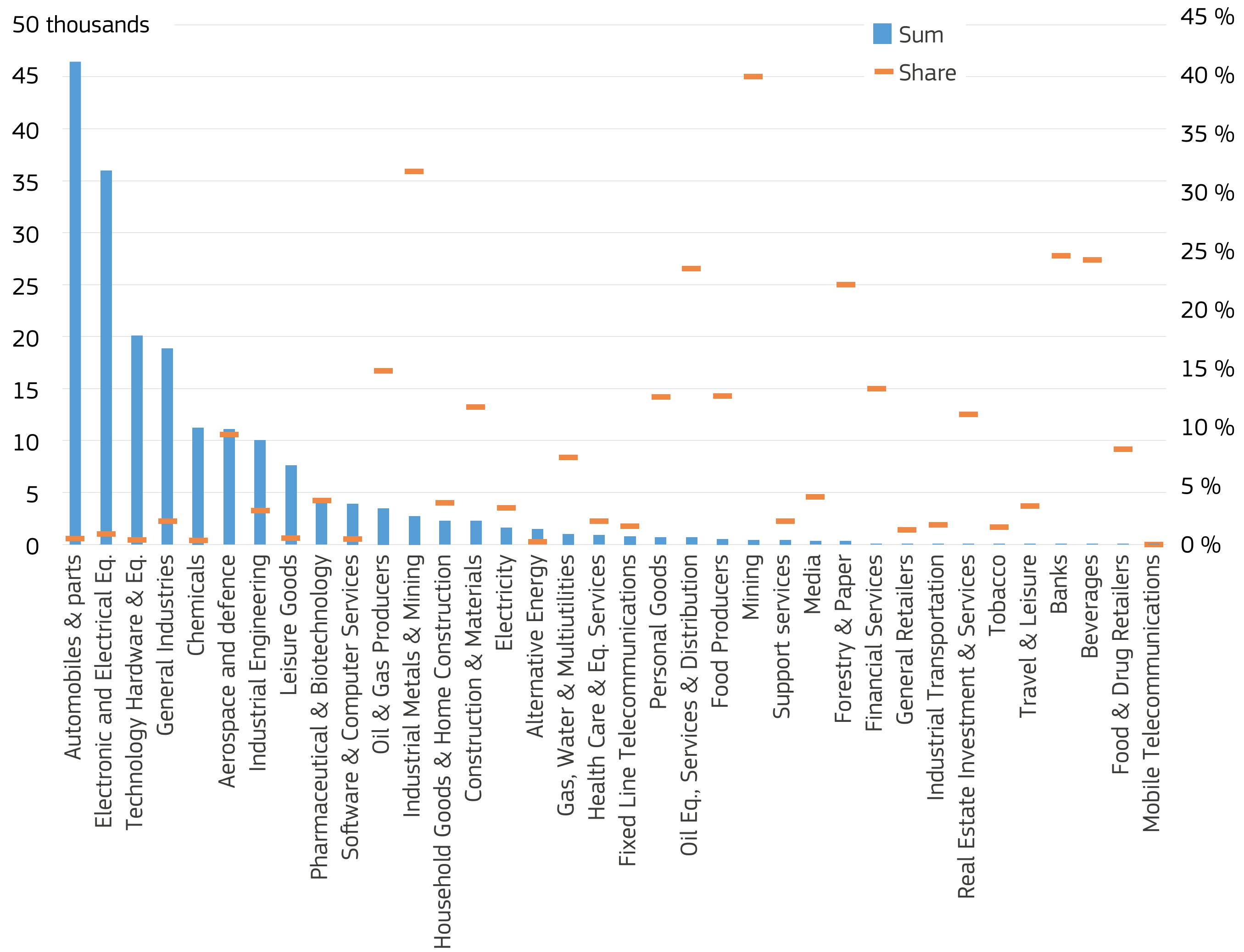
5.3 Global *Scoreboard* and the EU *Scoreboard*

In the following, the activity of subsidiary companies has been aggregated and attributed to the *Scoreboard* parent company. This introduces differences in the resulting performance and location (headquarters) of some companies, which are now referred to as a group and not as the subsidiaries which may have been referenced above.

Sector-level trends

Since 2010, the CET inventions of *Scoreboard* companies have accounted for 51% of the global total. Figure 5.10 presents their sectorial distribution. In general, companies active in sectors with high levels of green inventions also have a large patent portfolio for CETs. The top five sectors in absolute numbers are automobiles & parts, electronic & electrical equipment, technology hardware & equipment, general industrials and chemicals. In relative terms, however, the five sectors with the highest share of CET inventions are mining, oil equipment, services & distribution, forestry & paper, beverages and industrial metals & mining sectors. These ICB sectors are directly related to EIIs except for beverages, where efforts in CETs are related to the food industry, as well as the

Figure 5.10: *Scoreboard* companies' inventive activity in CETs by ICB sectors (2010-2019)



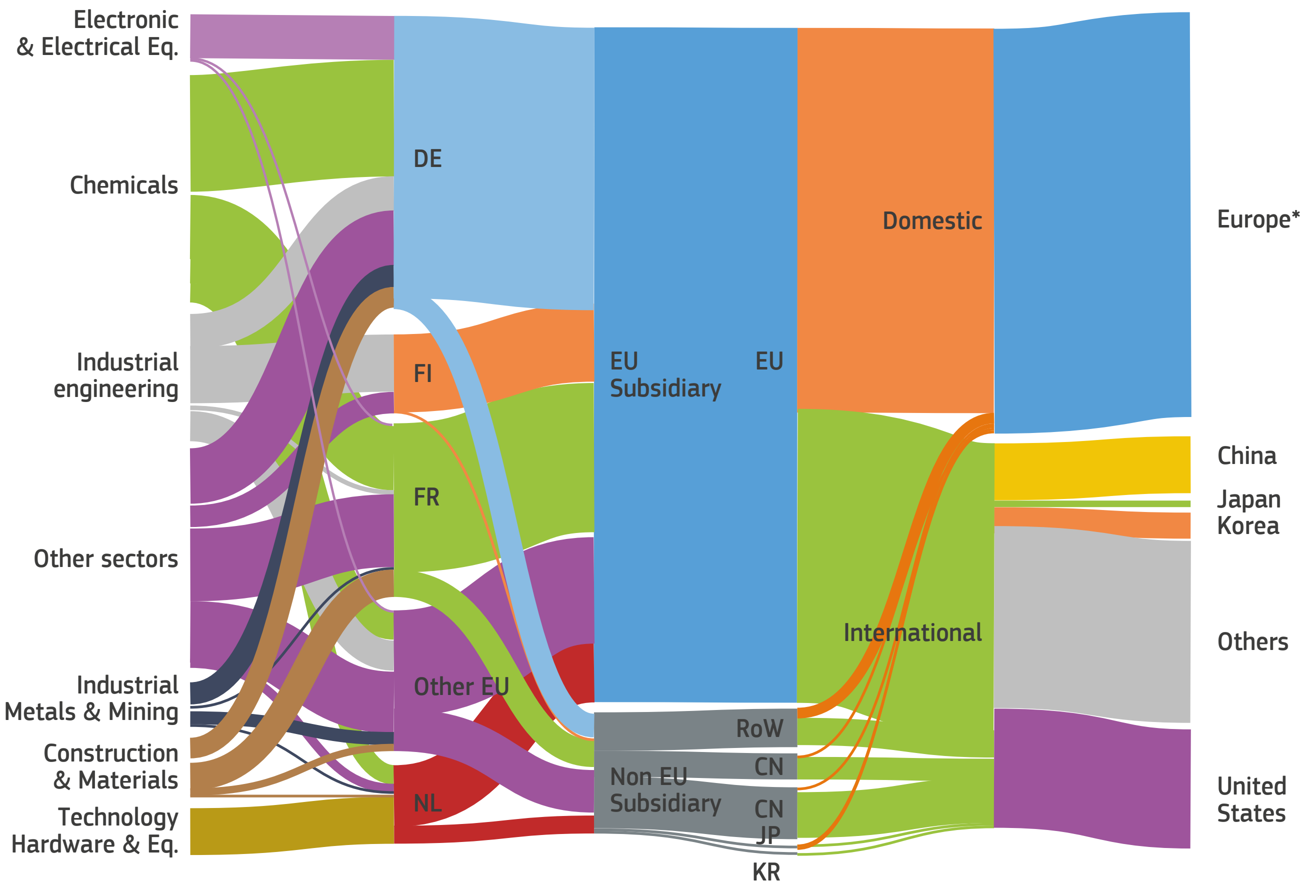
Note: Number of inventions (blue, left axis), and share in green inventions (red, right axis).
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

metal cans, plastics and glass bottles in packaging. The patenting statistics do indeed indicate that, in the period 2010-2019, CET inventions in the beverages sector concentrate on food (44%), followed by packaging (31%).

The EU companies active in the chemicals sector account for about 29% of the total CET inventions produced by EU *Scoreboard* companies (Figure 5.11), followed by industrial engineering (16%) and construction & materials (8%). In line with patterns shown for the EU Member States in Figure 10, German, French, Finnish and Dutch companies have the highest amount of filings among the EU *Scoreboard* firms, accounting for 81% of all EU *Scoreboard* CET inventions. The German and French companies active in CET patenting are mostly in the chemicals sector, the Finnish in industrial engineering and the Dutch in technology hardware & equipment.

About 85% of EU *Scoreboard* CET inventions are produced by EU subsidiaries, of which 43% are protected internationally, mostly in the US and other jurisdictions. Among the inventions produced by non-EU subsidiaries of EU *Scoreboard* companies, 44% originate from the US, followed by 18% produced by companies located in China. Overall, 51% of CET inventions produced by EU *Scoreboard* companies are protected in Europe, while the rest flow to other international jurisdictions, primarily to the US at about 15%.

Figure 5.11: EU *Scoreboard* companies' patenting activity in circular economy technologies by sector, country of headquarter and subsidiary, and targeted jurisdiction (2010-2019)



Note: Inventions by ICB sectors (1st column), country of headquarters (2nd column), country where subsidiaries are domiciled (3rd and 4th columns) and IPO jurisdictions targeted (5th and 6th columns).
* Europe: EPO and national IP offices of EPO members.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Top *Scoreboard* Companies in CET inventions

Globally, the Japanese *Scoreboard* companies lead patenting activity in CETs related to metals, pulp & paper and batteries & fuel cells, while the Chinese *Scoreboard* companies outperform in circular fertilisers (Table 5.3). EU *Scoreboard* companies are present among the top five companies in each category. EU *Scoreboard* companies lead in the number of CET inventions related to fuel from waste, and US *Scoreboard* companies lead in CET inventions related to construction and chemicals & plastics.

Table 5.3: Top five *Scoreboard* companies inventing in CETs per industry (2010-2019)

Rank	GLOBAL *SCOREBOARD*				EU *SCOREBOARD*			
	Company	**Country**	**Invention**	**Share**	**Company**	**Country**	**Invention**	**Share**
Construction								
1	Halliburton	US	95	51%	Saint-Gobain	FR	30	11%
2	LafargeHolcim	CH	35	39%	BASF	DE	30	3%
3	Sika	CH	33	65%	HeidelbergCement	DE	30	51%
4	USG	US	33	82%	Weatherford International	IE	11	5%
5	Saint-Gobain	FR	30	11%	Siemens	DE	9	0%
Chemicals & Plastics								
1	Dow Chemical	US	93	19%	BASF	DE	54	5%
2	BASF	DE	54	5%	Arkema	FR	45	22%
3	Honeywell	US	47	5%	STMicroelectronics	NL	24	1%
4	Saudi Basic Industries	SA	45	16%	Solvay	BE	22	10%
5	Arkema	FR	45	22%	Siemens	DE	20	0%
Fertilisers								
1	Guangzhou Pharmaceutical	CN	7	22%	BASF	DE	3	0%
2	Whirlpool	US	5	3%	SUEZ	FR	3	3%
3	Kingfa Science & Techology	CN	4	36%	Veolia Environnement	FR	2	3%
4	Procter & Gamble	US	4	2%	Altana	DE	2	6%
5	BASF	DE	3	0%	STMicroelectronics	NL	2	0%
Metals								
1	Sumomo Metal Mining	JP	120	39%	Metso Outotec	FI	77	52%
2	Metso Outotec	FI	77	52%	SMS Holding	DE	44	46%
3	JFE	JP	74	35%	STMicroelectronics	NL	42	2%
4	JXTG	JP	72	23%	Siemens	DE	37	1%
5	Nippon Steel	JP	69	15%	BASF	DE	23	2%

Rank	GLOBAL *SCOREBOARD*				EU *SCOREBOARD*			
	Company	Country	Invention	Share	Company	Country	Invention	Share
Pulp & Paper								
1	Seiko Epson	JP	43	10%	Voith	DE	21	14%
2	Voith	DE	21	14%	Valmet	FI	8	13%
3	Unicharm	JP	12	27%	Andritz	AT	7	11%
4	Valmet	FI	8	13%	Altana	DE	6	19%
5	Andritz	AT	7	11%	Siemens	DE	3	0%
Fuel from Waste								
1	L'Air Liquide	FR	16	2%	L'Air Liquide	FR	16	2%
2	Novozymes	DK	12	7%	Novozymes	DK	12	7%
3	Veolia Environnement	JP	11	14%	Veolia Environnement	JP	11	14%
4	Suez	FR	10	12%	Suez	FR	10	12%
5	BP	UK	10	2%	Siemens	DE	10	0%
Batteries & Fuel Cells								
1	Toyota Motor	JP	13	0%	STMicroelectronics	NL	5	0%
2	JXTG	JP	11	4%	Johnson Controls	IE	3	1%
3	SK Innovation	KR	8	2%	BASF	DE	2	0%
4	Sumitomo Metal Mining	JP	7	2%	Robert Bosch	DE	2	0%
5	STMicroelectronics	NL	5	0%	Daimler	DE	2	0%

Note: The total number of CET inventions per company is represented in blue and the share of CETs in overall green inventions per company is represented in green. Industrial categories are selected according to the total number of inventions per category.
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

CET inventions related to the construction industry

US companies lead in CET inventions related to the construction industry, followed by Swiss and French companies. This is in line with the significant country-level shares of CET inventions related to the construction industry in the US and the EU shown in Figure 5.5. The US company Halliburton is the global leader among the *Scoreboard* firms in the period 2010-2019. In the EU, the top inventing companies are mostly from Germany, while Saint-Gobain from France leads in the number of inventions.

CET inventions related to the chemicals & plastics industry

Although the EU leads in CET inventions related to the chemicals & plastics industry, with a 29% share in total CET inventions, Dow Chemical from the US is the leading *Scoreboard* company. Among the EU *Scoreboard* firms, the CETs related to chemicals & plastics account for 33% of CET inventions – the largest share together with metals. The top inventing companies are from Germany, France, Belgium and the Netherlands; and BASF from Germany leads despite a small share for CETs related to chemicals & plastics in its overall green portfolio.

CET inventions related to the fertilisers industry

CET inventions related to the fertilisers industry represent a small share in the patent portfolio of the *Scoreboard* firms from all regions except for China, with a share of around 13% circular fertilisers over all CET inventions. At firm level, companies from China and the US have the largest numbers of CET inventions related to fertilisers. In the EU, German, French and Dutch firms lead in the period 2010-2019.

CET inventions related to the metals industry

Despite the large share of metals-related inventions in the CET inventions of all major economies, those of Japanese and EU *Scoreboard* firms account for 73% of total CET inventions in the period 2010-2019, with a share of 40% and 33% respectively. The top five inventing firms are from Japan, with the single exception of Metso Outotec from Finland. Other leading EU companies in CET inventions related to metals are from Germany and the Netherlands.

CET inventions related to the pulp & paper industry

As with the metals industry, the Japanese and EU *Scoreboard* firms lead in CET inventions related to the pulp & paper industry, with shares of 46% and 43%, respectively. The top five inventing firms are from Japan and the EU, and the top five EU companies in CET inventions related to pulp & paper are from Germany, Finland and Austria.

CET inventions related to the fuel from waste industry

In the period 2010-2019, EU *Scoreboard* companies lead in CET inventions related to fuel from waste, with a share of 42% of all *Scoreboard* company inventions. In both the global and the EU *Scoreboard,* Áir Liquide, Veolia Environnement and Suez from France, and Novozymes from Denmark, are the top four inventors in the industry. Globally, Japanese companies come second, with 24% of *Scoreboard* company inventions.

CET inventions related to the batteries & fuel cells industry

In the period 2010-2019, CET inventions related to the batteries & fuel cells industry do not account for more than 5% of total CET inventions for any of the regions in the *Scoreboard.* Japanese companies lead, with a global share of 53% of CET inventions related to the batteries & fuel cells industry. The top five companies are mostly from Japan, with Toyota Motors in the lead. In Europe, companies from the Netherlands, Ireland and Germany lead the inventions, despite the very small share in their overall green patent portfolios.

5.4 Key points

- In 2018, the EU and Japan lead in green high-value patents, with the US in third place. The EU also has the highest specialisation index in green technologies among major economies. While *Scoreboard* companies dominate patenting efforts in Japan, the EU and the US have a more diverse contribution to green inventions from applicants beyond the *Scoreboard*.

- In the period 2010-2019, ICT producers lead in green inventions, followed by automobiles & other transport. Energy and transport are the largest technology areas in global high-value green inventions.

- In the period 2010-2019, CET inventions represent just 4% of overall green inventions. The EU leads in CET inventions both in absolute terms and as a share of green inventions globally. China ranks first in terms of the growth rate of CET inventions.

- In the period 2010-2019, global CET inventions are concentrated in chemicals & plastics, metals, construction and fuel from waste. CET inventions related to chemicals & plastics account for the highest share in the EU and US, while CET inventions related to metals account for the highest share in major Asian economies.

- In 2018, the EU is the only major economy with a positive specialisation index in most industrial categories related to CETs.
- In the period 2010-2019, the US and EU are the most targeted economies for international CET inventions.
- The Netherlands and France are the leading EU countries in international alliances and second and the third in the world after the US.
- In the period 2010-2019, Germany and France always rank among the top five inventing EU Member States in the industrial categories for CETs. The Netherlands, Finland, Italy Austria, Belgium, Denmark and Sweden are among the others.
- *Scoreboard* companies are the applicants of around 49% of global CET patent filings of high-value; i.e. a smaller contribution in these technologies compared to their contribution in global high-value green inventions.
- Globally, the five *Scoreboard* sectors with the highest shares of CET inventions are mining, oil equipment, services & distribution, forestry & paper, beverages and industrial metals & mining. In the EU, the chemicals sector accounts for the highest share of CET inventions, followed by industrial engineering and construction & materials.
- In the period 2010-2019, EU *Scoreboard* companies are among the top five inventing companies globally in all of seven major categories related to CETs, and leading in fuel from waste.

6 TOP R&D INVESTORS AND THE UN SUSTAINABLE DEVELOPMENT GOALS

Achieving sustainable development through the UN's 17 Sustainable Development Goals (SDGs)[95] of the 2030 Agenda is a priority the EU in the Political Guidelines of the von der Leyen Commission[96], which link most of the transformative policies to specific SDGs[97]. Commissioners are expected to implement the 2030 Agenda together and ensure that policies under their responsibility reflect one or more SDGs[98]. Several policy documents have been developed to better integrate SDGs into EU policies[99] to assure a timely monitoring of the implementation of SDGs in the EU[100] and, more importantly for this chapter, to highlight opportunities and challenges of linking SDGs to the competitive advantage of European industries[101].

EU institutions support the achievement of SDGs by directly investing in projects and developing appropriate monitoring and policy tools. For example, in 2021, the European Investment Bank supported projects that foster SDGs and contribute to the EU's competitive advantage with EUR 491 million[102]. In Member States, the capacity to monitor SDG progress increased thanks to the adoption of comprehensive monitoring tools and accurate reporting[103]. Methodological tools have also been developed to address SDGs' contribution to smart specialisation strategies[104, 105], evaluate the potential for scenario analysis with available simulation tools[106], develop roadmaps relevant to policy formulation[107], and overcome potential conflicts across multiple SDGs when designing effective economic policies[108].

This chapter focuses on the analysis of the SDG commitments of the top R&D investors, using reputa-

95 https://sdgs.un.org/
96 Ursula von der Leyen (2019), A Union that strives for more — My agenda for Europe. Political Guidelines for the next European Commission 2019-2024.
97 For example, the European Green Deal, the circular economy action plan, the 2030 climate target plan, and the European Climate Law. SDGs also play an important role in the European Semester country reports and the national recovery and resilience plans. For a more comprehensive overview, see EUROSTAT (2022), Sustainable development in the European Union. Monitoring report on progress towards the SDGs in an EU context. Luxembourg: Publications Office of the European Union.
98 European Commission (2020), Delivering on the UN's Sustainable Development Goals — A comprehensive approach, SWD(2020) 400 final, Brussels.
99 European Commission (2016), Next steps for a sustainable European future: European action for sustainability, COM(2016) 739 final, Brussels.
100 https://ec.europa.eu/eurostat/web/sdi/overview
101 European Commission (2019), Reflection Paper 'Towards a Sustainable Europe by 2030', COM(2019)22, Brussels.
102 Mostly on affordable and clean energy (SDG 7), industry and innovation infrastructure (SDG 9), and sustainable cities and communities (SDG 11). See European Investment Bank (2011). Sustainability report. European Investment Bank. DOI: https://doi.org/10.2867/50047.
103 Mostly on affordable and clean energy (SDG 7), industry and innovation infrastructure (SDG 9), and sustainable cities and communities (SDG 11). See European Investment Bank (2011). Sustainability report. European Investment Bank. DOI: https://doi.org/10.2867/50047.
104 Matusiak, M., Fuster Martí, E., Massucci F., Quinquillà A., Bosch J., Duran N., Amador R., Multari F., Iriarte M., Pilot methodology for mapping Sustainable Development Goals in the context of Smart Specialisation Strategies, EUR 30901 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-44398-8, doi:10.2760/400836, JRC126846.
105 Siragusa, A., Stamos, I., Bertozzi, C. & Proietti, P., European Handbook for SDG Voluntary Local Reviews - 2022 Edition, EUR 31111 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-53390-0, doi:10.2760/218321, JRC129381.
106 Barbero Vignola, G., Acs, S., Borchardt, S., Sala, S., Giuntoli, J., Smits, P. & Marelli, L., Modelling for Sustainable Development Goals (SDGs): Overview of JRC models, EUR 30451 EN (main) 30453 EN (annex), Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-25326-6 (main) 978-92-76-25330-3 (annex) (online),978-92-76-25327-3 (main) 978-92-76-25331-0 (annex) (print), doi:10.2760/697440 (main) 10.2760/108956 (annex) (online),10.2760/228158 (main) 10.2760/2726 (annex) (print), JRC122403.
107 Matusiak, M., Ciampi Stancova, K., Dosso, M., Daniels, C., & Miedziński, M., Background paper: Overview of the existing STI for SDGs roadmapping methodologies, EUR 30570 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-28936-4, doi:10.2760/2100, JRC123628.
108 Basheer, M., Nechifor, V., Calzadilla, A., Ringler, C., Hulme, D., & Harou, J. J. (2022). Balancing national economic policy outcomes for sustainable development. Nature Communications, 13(1), pp. 1-13.

tion and disclosure scores calculated at the firm level. Focusing on *Scoreboard* (SB) companies is particularly relevant for two reasons. First, *Scoreboard* companies are global players due to their economic, innovative, social, and environmental impact: SB companies account for approximately 90% of the world's business-funded R&D and own nearly two thirds of the patents filed at the world's five largest intellectual property offices. Large multinational companies, such as those in the *Scoreboard*, play a key role in strengthening the innovation environment given their large (direct and indirect) market and innovation powers. They are also an entry point to local upgrading through collaboration and internationalisation[109]. By adopting sustainable business practices and technologies (for example, addressing gender inequality in the workplace, reducing greenhouse gas emissions), SB companies produce significant spillover effects along their value chain: they can pressure customers and competitors to adopt similar practices and technologies. The second reason is that SB companies are key players that can contribute to tackling SDG-related challenges with new technological and organisational solutions.

In fact, the industry has increased recently its commitment to the SDGs by being more transparent on sustainability matters. Notably, private companies are putting more and more effort into capturing and reporting Key Performance Indicators (KPIs). They are also experimenting and adopting more sustainable business models, which is important to achieve SDG-related milestones[110]. In this respect, the Non-Financial Reporting Directive[111] requires companies with more than 500 employees to report relevant non-financial information about environmental, social, and governance issues[112].

Following the past two editions of the *Scoreboard*, this chapter deepens our understanding of the top R&D investors' commitments to sustainable development. Sections 6.1 and 6.2 provide an overview of the adoption of new internal business practices and technologies to tackle SDG-related challenges. In particular, Section 6.1 provides an update on how the efforts of top R&D investors to progress on sustainability and social issues changed in 2021 compared with the previous 5 years (2016-2020) by employing scores comprising a quantitative (non-financial data reporting) and a qualitative component (corporate communications). Section 6.2 analyses the climate action SDG (13) and the affordable and clean energy SDG (7) and focuses on core data disclosed by SB companies. The focus is on CO_2 emissions and energy use, which are quantifiable targets for the green transition to a climate-neutral EU, from different points of view (e.g. direct vs indirect emissions) and across sectors of activity and regions of the world. Section 6.3 investigates the association between the outcome of R&D investment of SB companies and innovation for the SDGs. Notably, it focuses on the development of new scientific and technological solutions addressing the SDGs. It does so by gauging the ability of top R&D investors to develop relevant and potentially breakthrough research and innovation that directly tackles SDG-related challenges. It resonates with the importance of deep tech highlighted in the New European Innovation Agenda[113]. Overall, the results of the analysis in this chapter should inform policymakers about the strengths and weaknesses of EU companies in sustainable competitiveness.

Not all SDGs are tackled in the chapter. We leave out of the analysis the following SDGs: No poverty (SDG 1), Zero hunger (SDG 2), Quality education (SDG 4), Reduced inequalities (SDG 10), Sustainable cities and communities (SDG 11), Peace, justice and strong institutions (SDG 16) and Partnerships for the goals (SDG 17). We do so because of their lack of relevance to the corporate sector, which is often reflected in the lack of reliable data reported by SB companies for these SDGs.

[109] Humphrey, J., & Schmitz, H. (2002). How does insertion in global value chains affect upgrading in industrial clusters?. Regional studies, 36(9), pp. 1017-1027.

[110] Scheyvens, R., Banks, G., & Hughes, E. (2016). The private sector and the SDGs: The need to move beyond 'business as usual'. Sustainable Development, 24(6), pp. 371–382. https://doi.org/10.1002/sd.1623

[111] Directive 2014/95/EU of The European Parliament and of the Council of 22 October 2014 amending Directive 2013/34/EU as regards disclosure of non-financial and diversity information by certain large undertakings and groups. http://data.europa.eu/eli/dir/2014/95/oj

[112] Pizzi, S., Rosati, F., & Venturelli, A. (2021). The determinants of business contribution to the 2030 Agenda: Introducing the SDG Reporting Score. Business Strategy and the Environment, 30(1), pp. 404-421.

[113] European Commission (2022). A New European Agenda. Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions. Brussels, European Commission COM(2022) 332, 5 July.

6.1 Environmental and socio-economic practices of top R&D investors – 2021 update

Box 6.1: Methodology for computing SDG scores

The SDG scores used for the analysis are based on data collected by Covalence SA[114]. The scores produced by Covalence aim to measure the extent to which companies' practices affect their compliance with Environmental, Social and Governance (ESG) targets and report on the contribution these practices bring to solving SDG challenges[115]. The data retrieved by Covalence comprise two different scores: reputation and disclosure.

Reputation scores cover qualitative data published by company stakeholders, such as governments, international organisations, NGOs, the media, and other third-party sources. This data are sourced mainly from news and media content covering specific activities or practices of a company (e.g. web pages, news articles). Covalence applies sentiment analysis techniques to the gathered data. Content whose sentiment is deemed positive increases the reputation score of a company, while content whose sentiment is deemed negative reduces the score[116].

Disclosure scores originate from self-reported information published by the companies. Such information is extracted from quantitative and qualitative data[117]. The disclosure score aggregates the qualitative and quantitative information in a composite index ranging between 0 to 100.

Finally, for each SDG, Covalence calculates a global score ranging from 0 to 100 combining the disclosure and reputation indicators. These global scores are used in this analysis. A score of 50 is a neutral value; if a company scores above 50 in an SDG, it means that the assessment of its contribution to that SDG in positive. Conversely, a score below 50 means that a company is not doing enough or has performed poorly on that SDG[118].

The EU Industrial R&D Investment Scoreboard report already covered SDG scores calculated by Covalence in previous editions. The 2021 report focused on the performance of the top R&D investing companies worldwide in a subset of 10 SDGs, grouped into environmental and socio-economic categories[119]. In this edition, we take a deeper dive into two environmental SDGs (7 and 13) that are closely related to emissions and energy consumption.

[114] Covalence SA, based in Geneva (Switzerland) since 2001, is specialised in environmental, social and governance research and ratings. For more information, see https://www.covalence.ch/.

[115] The Covalence approach is not the only way to analyse SDG compliance at the company level. An interesting overview is given in the following report: OECD (2021). Industrial Policy for the Sustainable Development Goals – Increasing the Private Sector's Contribution, https://doi.org/10.1787/2cad899f-en.

[116] For a more detailed discussion about Covalence SDG scores and their computation, see Chapter 5 of the 2021 EU industrial R&D Scoreboard: https://op.europa.eu/en/publication-detail/-/publication/02ab5f6a-c9bd-11ec-b6f4-01aa75ed71a1/language-en/format-PDF/source-257925010.

[117] This comes from combining environmental, social and governance indicators (e.g. water consumption, percentage of women in executive positions), which are sourced from external providers (e.g. Refinitiv) and sustainability-related corporate communications.

[118] For a detailed explanation of the data sources and methodologies employed by Covalence to compute reputation, disclosure and global scores, see https://www.covalence.ch/docs/Covalence_SDG_Mapping_Methodology.pdf.

[119] The composition of the two groups was the following. Socio-economic SDGs: Good health and well-being; Gender equality; Decent work and economic growth; Industry; Innovation and infrastructure. Environmental SDGs: Clean water and sanitation; Affordable and clean energy; Responsible consumption and production; Climate action; Life below water; Life on land.

Before moving to this analysis, we show how the environmental and socio-economic SDG scores presented in the 2021 *Scoreboard* have evolved over the past year for those companies covered between 2016 and 2021 (679 companies in total). We first analyse the overall trend of each SDG and then present regional and sectoral breakdowns of the scores. Table 6.1 contains a breakdown by sector and region of the number of *Scoreboard* companies included in the analysis. The rightmost columns containing the totals by region shows that the EU, the US, and Japan are by far the most represented regions in the sample; companies based in China reporting SDG scores instead are still a minority. From a sectoral viewpoint, the sample is dominated by companies operating in ICT, followed closely by companies from the industrials[120] and the health sectors. The sectoral composition of the sample differs considerably across regions: EU-based companies operate mostly in the industrials, health, and energy sectors; Japan-based companies operate mostly in ICT, Industrials, and Automotive; US-based companies are mostly active in ICT producers, ICT services, and health.

Table 6.1: Number of *Scoreboard* companies included in the SDG analysis by region and sector

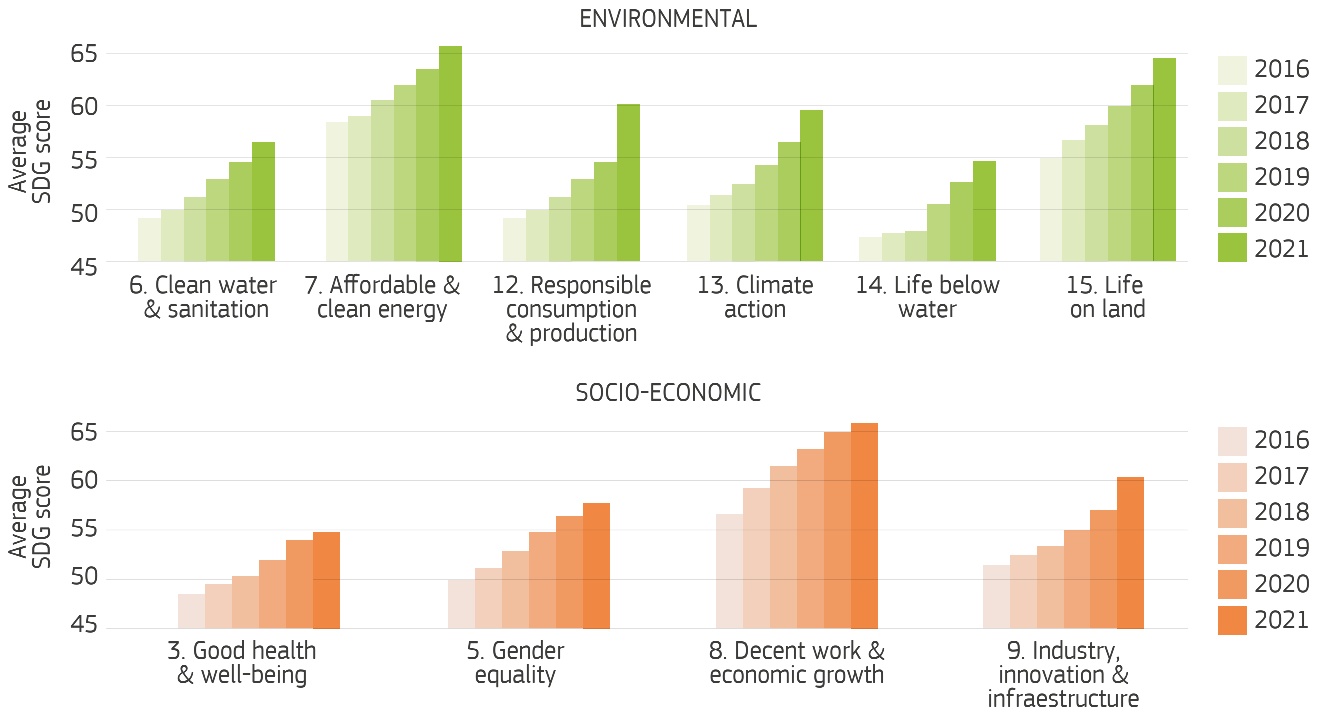
	China	EU	Japan	US	RoW	Total
Aerospace & Defence	0	7	0	5	5	**17**
Automobiles & oth. transport	5	12	20	13	13	**63**
Chemicals	1	12	13	10	12	**48**
Construction	3	8	8	2	4	**25**
Energy	4	22	12	7	6	**51**
Financial	0	16	1	1	4	**25**
Health industries	1	23	11	31	13	**79**
ICT producers	5	16	30	31	21	**103**
ICT services	2	13	7	26	14	**62**
Industrials	7	28	23	13	19	**90**
Others	3	33	28	34	18	**116**
Total	**31**	**190**	**153**	**176**	**129**	**679**

Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Covalence.

Figure 6.1 presents the overall change in SDG scores between 2016 and 2021 of the 679 SB companies for which complete data are available. It shows that the commitment of the top R&D investing companies to social and environmental responsibility continued in 2021. In line with the past, clean and affordable energy (SDG 7), decent work and economic growth (SDG 8), and life on land (SDG 15) achieve the highest absolute scores, suggesting that they are still the SDGs on which the top R&D investors are focusing their efforts the most. In terms of overall growth, all indicators are stable: all scores increased by 10% or more over the entire period, and some grew by almost 20% (e.g. climate action - SDG 13). Industry innovation and infrastructure (SDG 9) is particularly striking having increased by 7% in 2021 alone. The regional and sectoral breakdown of the scores presented later in this section attempt to make sense of this evidence.

[120] The Industrials group includes the following industries: general industrials, industrial engineering, manufacturing of metals and mining, industrial transportation.

Figure 6.1: Average SDG scores by year – 2016-2021



Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Covalence.

The rest of this section works with the same companies as above, and looks at the sectoral and regional dimensions. For readability, in both exercises we present a separate heat map for environmental scores and for socio-economic scores. We assign a green colour palette to environmental SDG scores and an orange palette to socio-economic scores.

Figure 6.2 illustrates the progression in each SDG of the *Scoreboard* companies belonging to the same industrial sector, based on a score comparing the average 2016-2020 values with the 2021 values. Similarly to what we observed in last year's *Scoreboard* report, the results show some differences across industries. Companies from the energy, chemicals, and transport sectors scored the highest (darker colour), especially in the environmental SDGs. However, companies in the health sector had, on average, lower SDG progression scores compared with the rest of the sample, especially in the environmental scores (as suggested the very light green vertical strip corresponding to the health sector in the top heatmap). We observe a similar pattern in financials, which, however, has a remarkably high score in SDG 7 (affordable & clean energy), but achieved relatively low scores in the socio-economic SDGs. On the contrary, companies in the automotive sector and the chemicals sector achieve on average high SDG progression scores in almost all of the environmental SDGs as well as in the socio-economic SDGs 8 (decent work and economic growth) and 9 (industry, innovation & infrastructure). In terms of changes over time, we see improvements across the board but also some interesting differences between sectors. The energy sector witnessed an average increase of at least 6.5 points in all but two SDGs, namely SDGs 3 (good health) and 8 (decent work), and up to 9 points in SDGs 12 (responsible consumption) and 13 (climate action). We observe a similar pattern also in the chemicals sector, whose scores in the environmental SDGs increased by 6.2 points or more in all SDGs except SDG 6 (clean water) and whose score in SDG 9 (industry, innovation and infrastructure) increased by 9.1 points in 2021 with respect to the average for the period 2016-2020. At the opposite end of the spectrum, the health sector and the aerospace sector show positive, yet considerably more moderate increases in both the socio-economic and environmental SDGs.

Figure 6.2: SDG progression scores - sectoral comparison: 2016-2020 vs 2021

ENVIRONMENTAL

	Aerospace & Defence	Automobiles & other transport	Chemicals	Construction	Energy	Financials	Health industries	ICT producers	ICT services	Industrials	Others
6. Clean water & sanitation	2.8	2.9	6.2	3.9	6.7	5.5	3.7	4.5	4.4	5.2	4.5
7. Affordable & clean energy	5.6	5.2	4.8	3.7	8.0	4.9	3.3	4.6	4.5	5.0	3.7
12. Responsible consumption & production	4.2	6.2	7.9	5.5	9.0	6.1	5.2	6.7	6.4	6.4	5.6
13. Climate action	4.7	6.8	7.2	4.8	9.0	6.2	4.8	5.7	6.1	6.9	5.3
14. Life below water	3.8	3.7	7.9	4.3	7.3	5.3	4.3	5.0	5.0	4.2	5.9
15. Life on land	4.4	5.0	7.7	3.4	7.4	5.3	4.7	5.5	6.0	6.0	6.1

SOCIO-ECONOMIC

	Aerospace & Defence	Automobiles & other transport	Chemicals	Construction	Energy	Financials	Health industries	ICT producers	ICT services	Industrials	Others
3. Good health & well-being	2.5	3.5	4.0	3.6	4.7	4.6	5.0	4.3	4.8	3.0	4.9
5. Gender equality	4.9	4.6	4.6	5.8	6.5	1.5	5.7	4.4	4.9	4.6	5.6
8. Decent work & economic growth	5.1	4.8	4.8	5.0	5.3	4.5	6.8	5.5	7.5	4.7	5.6
9. Industry, innovation & infrastructure	5.0	7.2	9.1	6.2	8.7	5.3	6.5	7.3	6.2	6.2	6.5

Note: Each cell refers to a unique combination of industrial sector and SDG. The number and the colour in each cell convey different information. The colour represents the average score achieved in 2021 in a given SDG (see row) by companies from a given sector (see column); darker colour shades correspond to a higher score in 2021. The number in the cell is the difference between the average score achieved in a given SDG by *Scoreboard* companies from a given industry computed in 2021 and in 2016-2020; the number in the cell is the growth in the score achieved in 2021 with respect to 2016-2020.
Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Covalence.

Figure 6.3 shows the average SDG performance of *Scoreboard* companies headquartered in the same region. *Scoreboard* companies based in the EU and Japan have higher SDG scores , and thus a darker shade of colour in their respective columns, compared with other regions. Looking at environmental scores, the EU clearly led in 2021 in affordable and clean energy (SDG 7) and life on land (SDG 15). EU-headquartered SB companies also performed remarkably well in responsible consumption & production (SDG 12) and climate action (SDG 13). The same holds for the socio-economic SDGs – the colour pattern suggests they had the highest score in 2021. In terms of changes over time, we observe solid improvements in both environmental and socio-economic scores in all regions. For instance, SDG 9 (industry, innovation, and infrastructure) increased by 6.5 points or more on average in every region, with companies from China (+7.6 points) and the Rest of the world (+7.2 points) performing significantly better than average along this dimension. The ongoing positive development of EU-based companies signals a strong commitment to pursue the objectives set by the EU to move towards a more just and climate-neutral society. Chinese-headquartered companies improved the most, especially in the environmental SDGs; it is too soon to tell whether this is an early sign of catching up with other major economies, but it is certainly worth monitoring in the future.

Figure 6.3: SDG progression scores - sectoral comparison: 2016-2020 vs 2021

ENVIRONMENTAL

	CN	EU	JP	RoW	US
6. Clean water & sanitation	6.7	5.0	4.4	3.8	4.6
7. Affordable & clean energy	6.5	4.6	3.7	5.7	4.5
12. Responsible consumption & prod.	9.0	6.2	5.7	6.8	6.5
13. Climate action	9.1	5.7	5.8	6.9	5.8
14. Life below water	6.1	6.3	3.5	5.3	5.2
15. Life on land	8.3	6.4	4.8	5.4	5.7

SOCIO-ECONOMIC

	CN	EU	JP	RoW	US
3. Good health & well-being	5.8	3.9	3.6	4.3	4.7
5. Gender equality	3.6	5.3	5.0	5.4	4.6
8. Decent work & economic growth	6.3	4.9	5.0	5.4	6.8
9. Industry, innovation & infrastructure	7.6	6.5	6.9	7.2	6.9

Note: Each cell refers to a unique combination of area SDG. The number and the colour of each cell convey different information. The colour represents average score achieved in 2021 in a given SDG (see row) by companies from a given region (see column); darker colour shades correspond to a higher score in 2021. The number in the cell is the difference between the average score achieved in a given SDG by *Scoreboard* companies from a given region computed in 2021 and in 2016-2020; the number in the cell is the growth in the score achieved in 2021 with respect to 2016-2020.
Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Covalence.

6.2 Environmental impact of the top R&D investors – analysis of climate action (SDG 13) and affordable and clean energy (SDG 7)

This section examines the performance of top R&D investors across industries, regions, and time in targeting climate action (SDG 13) and affordable and clean energy (SDG 7) by reducing carbon dioxide (CO_2) emissions and increasing energy efficiency. Reducing greenhouse gas emissions and dependence on non-fossil fuel-based energy sources is crucial in the current climate and energy crises. The 2030 climate target plan[121] and the European Climate Law[122] set ambitious targets for CO_2 emissions by 2030 and expect the EU to be climate-neutral by 2050.

We focus on some of the most pressing environmental SDGs by using data collected at company level[123]. In particular, the amount of total (direct and indirect) CO_2 emissions is one of the main KPIs to measure the ability of *Scoreboard* companies to achieve climate action goals (SDG 13). To gauge these companies' abilities to address affordable and clean energy (SDG 7), we use the amount of total energy consumed by the company[124]. Box 6.2 describes the main data source and methods used in the analysis.

Box 6.2: Data and methods for the analysis of climate action (SDG 13) and affordable and clean energy (SDG 7)

The measures used in the analysis are based on data in the Eikon database from Refinitiv[125]. We focus on data reported by *Scoreboard* companies on their CO_2 emissions and energy use. CO_2 emissions include total CO_2 and CO_2 equivalent emissions in tonnes. Data are collected following the greenhouse gas (GHG) protocol[126] for all emission classification types and, therefore, refer to CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCS), perfluorinated compound (PFCS), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3). Total CO_2 emissions are further separated into direct and indirect emissions. Direct emissions refer to emissions coming from sources that are owned or controlled by the company, while indirect emissions come from purchased electricity, heat or steam. Energy use is defined as total direct and indirect energy consumption in gigajoules. It includes the total amount of energy consumed (both purchased and produced) as part of the company's operations[127].

121 European Commission (2020), Stepping up Europe's 2030 climate ambition — Investing in a climate-neutral future for the benefit of our people, COM(2020) 562 final, Brussels.

122 Regulation (EU) 2021/1119 of the European Parliament and of the Council of 30 June 2021 establishing the framework for achieving climate neutrality and amending Regulations (EC) No 401/2009 and (EU) 2018/1999 ('European Climate Law').

123 In this respect, the analysis in this chapter differs from the approach taken in related studies looking at emissions at the country level. Nevertheless, general trends reported here are in line with country-level macro-dynamics. See for example, Crippa M., Guizzardi D., Banja M., Solazzo E., Muntean M., Schaaf E., Pagani F., Monforti-Ferrario F., Olivier, J.G.J., Quadrelli, R., Risquez Martin, A., Taghavi-Moharamli, P., Grassi, G., Rossi, S., Oom, D., Branco, A., San-Miguel, J., & Vignati, E. CO2 emissions of all world countries – JRC/IEA/PBL 2022 Report, Publications Office of the European Union, Luxembourg, 2022, doi:10.2760/07904, JRC130363; The European Round Table for Industry (ERT), European Competitiveness and Industry Benchmarking Report 2022; Enerdata – Global Energy and Climate Trends 2022 Edition.

124 These measures are used for monitoring countries' achievements in SDGs by, among others, the UN and Eurostat. See https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%20refinement_Eng.pdf and https://ec.europa.eu/eurostat/web/sdi.

125 Refinitiv's Eikon is a well-known database used extensively for financial analysis, academic work, and policy reporting. It provides transparent, objective, and auditable extra-financial information based on public disclosures from companies. Refinitiv offers a transparent rating methodology and facilitates the understanding of how the data are aggregated from different information sources. It includes more than 12 000 global companies across 76 countries, covering more than 85% of global market capitalisation and has data going back to 2002.

126 See https://ghgprotocol.org/.

127 For companies in the utility sector, transmission / grid loss resulting from business activities is considered as total energy consumed. Electricity produced to satisfy demand by third parties is not included (i.e. utility companies producing energy for sale). Furthermore, raw materials such as coal, gas or nuclear used in the production of energy are not considered.

We derive a number of indicators to better characterise emissions and energy use by relevant dimensions. First, we compute CO_2 intensity to weigh a company's emissions by the scale of its operations:

$$\text{Carbon intensity} = \frac{CO_2 \text{ emissions (thousand tonnes)}}{\text{Net sales (EUR)}}$$

This measures a company's carbon footprint better as it associates the generation of emissions to the company's size. We also provide two breakdowns of carbon intensity. The first one refers to direct vs indirect emissions:

$$\frac{CO_2 \text{ emissions (thousand tonnes)}}{\text{Net sales (EUR)}} = \frac{\text{Direct } CO_2 \text{ emissions (thousand tonnes)}}{\text{Net sales (EUR)}} + \frac{\text{Indirect } CO_2 \text{ emissions (thousand tonnes)}}{\text{Net sales (EUR)}}$$

The second breakdown helps shed light on the efficiency of energy use compared with how clean the energy source used is:

$$\frac{CO_2 \text{ emissions (thousand tonnes)}}{\text{Net sales (EUR)}} = \frac{CO_2 \text{ emissions (thousand tonnes)}}{\text{Energy use (thousand joules)}} \times \frac{\text{Energy use (thousand joules)}}{\text{Net sales (EUR)}}$$

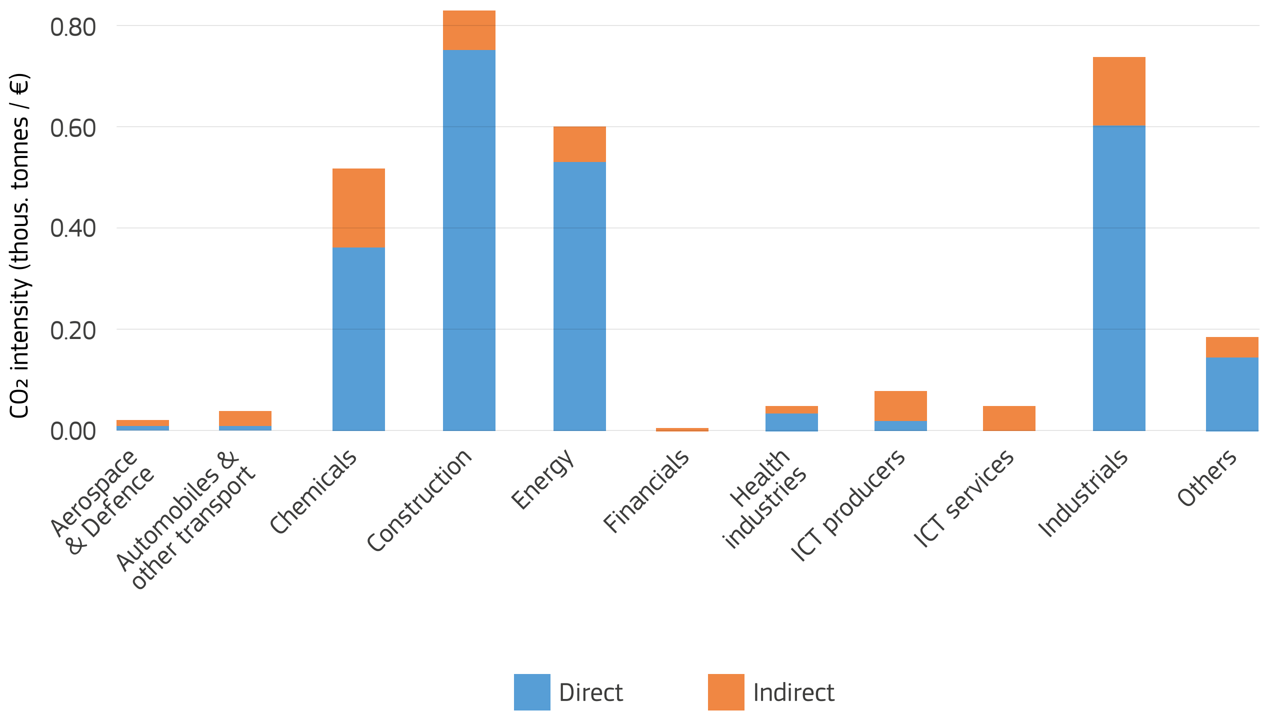
The first term on the right-hand side of the equation above (carbon energy intensity) measures how clean the energy sources used by a company are. A decrease in this term implies that a company has adopted breakthrough carbon-saving technologies / production processes (e.g. circular economy principles) or deployed new green energy sources (e.g. renewables, hydrogen). The second term (energy intensity) is an indicator of a company's energy efficiency. A fall in this term suggests the adoption of (mostly incremental) energy-saving technologies / operational practices (e.g. low energy light bulbs, energy-saving machinery).

Figure 6.4 reports CO_2 intensity for 2020 (the last year available) across sectors of activity of *Scoreboard* companies. The figure also provides a breakdown by emission sources (direct or indirect). Companies in the construction, industrials, energy, and chemical sectors are the most carbon-intensive and account for 76% of the overall carbon emissions from *Scoreboard* companies[128]. Within industrials, steel and aluminium manufacturers account for the largest share of carbon emissions with nearly 40%, while the second largest contributors – manufacture of coke and refined petroleum products – account for a mere 3%. Moreover,

[128] This is calculated as the ratio of the weighted sum of total emissions for the four sectors over the total weighted sum.

these sectors (together with the health sector) are characterised by a disproportionate amount of direct emissions compared with indirect ones. Aerospace and defence, automobile, financial, and ICT (services and producers) sectors have a higher share of indirect emissions, which means that most of their emissions come from purchased energy rather than from internal production processes.

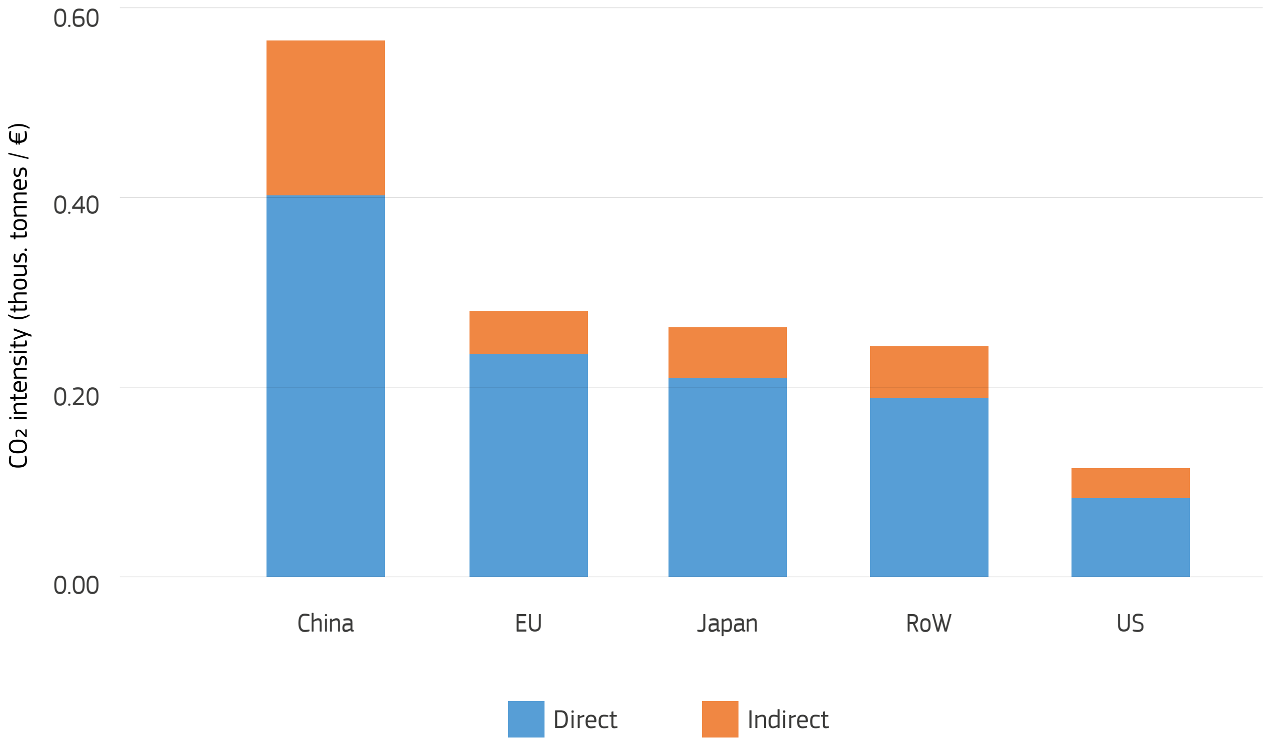
Figure 6.4: Average direct and indirect carbon intensity by sector in 2020



Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Refinitiv.

Figure 6.5 shows carbon intensity across regions of the world. US-headquartered *Scoreboard* companies have the lowest carbon footprint, followed by companies in the rest of the world, Japan, and the EU. Those headquartered in China have the highest carbon footprint. The EU (jointly with US) leads in indirect emissions with one of the lowest values.

Figure 6.5: Average direct and indirect carbon intensity by region in 2020

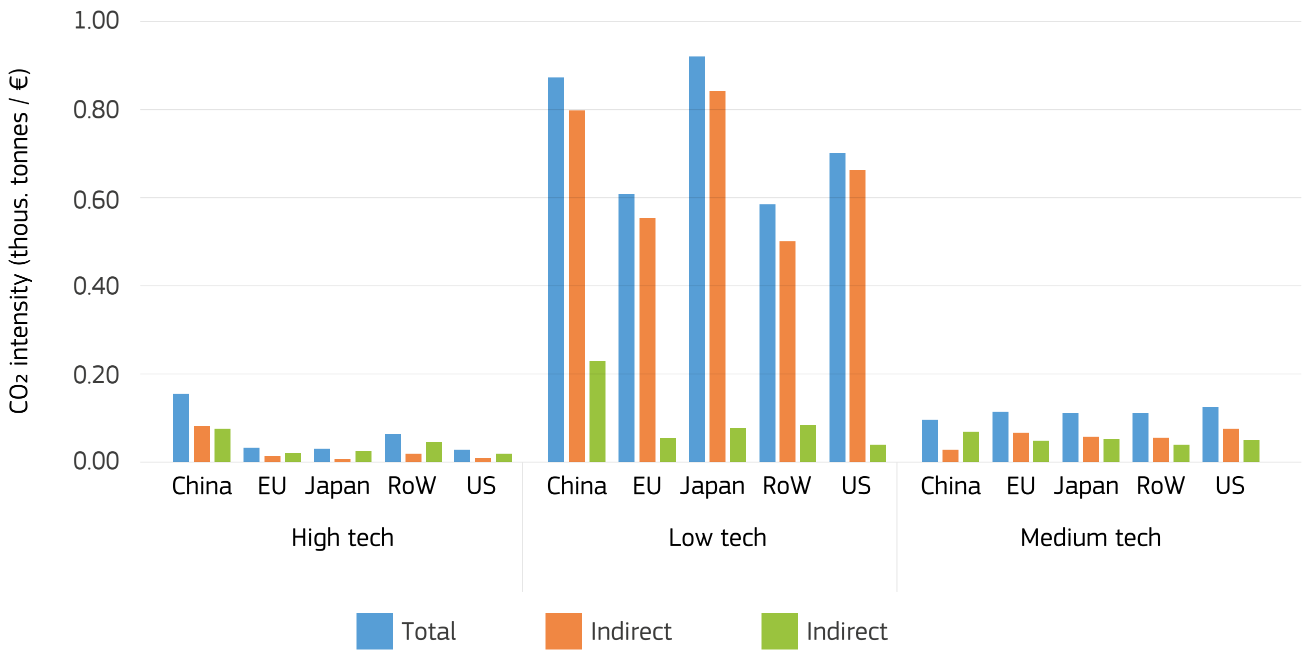


Note: Data refers to 1045 companies for which data on carbon emission is available representing 70% of the R&D invested in the whole sample.
Source: JRC extraction from EIC working paper "Identification of emerging technologies and breakthrough innovations." Available online at: https://eic.ec.europa.eu/system/files/2022-02/EIC-Emerging-Tech-and-Breakthrough-Innov-report-2022-1502-final.pdf".

Figure 6.6 presents a further breakdown by world region and type of industry[129] and illustrates the big differences of top R&D investors' carbon footprints. As expected, low technology sectors are those with the highest CO_2 intensity, irrespective of where the companies are headquartered. Japanese companies show the highest score in the low-tech group. Low- and medium-tech Chinese companies have high carbon-intensity scores, and high-tech companies have the highest CO_2 intensity. EU companies fare well across all three types of industry and lead or co-lead for both direct and indirect carbon intensity.

[129] This classification takes into account the average R&D intensity of all companies aggregated by ICB 3-digits sectors: high is above 5%; medium between 1% and 5%; and low below 1%. To compensate for the insufficient representativeness of the *Scoreboard* in some sectors, they are adjusted using the OECD definition of technology intensity for manufacturing sectors. For simplification, in this report the three groups are also referred to as high tech, medium tech and low tech.

Figure 6.6: Average direct and indirect carbon intensity by world region and industry in 2020

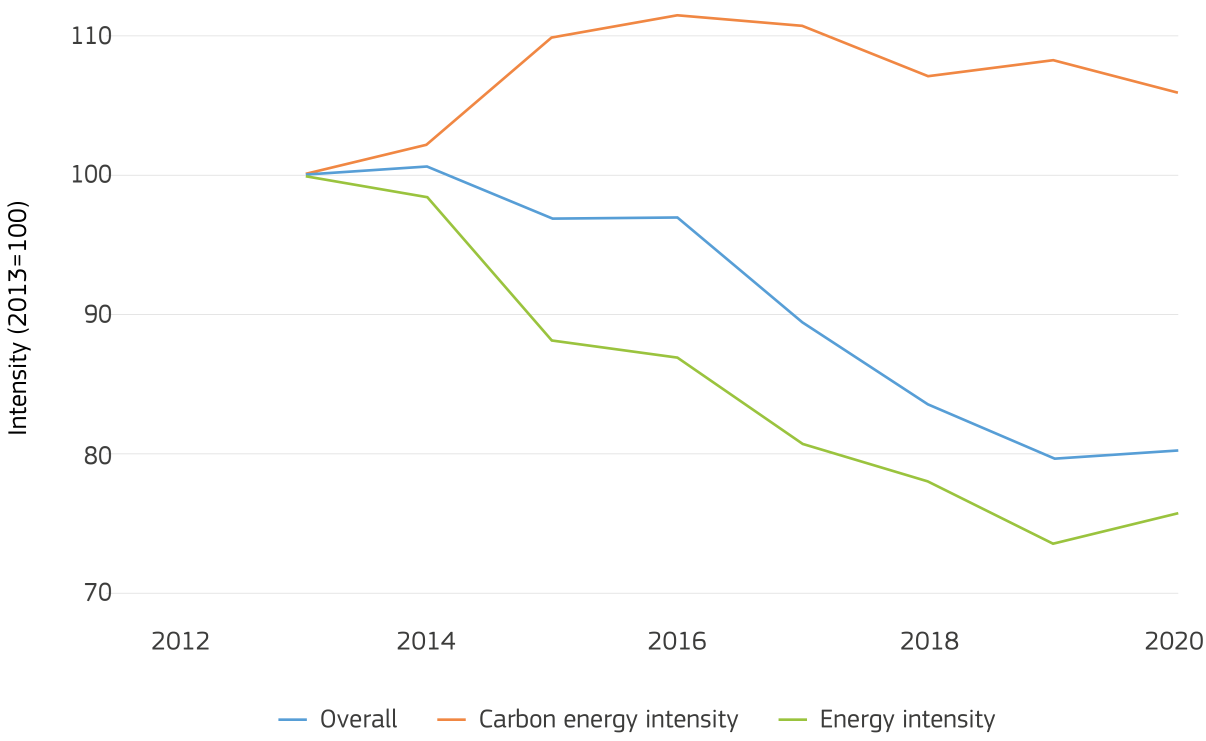


Note: Data refers to 1045 companies for which data on carbon emission is available representing 70% of the R&D invested in the whole sample. The numbers of films for the US in low-tech sector is less than 10, so the figure should be interpreted with caution.
JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Refinitiv.

Figure 6.7 presents the trend in carbon intensity and its two main dimensions (carbon energy intensity and energy intensity) between 2013 and 2020 for the *Scoreboard* companies for which the relevant data are available for at least 6 years (627 companies)[130]. The figure shows that carbon intensity fell sharply for *Scoreboard* companies. On average, carbon intensity decreased by 20% between 2013 and 2020, with the sharpest fall taking place between 2016 and 2019[131]. The main driver reducing SB companies' carbon footprints is the drop in energy intensity, which in 2020 was 25% lower than in 2013. On the contrary, carbon energy intensity is over 5% higher than in the base year although it has been falling since 2016. The sharp decrease in energy intensity reflects the adoption of energy-saving technologies by top R&D investors as well as organisational change due to, for example, increased servitisation of energy-intensive manufacturing processes[132]. Comparatively less effort has been made in reducing emission intensity in energy production (carbon energy intensity). This reflects attempts to substitute fossil fuels with alternative energy sources (e.g. renewables, biomass, hydrogen), which has gotten closet to but contributed less to the overall decrease in carbon emissions. Overall, *Scoreboard* companies have meeting the emission target for climate action (SDG 13) and the energy efficiency target for affordable and clean energy (SDG 7). They have also contributed to reducing their primary energy consumption for affordable and clean energy (SDG 7), albeit to a lesser extent.

130 Similar results are obtained when companies with data on all years (2013-2020) are retained (541 companies).
131 Figures 6.7, 6.8 and 6.9 do not point to a significant drop in emissions in 2020 following closures due to the COVID-19 pandemic. This is because we represent indexes where both emissions and sales were heavily affected by health restrictions. When looking at absolute numbers, there are decreases overall and in relevant sectors.
132 Servitisation is where companies pay for a service rather than buying the equipment or machinery and it goes hand in hand with the increasing relevance of the service sector in major economies. This can be a major contributor to decarbonisation. Mulder, P., De Voigt, S., De Cian, E., Schymura, M., & Verdolini, E. (2014). Energy intensity developments in 40 major economies: structural change or technology improvement?. Energy Economics, 41, pp. 47-62.

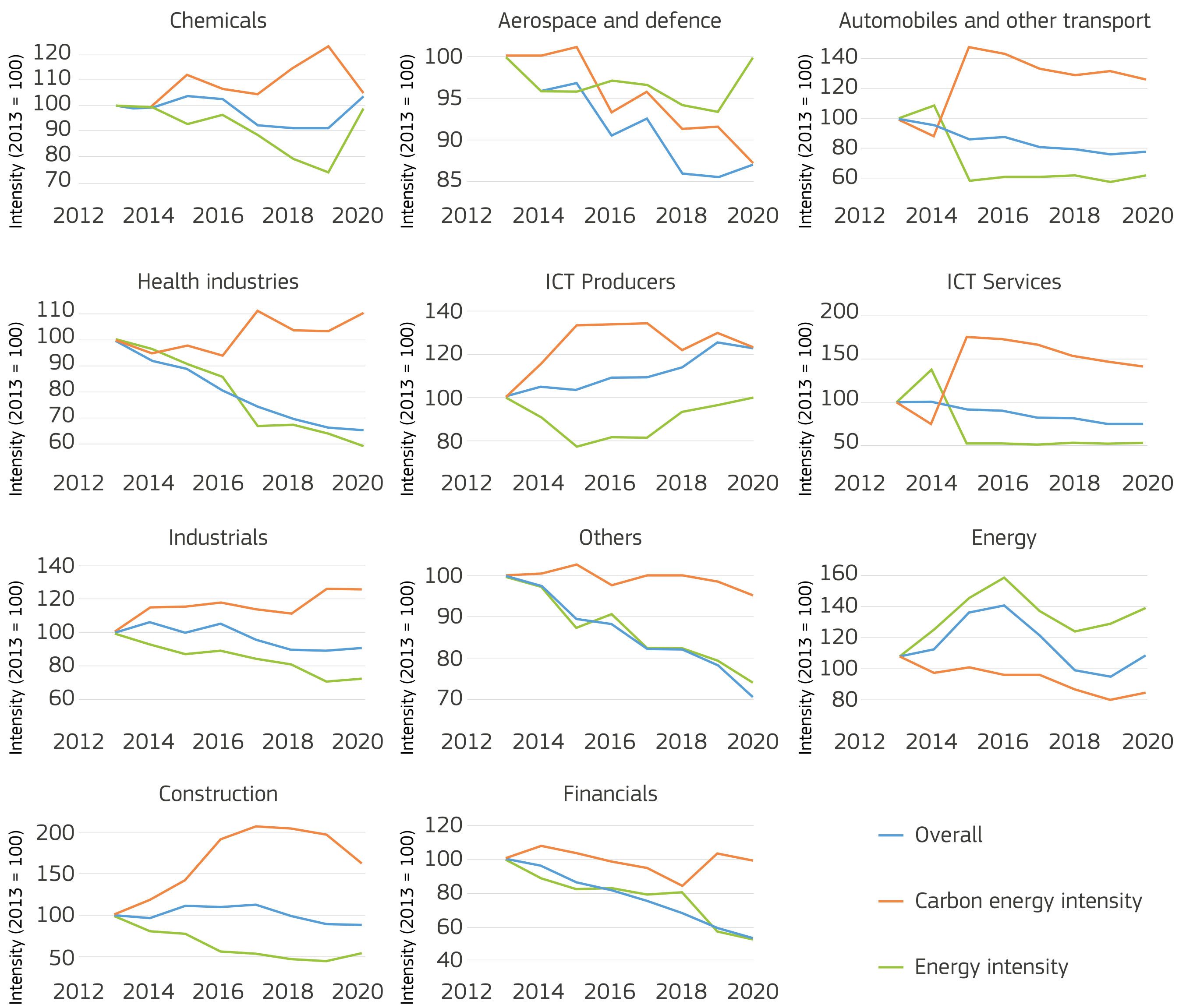
Figure 6.7: Carbon intensity by year – 2013-2020 (2013 base year = 100)



Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Refinitiv.

Figure 6.8 and Figure 6.9 present a breakdown of carbon scores by industry and world region and illustrate the difference in SB companies' responses to SDG 13 and SDG 7. Figure 6.8 shows that the sectors contributing the most to the fall in carbon intensity between 2013 and 2020 included *Scoreboard* companies from the financial (-47%), health (-34%), ICT services (-27%), and automobile (-22%) sectors. Companies from the aerospace (-13%), construction (-12%), and industrial (-9%) sectors also contributed but to a lesser extent. Carbon intensity increased in the energy (+0.5%) and chemical (+4%) sectors, but the largest increase came from ICT producers (+23%). In contrast, all sectors saw a drop in energy intensity between 2013 and 2020. The financial, ICT services, construction, health, and automobile sectors reduced their energy intensity by 40% or more. The main exception were *Scoreboard* companies in the energy industry, which increased their energy intensity by more than 30%. This was counter-balanced by a comparable decrease in carbon energy intensity (-24%), which indicates progress in decarbonising energy production. *Scoreboard* companies in other sectors (aerospace and financials, with -13% and -0.23% respectively) witnessed a decline in carbon energy intensity, while most other industries experienced an increase of 20% or more.

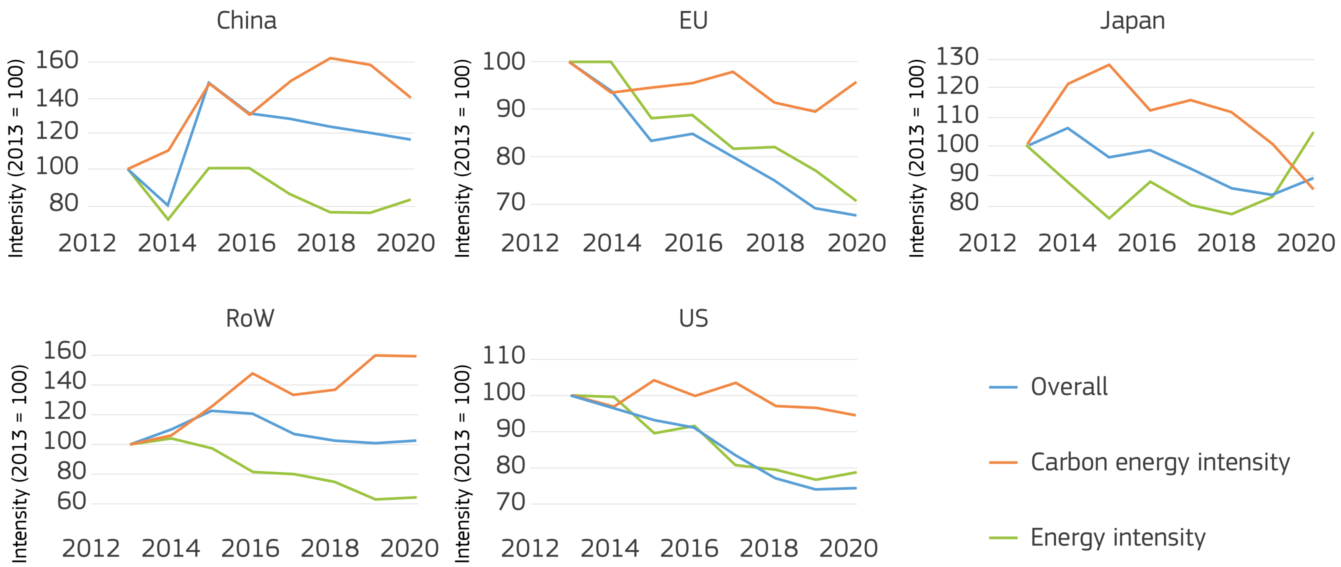
Figure 6.8: Carbon intensity by industry – 2013-2020



Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Refinitiv.

Figure 6.9 shows average carbon-intensity scores by world regions where the *Scoreboard* companies are headquartered. *Scoreboard* companies based in the EU and the US had the largest drop in overall carbon intensity over the period. EU-headquartered companies lead this reduction with a 32% decrease compared with 2013 levels. Companies based in the US and Japan have a similar trend albeit less steep, with reductions in carbon intensity of 25% and 10% respectively. *Scoreboard* companies headquartered in the Rest of the world and China increased their overall carbon intensity (+3% and +16% respectively). Similar to the industry breakdown, most carbon-intensity reduction comes from the steep decline (-15% or higher) in the energy intensity of *Scoreboard* companies in all world regions, except for those from Japan, which experienced a sharp increase in the last year alone. Companies based in Japan, the US, and the EU also witnessed a decrease in carbon energy intensity (-14%, -5.5% and -4.5% respectively), while China and the Rest of the world experienced a huge increase (+37% and +60%). This highlights a significant divide between world regions in achieving targets for climate action (SDG 13) and affordable and clean energy (SDG 7). On one hand, SB companies headquartered in EU, US, and Japan have been able to reduce their carbon footprints by: i) adopting energy-saving technologies; and ii) substituting fossil fuels in energy consumption (to a lesser extent). On the other hand, companies based in China and the Rest of the world saw an increase in their carbon footprints mainly due to their inability to counterbalance a steep increase in carbon energy intensity with improved energy efficiency.

Figure 6.9: Carbon intensity by world region – 2013-2020



Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Refinitiv.

6.3 SDG-related innovative output by top R&D investors

In this section, we keep the focus on affordable and clean energy (SDG 7) and climate action (SDG 13). However, we now look at specific scientific outputs and technological innovations of the top R&D investing companies that signal their ability and commitment to engage in breakthrough research that helps achieve SDGs. The New European Innovation Agenda[133] places great importance on deep technologies (deep-techs), which are expected to 'drive innovation across the economy and society addressing the most pressing societal challenges, including by achieving the SDGs[134]. In line with this, we sharpen our focus on the technological and scientific outputs that fall under the deep-tech category.

[133] https://ec.europa.eu/commission/presscorner/detail/en/IP_22_4273
[134] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52022DC0332&from=EN

Box 6.3: Identifying innovation in deep technologies by *Scoreboard* companies

Identifying the technological and scientific outputs that fall under the deep-tech category involves two steps:

- Linking *Scoreboard* companies to technological and scientific outputs that are relevant to SDGs;
- Selecting deep-tech outputs from among the SDG-relevant outputs of the *Scoreboard* companies above.

For the first step, we relied on an exploratory study[135] conducted by SIRIS Acedemic[136] (SIRIS) that produced a database identifying patents, scientific publications, and Horizon 2020 (H2020) projects carried out by *Scoreboard* companies that are relevant to one or more SDGs. To do so, the study first used tailored string matching techniques to retrieve *Scoreboard* companies and the associated records in Elsevier's abstract and citation database Scopus[137] (to collect scientific publications by authors affiliated to *Scoreboard* companies) and in CORDIS[138] (to collect H2020 projects in which *Scoreboard* companies participate).

To identify the patents of SB companies, SIRIS used the 2021 edition of the JRC/OECD COR&DIP database, which lists international patents filed between 2016 and 2019 by the companies listed in the 2019 *Scoreboard* report. After retrieving the records associated with the *Scoreboard* companies from the above databases, SIRIS applied natural language processing techniques to the textual descriptions (H2020 project descriptions, abstracts of patents and scientific publications) to determine which records had a meaningful connection to one or more SDGs. The final output of the SIRIS project consisted of:

- the list of *Scoreboard* companies involved in SDG-relevant R&D related outputs (patents, publications or H2020 projects) between 2017 and 2020;
- the unique identifier of all selected R&D outputs (the Patent application ID[139], the Scopus ID, and the CORDIS ID, respectively);
- the SDG(s) for which each selected R&D related output was deemed relevant.

With this information, we retrieved the titles and abstracts (project descriptions for H2020 projects) of the database items identified by SIRIS. In parallel, a way to identify technologies that we could classify as deep-techs was developed. This is not a trivial task because there is not a clear consensus yet on what exactly should be considered deep-tech. A guiding principle is that deep-techs concern cutting-edge physical, biological, and digital advances, which entail long development phases, massive R&D and capital investment, and have a significant societal impact. This principle is close to a recent working paper published by the European Innovation Council (EIC) identifying several emerging technologies and breakthrough innovations of high interest to the EIC because of their 'potential for future technological, economic and social impacts'[140].

135 See Massucci, F. & Seri, A.: 'Exploratory study understanding the SDG alignment along research activities and technological innovation of *Scoreboard* companies', JRC Technical Report, October 2022.
136 https://sirisacademic.com/
137 https://www.scopus.com
138 https://cordis.europa.eu/projects
139 As recorded in the COR&DIP database and in the European Patent Office's worldwide patent database, Patstat (https://www.epo.org/searching-for-patents/business/patstat.html).
140 European Commission, European Innovation Council and SMEs Executive Agency, Lopatka, M., Pólvora, A., Manimaaran, S., et al. 2022:, Identification of emerging technologies and breakthrough innovations https://op.europa.eu/en/publication-detail/-/publication/7c1e9724-95ed-11ec-b4e4-01aa75ed71a1

The report describes several breakthrough technologies related to the European Green Deal, health, and the digital domain. It also provides a set of associated keywords for each technology. The EIC report identifies technologies that fit the current definition of deep-tech, and, by leveraging the keywords, it was possible to look for deep technologies in the description of the SDG-related outputs listed in the exploratory study data.

Table 6.2: EIC breakthrough technologies and keywords

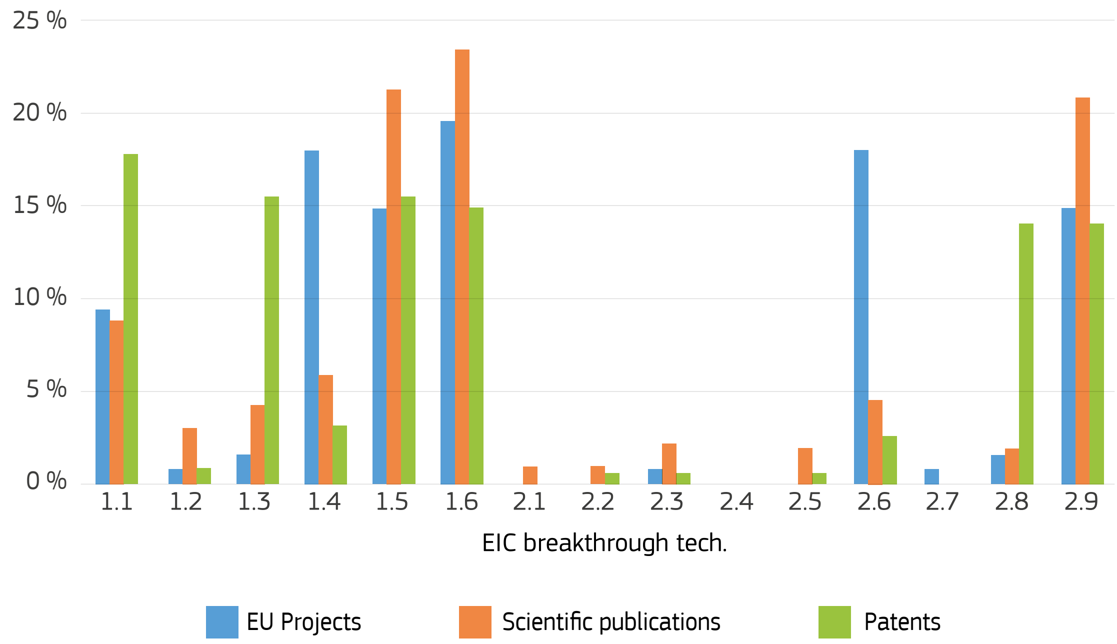
No	Dimension	Deep-tech	Keywords
1.1	Green deal	Energy harvesting, conversion, and storage	aluminium-based energy; molten salt reactors; hydrogen fuel; airborne wind turbine; bioelectronics; artificial photosynthesis
1.2	Green deal	Cooling and cryogenics	nanowires; optoelectronics; flexible electronics; hydrogels; metamaterials
1.3	Green deal	Industry and agriculture decarbonisation and pollution abatement	artificial photosynthesis; bioplastic; microbial fuel cells; precision farming; automated indoor farming; plant communication
1.4	Green deal	Environmental intelligence and monitoring systems	artificial intelligence; geoengineering precision farming; molecular recognition; flexible electronics; plant communication
1.5	Green deal	Water-energy nexus	energy harvesting; water splitting; desalination; precision farming; tidal power technologies; wastewater nutrient recovery
1.6	Green deal	Sustainable, safe and regenerative buildings	energy harvesting; smart windows; nanoleds; self-healing materials; 3D printing of glass; wastewater nutrient recovery
2.1	Digital & industry	Next-generation computing devices and architectures	computing memory; quantum computers; graphene transistors; neuromorphic chip; spintronics
2.2	Digital & industry	Chip-scale frequency combs	high-precision clock; optoelectronics; quantum computers; quantum cryptography
2.3	Digital & industry	Photon, phonon, electron triangle	2D materials; metamaterials; optoelectronics; spintronics; quantum computers; computing memory
2.4	Digital & industry	DNA-based digital data storage	bioelectronics
2.5	Digital & industry	Alternative approaches to quantum computation	flexible electronics; computing memory; quantum computers; optoelectronics; spintronics
2.6	Digital & industry	AI-based local digital twins	local digital twin; artificial intelligence (AI)
2.7	Digital & industry	New uses of space	asteroid mining
2.8	Digital & industry	2D materials for low-power electronics	2D materials; carbon nanotubes; graphene transistors
2.9	Digital & industry	Sustainable electronics	flexible electronics; biodegradable sensors; bioelectronics; self-healing materials; graphene transistors; artificial photosynthesis;

Note: The first column contains a numerical index used as a shorthand for the deep-techs in this section. The last column in the table contains a sample of the keywords associated to each deep-techs in the EIC report.
Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard and Refinitiv.

Table 6.1 presents a list of all deep-techs selected from the EIC report[141]. We performed a string search with all the keywords in the abstracts and project descriptions linked to SDGs 7 and 13 in the exploratory study. We were able to associate 70 H2020 projects, 734 scientific articles, and 206 patents with one or more deep technologies. These associations are found in 234 *Scoreboard* companies, revealing a base of real corporate activities in deep-techs. In the rest of this section, we first provide a general overview of the relevance of each deep-techs for the SDG-related R&D outputs (publications, patents, and research projects).

Figure 6.10 presents the percentage of H2020 projects (blue bars), scientific articles (orange bars), and patents (green bars) that we link to each EIC technology. The figure clearly shows that technologies are not equally relevant. For instance, technology 1.2 (cryogenics) and most of the digital deep technologies (2.1 to 2.5, 2.7) are either marginal or missing, irrespective of the type of output considered[142]. Moreover, the relevance of deep-techs varies with the type of output. For instance, the deep-techs that are associated to a large number of documents are rather evenly distributed across patents. The same is not true for H2020 projects, in which technologies 1.4 (environmental monitoring) and 2.6 (local digital twins) are the most represented. For scientific articles, keywords associated to deep-techs 1.5 (water-energy nexus), 1.6 (sustainable buildings), and 2.9 (sustainable electronics) are the most common.

Figure 6.10: **Percentage of H2020 projects, scientific articles, and patents associated with SDG 7 or SDG 13 and linked to each EIC deep technology**



Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard, EIC, and SIRIS.

Figure 6.11 breaks down the relevance of deep-techs by SDG and document type. The orange heat maps refer, respectively, to H2020 projects, scientific articles, and patents involving any of the *Scoreboard* companies; the blue heat maps only refer to scientific articles and patents involving EU-based companies. A darker

[141] The EIC report identifies technologies related to the Green Deal, health, and the digital domain. However, due the focus on environmental SDGs, we rule out health-related deep-techs and focus on the other two categories.

[142] For technologies 2.4, 2.6, and 2.7, the very short list of associated keywords could be driving the result.

colour shade in a cell indicates a higher percentage of documents linked to the corresponding technology.

In the data on all SB companies (orange heat maps), patenting linked to SDG 13 is concentrated in deep technologies 1.1 (energy storage), 1.3 (decarbonisation) and 2.8 (2D materials for low-power electronics). The same technologies are also relevant for SDG 7; however, technological innovation in 1.5 (water-energy nexus), 1.6 (green buildings) and 2.9 (sustainable electronics) is also relevant in this case.

In contrast, scientific research relevant to SDG 7 is relatively concentrated in deep technologies 1.5 (water-energy nexus), 1.6 (sustainable buildings) and 2.9 (sustainable electronics). Scientific research related to SDG 13 is spread among a wider range of technologies: most of the Green Deal related deep technologies as well as technologies 2.6 (local digital twins) and 2.9 (sustainable electronics). Patenting and scientific articles in technologies 2.1 to 2.7 are not relevant to either SDGs, with the notable exception of technology 2.6 (AI-based local digital twins), which shows a high percentage of scientific publications linked to SDG 13.

For EU-based companies (blue heat maps), the relevance of deep technologies in scientific publications follows a similar pattern to the one observed for all SB companies (in the orange heat map). However, patenting in deep technologies by EU-based *Scoreboard* companies shows some obvious specificities. Comparing patents for all SB companies with patents for EU-based companies, we observe EU-based companies seem to mostly specialise in technologies 1.5 (water-energy nexus), 1.6 (sustainable buildings), and 2.9 (sustainable electronics). At the same time, patenting in technologies 1.3 (decarbonisation) and 2.8 (2D materials) appears to be less relevant to EU-based companies than in SB companies in general.

Figure 6.11: Breakdown of the relevance of each EIC deep technology by SDG and document type

EU projects

	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
SDG 7	10.4 %	0.9 %	1.7 %	15.7 %	14.8 %	21.7 %			0.9 %			15.7 %		1.7 %	16.5 %
SDG 13	12.0 %			24.0 %	10.0 %	18.0 %						24.0 %	2.0 %		10.0 %

Scientific publications

	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
SDG 7	8.8 %	3.0 %	3.6 %	5.1 %	21.7 %	24.5 %	1.0 %	1.0 %	2.2 %		2.0 %	3.9 %		1.6 %	21.5 %
SDG 13	10.4 %	0.5 %	10.0 %	14.9 %	18.1 %	19.0 %			0.5 %			12.7 %		2.3 %	11.8 %

Patents

	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
SDG 7	18.3 %	0.5 %	15.5 %	3.8 %	13.7 %	14.8 %		0.3 %	0.3 %		0.3 %	3.6 %		15.3 %	13.7 %
SDG 13	24.0 %	1.1 %	22.9 %	2.3 %	10.9 %	8.0 %		0.6 %	0.6 %		0.6 %	1.1 %		20.0 %	8.0 %

Scientific publications

	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
SDG 7	7.5 %	4.6 %	4.1 %	6.0 %	20.2 %	21.2 %	1.0 %	1.7 %	2.4 %		2.9 %	4.8 %		1.4 %	22.4 %
SDG 13	9.4 %		11.3 %	20.8 %	13.2 %	13.2 %						18.9 %		3.8 %	9.4 %

Patents

	1.1	1.2	1.3	1.4	1.5	1.6	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
SDG 7	13.2 %	1.9 %	7.5 %		22.6 %	22.6 %								7.5 %	24.5 %
SDG 13	23.5 %	5.9 %	5.9 %		17.6 %	17.6 %								5.9 %	23.5 %

Note: The orange heat map shows outputs of all *Scoreboard* companies while the blue heat map only shows outputs by EU-based *Scoreboard* companies. The colour shading and the number in the cells convey the same information: a darker shade corresponds to a higher percentage of documents linked to a given technology.
Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard, EIC, and SIRIS.

To better illustrate the evidence above, Table 6.3 provides examples of breakthrough EU-funded collaborative projects, technological advances, and scientific discoveries. There is an example of each of the three different output types (projects, patents, and scientific publications) for each SDG along with other information (the number of breakthrough categories, year of publication, region of the headquarters of the corresponding *Scoreboard* company, name of the company, and a brief description). For example, Airbus has received EU funding to lead a consortium in the aviation industry with the aim of reducing the industry's environmental footprint, which has significant implications for achieving SDG 13. Similarly, Fujifilm contributed to a scientific discovery in the area of radiative cooling, which brings the promise of harvesting the coldness of the universe as a thermodynamic resource and is thus relevant to achieving both SDG 13 and SDG 7. Also for SDG 7, LG CHEM filed a patent application protecting an AI fuel cell system, which can generate energy more efficiently thanks to the feedback received by an AI unit processing relevant data gathered through sensors.

Table 6.3: Examples of breakthrough research projects, patents and publications for achieving SDG 13 and 7

SDG	Breakthrough categories	Year	Type	Region	Company name	Short description of output
SDG 13	Environmental intelligence and monitoring systems; AI-based local digital twins	2020	EU-funded project	EU	AIRBUS	Albatross is a modernisation programme for European air traffic control infrastructure. It is managed by major European aviation stakeholders and aims to reduce aviation's environmental footprint.
SDG 7; SDG 13	Energy harvesting, conversion, and storage; Cooling and cryogenics; Chip-scale frequency combs; Photon, phonon, electron triangle; Alternative approaches to quantum computation; Sustainable electronics	2018	Patent	US	BIOGEN	Transparent wood composite able to yield an improvement in overall energy conversion efficiency and emission abatement with a range of applications in biodegradable electronics and optoelectronics.
SDG 7; SDG 13	Water-energy nexus; Sustainable, safe and regenerative buildings; Sustainable electronics	2018	Publication	Japan	FUJIFILM	Self-adaptive radiative cooling based on phase-change materials.
SDG 7	Environmental intelligence and monitoring systems; Water-energy nexus; Sustainable, safe and regenerative buildings; AI-based local digital twins; Sustainable electronics	2020	EU-funded project	EU	THALES	Nanomaterials enabling smart energy harvesting for next-generation internet-of-things.
SDG 7	Environmental intelligence and monitoring systems; AI-based local digital twins	2018	Patent	Rest of the world	LG CHEM	AI fuel cell system comprising fuel cell stack for generating electric energy, sensors to gather real time data and AI unit to process the data to provide feedback on optimal and efficient operation of the fuel cell stack.
SDG 7	Energy harvesting, conversion, and storage; Sustainable, safe and regenerative buildings	2018	Publication	EU	DAIMLER	Batteries and fuel cells for emerging electric vehicle markets.

Source: JRC own compilation based on data from the EU Industrial R&D Investment Scoreboard, EIC, and SIRIS.

6.4 Key points

- The clear upward trend across SDG scores between 2016 and 2020 is confirmed by the 2021 data. This signals an ongoing commitment of the top R&D investing companies to social and environmental responsibility. In line with past evidence, clean and affordable energy (SDG 7), decent work and economic growth (SDG 8) and life on land (SDG 15) achieve the highest absolute scores. Overall, the scores increased by 10% or more between 2016 and 2021, with some growing by almost 20% (e.g. climate action - SDG 13).

- In 2021, EU-based companies led in many environmental SDGs: affordable and clean energy (SDG 7), life on land (SDG 15), responsible consumption & production (SDG 12), and climate action (SDG 13). These companies also achieved the highest scores across the board in the socio-economic SDGs.

- By adopting new processes and technologies to tackle SDG challenges, *Scoreboard* companies reduced carbon intensity by more than 20% compared with 2013, which is relevant to both climate action (SDG 13) and clean and affordable energy (SDG 7). This decrease is entirely due to increased energy efficiency by top R&D investors, while the adoption of clean energy production technologies still lags behind. EU companies are leading the way with a decrease of more than 30% in energy intensity and 5% in carbon energy intensity.

- Companies operating in the automotive sector and the chemicals sector achieve on average high SDG progression scores in almost all of the environmental SDGs as well as in the socio-economic SDGs 8 (decent work and economic growth) and 9 (industry, innovation & infrastructure). Notably, SDG 9 (industry, innovation and infrastructure) increased by 9.1 points in 2021 with respect to the average for the period 2016-2020 for companies in the chemicals sector. It also increased by 6.5 points or more on average in every region, with companies from China (+7.6 points) and the Rest of the world (+7.2 points) performing significantly better than average along this dimension.

- *Scoreboard* companies are central in developing breakthrough technological and scientific solutions to tackle SDG-related challenges. Patenting linked to climate action (SDG 13) is concentrated in technologies related to energy storage, decarbonisation, and materials for low-power electronics. These technologies are also relevant to clean and affordable energy (SDG 7) as are technologies in the water-energy nexus, green buildings, and sustainable electronics. In contrast, scientific research relevant to SDG 7 is concentrated in relatively few technologies, while scientific research linked to SDG 13 is spread across a much wider range of fields. This indicates the potential for deep technologies to help achieve green and energy policy goals as well as SDG targets.

7 POLICY IMPLICATIONS

Since the establishment of the EU Industrial R&D Investment *Scoreboard* in 2003[143], private R&D investment has captured substantial attention by policy-makers. EU innovation and industrial policy initiatives highlight the importance of monitoring and analysing the state of overall innovation activity in Europe, including private R&D investment (ERA Policy agenda, Digital Compass, European Education Area, and New European Innovation Agenda)[144]. The *Scoreboard* is being developed to contribute to policy monitoring, in particular combining R&D investment data with other data and indicators.

The war in Ukraine has no impact on the 2022 Scoreboard data due to the earlier cut-off dates for financial accounts in 2021, but statements by EU firms are available in the *2022 Survey on EU Industrial R&D Investment Trends*, which has been taken between June-September 2022 and is published together with this report[145]. The 100 EU-based *Scoreboard* firms participating therein indicated that, despite generally worsening economic prospects during the surveyed period due to the Russian war in the Ukraine, they expect their sales, profits and employment to increase in 2022 and 2023. This indicates the resilience of innovative EU companies, especially in high-tech segments, such as ICT and health. During the surveyed time until autumn 2022, the war in Ukraine did not cause any change in R&D investment for 86% of the respondents with little effect on the research portfolio of these rather large firms. Delay of existing R&D projects participants are expected most frequently by respondents in aerospace and defence, construction, health industries and automobiles and parts. But respondents also report that they started new R&D projects that were inspired by the war: this is the case for 80% of the companies in aerospace and defence – which are also the ones facing the most interruptions. Also several respondents in the energy sector and in ICT services report new R&D projects that were influenced by the war context. Overall, the impact of the war on R&D was still limited at the time of this Survey and mostly for the above sectors.

Despite COVID-19, the 2022 *Scoreboard* data show strong global growth of industrial R&D investments for the 12th consecutive year, revealing the strategic nature of such investments. However, the growing differences between the R&D investment levels and growth rates for EU companies and those from the US and China are a cause for concern and action to be taken in both the private sector and public policy domains. Here, also population size enters the equation raising the question why the EU and the US, which are comparable in population size, have taken such different paths in sector specialisation in the past decades and how the EU can create and grow more key players in the ICT and health sectors.

The following EU-level policy measures could be considered to accelerate growth in private R&D investment:

- **Support reindustrialisation of Europe.** Innovation policies need to be promoted to harness the broad industrial base in Europe including particularly the medium and low-tech sectors. The Industrial Strategy includes the establishment of transition pathways for the identified industrial ecosys-

[143] Under the ERA 2003 with a direct mandate from the 3% Action Plan COM(2003) 226 final: Action 6.6: "Set up an industrial research monitoring activity, including a score-board, to analyse trends and facilitate benchmarking of research investment and research management practices between firms, building on experience in Member States (Implementation: Commission support; first report early 2005)".

[144] September 2020 ERA Communication COM (2020) 628 final, May 2021 updated Industrial Strategy for Europe COM (2020) 102 final, 2030 Digital Compass COM (2021) 118 final, and European Education Area COM (2020) 625 final, and the New European Innovation Agenda COM (2022)332 final. The data have been used in SRIP reports and lately in the McKinsey report "Securing Europe's competitiveness – Addressing its technology gap" of September 2022.

[145] The aim of the 2022 Survey on Industrial R&D Investment Trends is to gain further insight on the trends in R&D and innovation and to address factors and policies that influence these investment decisions from the EU-1000 subsample of *Scoreboard* firms. The 2022 questionnaire addresses R&D investment expectations, financing and collaboration, technology transfer & open innovation, as well as short assessments of the effects of the COVID-19 pandemic and the war in Ukraine. See: https://iri.jrc.ec.europa.eu/rd_monitoring

tems[146] and initiatives with industry and Member States which will benefit from links with ERA policy instruments (common industrial technology roadmaps, industrial alliances, and Horizon Europe missions and partnerships). This can benefit from enhanced coordination and directionality of regional, national and EU innovation policies, which can mobilise and accelerate sustainability-oriented economic growth.

- **Promote Corporate Open Innovation to advance industrial transformation.** Although large players, such as top R&D investors, play a key role in R&D investment worldwide due to their size and centrality, radical and game-changing innovations often come from young and innovative companies which were able to grow and scale-up quickly. The EU has an existing base of smaller firms in key sectors, such as ICT and health, and excellent technology capacities across Member States. The EU policy objective in the medium-term could be to provide incentives to retain home-grown technologies and firms, and to facilitate their growth into emerging sectors, particularly green and/or digital[147]. This concerns policies to integrate digital talent and technologies better in traditional manufacturing sectors, support growth strategies of start-ups as well as midcap companies (e.g. to grow beyond SME status, go on international markets), and to increase industrial capacities where more/most of the added value in value chains is produced (e.g. "down" the value chain). Also the New European Innovation Agenda inter alia addresses firm creation and growth in emerging technologies to trigger spill overs between sectors. This would have the effect of reducing both EU R&D investment and R&D intensity gaps vis-à-vis its main global competitors[148].

- **Explore start-up and scale-up measures in relation to Corporate Venture Capital (CVC) activities of existing European and global lead firms.** On a general level, CVC investments of EU-headquartered *Scoreboard* companies are 2.4% of own-funded internal R&D, compared to 4% of their US-headquartered peers. However, 80% of funds from EU-based companies goes to US-based start-ups. A positive regard is that this already produces spill overs, which are also at the heart of the New European Innovation Agenda. Potential measures to close the gap to the higher developed US VC capital[149] market could include better exit opportunities (e.g. facilitating easier floating on the stock market), the promotion of VC networks, or to enhance the visibility of European start-ups, especially outside the country of the headquarters of the mother company to increase the deal flow across national borders and sectors of activity. On a sectoral level, ICT producers and ICT services and health sector have shown a particularly strong positive correlation and high complementarity between R&D and CVC investments. This indicates potential to explore further firms' CVC portfolios towards understanding where to focus the start- and scale-up funding of the New Innovation Agenda[150], e.g. via the European Innovation Council (EIC) Fund.

- **Strike the right balance between the objectives of strategic autonomy/technological sovereignty, industrial transformation (green and digital) and industrial competitiveness/welfare, together with international key partners[151].** In the currently challenging geopolitical and global competition context, the question arises on how to boost industrial innovation, while achieving a proper

[146] These 14 industrial ecosystems are: aerospace and defence, agri-food, construction, cultural and creative industries, digital, electronics, energy intensive industries, energy-renewables, health, mobility – transport – automotive, proximity, social economy and civil security, retail, textile and tourism (see https://ec.europa.eu/info/strategy/priorities-2019-2024/europe-fit-digital-age/european-industrial-strategy_en).

[147] Diodato D., P. Moncada-Paternò-Castello, F. Rentocchini and A. Tübke (2022) 'Industrial innovation for sustainable competitiveness: Science-for-policy insights'. Science for Policy Brief – Industrial Innovation & Dynamics Series. JRC 128430. European Commission, Joint Research Centre – Directorate for Growth and Innovation, Seville (Spain), February 2022.

[148] Moncada-Paternò-Castello, P. Top R&D investors, structural change and the R&D growth performance of young and old firms. Eurasian Bus Rev 12, 1–33 (2022). https://doi.org/10.1007/s40821-022-00206-3.

[149] Available venture capital investment in the EU is about one sixth of the amount it is in the US with a particularly worrying situation for scale-ups in their growth or later stage phases. These figures are from JRC analysis based on Dealroom data that was presented at the expert webinar "Tackling the Scale-Up Gap" on 5 October 2021. This webinar was introduced by Commissioner Mariya Gabriel and was organised by the JRC together with DG-R&I and EISMEA to better quantify the scale-up financing gap, establish what is known about the causes of the gap and its negative economic consequences and to identify how best to address the gap, see: https://publications.jrc.ec.europa.eu/repository/handle/JRC127232).

[150] COM (2022) 332 final.

[151] Technology Sovereignty as an Emerging Frame for Innovation Policy - Fraunhofer ISI Discussion Papers, July 2021.

balance between these three objectives, and in particular the potential trade-offs between Open Strategic Autonomy and the transformative agenda, on one hand, and global industrial competitiveness, on the other[152]. From the point of view of industrial innovation, digital, trade and competition policies, this brings new requirements for key sectors and technologies[153]. The more than tripling number of Chinese *Scoreboard* firms over the past decade benefited from a favourable globalisation context and came mostly from organic growth and growth via acquisition of R&D investing companies. These Chinese M&A peaked around 2018[154], and are now at a 10-year low[155]. This contributed to a higher sensitivity for the possible impact of foreign takeovers and their innovation dimension, e.g. also reflected in the new referral possibility to the Commission of smaller take-overs under the Merger Regulation.

- **Build global partnerships.** In the current geopolitical and competition context, the Global Approach to R&D aims at building stronger partnerships with like-minded countries and at adopting a modulated approach with non-EU countries based on reciprocity, a level-playing field and respect of fundamental and shared values and principles. The application of Article 22 (5) of Horizon Europe is one of the tools that help the EU to safeguard its assets, interests, technological autonomy or security. The overall new geopolitical situation affects also EU strategies for stepping up science diplomacy, strategic partnerships with countries that share EU values, standard-setting or capitalising on leadership in technological circularity. Maintaining strong EU input at international level, such as standard-setting, circularity or Mission Innovation 2.0 as important channels to demonstrate Europe's "green tech" leadership.

- **Take into account the "glocal" nature of innovation ecosystems.** Innovation ecosystem have both a global and a local dimension. Global lead companies, such as those in the *Scoreboard*, play a key role in vitalising innovation ecosystems given their large (direct and indirect) market and innovation power, and an as entry point towards regional and local upgrading via collaboration and internationalisation[156]. Presence of such large companies or their subsidiaries in regional innovation ecosystems could leverage the New Innovation Agenda's connected regional innovation valleys[157] or other territorial policies[158]. The Partnerships for Regional Innovation (PRI)[159] enhance the coordination and directionality of regional, national and EU innovation policies, bringing the above aspects into policy implementation.

- **Pursue the policy strategies rooted in the renewed ERA strategy and the (updated) Industrial Strategy.** This includes *transition pathways* for some of the 14 identified industrial ecosystems,

152 2022 Strategic Foresight Report: Twinning the green and digital transitions in the new geopolitical context COM (2022) 289 final, and Communication on the Global Approach to Research and Innovation COM (2021) 252 final.

153 See Muench, S., Stoermer, E., Jensen, K., Asikainen, T., Salvi, M. and Scapolo, F., Towards a green and digital future, EUR 31075 EN, Publications Office of the European Union, Luxembourg, 2022, ISBN 978-92-76-52452-6, doi:10.2760/54, JRC129319

154 Chinese Mergers and Acquisitions (M&A) in the EU grew strongly (21% between 2017-2019 vs. 2013-2016) and faster than inbound deals from any other strategic partner country (such as the US or Japan), in the EU targeting mostly manufacturing firms (45%). Technology-oriented Chinese companies prefer to acquire radically new technologies not already in their portfolios compared to their European peers that engage in a higher share of coherently diversified (i.e. technologically related) M&As deals. See: Alves Dias, P., Amoroso, S. et al. China: Challenges and Prospects from an Industrial and Innovation Powerhouse, Preziosi, N., Fako, P., Hristov, H., Jonkers, K. and Goenaga Beldarrain, X. editor(s), EUR 29737 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-02997-7, doi:10.2760/445820, JRC116516.

155 See the Second Annual Report on the Screening of Foreign Direct Investments into the Union, COM(2022)433.

156 Home-bases of *Scoreboard* firms drive the knowledge flows of their home regions on the international scene, see Dosso, M. and Lebert, D.: "A geography of corporate knowledge flows across world regions: evidence from patent citations of top R&D-investing firms", JRC Working Papers on Corporate R&D and Innovation No 03/2019, JRC 118006, https://iri.jrc.ec.europa.eu/sites/default/files/2019-10/TR%20Geografy% 20of% 20corporate_0.pdf

157 These valleys will bring together less with more innovative regions by building on strategic areas of regional strength and specialisation in support of key EU priorities. For this purpose, 3-4 inter-regional innovation projects will be launched by the end of 2023 building on Smart Specialisation Strategies and, where applicable, on the participation in the Partnerships for Regional Innovation (PRIs), see: https://s3platform.jrc.ec.europa.eu/pri

158 Such as I3 start-up villages under Cohesion Policy as part of the long-term vision for rural areas policy; Euroclusters under the Single Market Programme; and Horizon Europe, including European Innovation Ecosystems, Start-up Europe, Widening Participation and Strengthening the ERA, Missions, and the work of the European Institute of Innovation and Technology's Knowledge and Innovation Communities and the regional innovation scheme.

159 See https://s3platform.jrc.ec.europa.eu/pri.

ERA Common industrial technology roadmaps (a key tool to help accelerating transfer of R&I results into the economy through R&I investment agendas developed with Member States and stakeholders), *industrial alliances* (to mobilise and build industrial capacities in key industrial and technological areas) and Horizon Europe partnerships with industry (as a stepping-stone for such alliances to develop industrial investment plans, and to provide the starting basis for ERA technology roadmaps.)

Focus should be on the effective implementation of the agreed actions, and careful selection and design of possible new ones, based on a co-creation approach with Member States and stakeholders. Some industrial eco-systems benefit from a combination of initiatives, e.g. *Horizon partnerships* with industry and industrial alliances, which is a good basis for effective public-private synergies building on complementarity, relevant R&I results and mutual input.

More information, including activities and publications surrounding the *Scoreboard,* is available at:
https://iri.jrc.ec.europa.eu/home/
https://research-and-innovation.ec.europa.eu/strategy/support-policy-making_en

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Annex 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[160] with a 3 % headline target for intensity of research and development (R&D)[161]. R&D investment from the private sector plays also a key role for other relevant European initiatives such as the Industrial Policy[162], Digital Agenda and New Skills for New Jobs flagship initiatives.

The project "Global Industrial Research & Innovation Analyses" (GLORIA)[163] supports policymakers in these initiatives. 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.

This report describes and analyses the *Scoreboard* data and provides additional information on the positioning of *Scoreboard* companies in relation to other key indicators of relevance for industrial innovation policy and industrial R&D positioning. The annual publication of the *Scoreboard* 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[164]. 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[165]. **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 private sector R&D investments and positioning and benchmarking company commitments and performance (e.g. companies, investors and policymakers). 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

160 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.

161 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).

162 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.

163 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 R&I R&I A; see: http://ec.europa.eu/research/index.cfm?lg=en) and the Joint Research Centre, Directorate Growth and Innovation (JRC-Seville; see: https://ec.europa.eu/jrc/en/science-area/innovation-and-growth).

164 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.

165 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).

approach of the *Scoreboard*, its scope and limitations are further detailed in Annex 2 below.

Scope and target audience

The *Scoreboard* is a benchmarking tool which provides reliable up-to-date information on R&D investment and other economic and financial data, with a unique EU-focus. The 2500 companies listed in this year's *Scoreboard* account for around 86%[166] 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.

- **Policy-makers, government and business organisations** can use R&D investment information as an input to industry and R&D assessment, policy formulation or other R&D-related actions such as R&D tax incentives.
- **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.
- **Researchers, investors, and financial analysts** can use the *Scoreboard* to assess investment opportunities and risks, as well as analyse investment trends.

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

Annex 2: Methodological notes

The data for the 2022 *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 2021 fiscal year accounts, although due to different accounting practices throughout the world, they also include accounts ending on a range of dates between late 2020 and mid-2022. Furthermore, the accounts of some companies are publicly available more promptly than others. Therefore, the current set represents a heterogeneous set of timed data. However, around 70% of companies closed their accounts in December 2021.

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 another 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.

166 According to latest Eurostat statistics.

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[167] nd 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 1.2, paragraph 1.2.2 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 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 are 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. Indeed, for US companies, the GAAP accounting standards are always used because they are the official, audited ones, however non-GAAP results may give a more realistic view of true R&D investments.

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; ii) different companies' information systems for measuring the costs associated with R&D processes; iii) different countries' fiscal treatment of costs. Some companies view a process as an R&D process while other companies may view the same process as an engineering or other process.

[167] NACE is the acronyme for “Nomenclature statistique des activités économiques dans la Communauté européenne”.

Interpretation

There are some fundamental aspects of the *Scoreboard* which affects the interpretation of the data. The focus on R&D investment as reported in group accounts means that the results do not indicate the location of the R&D activity. The *Scoreboard* indicates rather 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 only at the group and the at global level.

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. In contrast, 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, i.e. the aggregate of the 2500 companies R&D investment can be compared with the global total BES-R&D.**

Further, the *Scoreboard* collects data from audited financial accounts and reports. In contrast, BES-R&D typically takes a stratified sample, covering all large companies and a representative sample of smaller companies. An additional difference 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 because value added data is not available at a micro-level

Sudden changes in R&D figures may arise because a change in company accounting standards. For example, the first time adoption of IFRS[168], may lead to information discontinuities due to the different treatment of R&D, i.e. R&D capitalisation criteria are stricter and, where the criteria are met, the amounts must be capitalised.

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

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 2021* as shown in Table A2.1[169]. 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.

[168] 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/).

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

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 that 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.

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 (31.12.2021). 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 appreciated by 9.8%, 3.8% and 5.8% against the US dollar, the Japanese Yen and the Pound Sterling respectively. 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 not 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 understated because the 'losses' of their overseas investments due to the depreciation of the US dollar against the Euro (from $1.12 to $1.23). Conversely, the R&D growth rate of US companies is partly overstated due to the 'benefits' 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, 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. In some cases where company are headquartered in countries for fiscal reasons with little R&D or other activity in that country, a misleading impression may be received.

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)[170].

Table A.1: Euro exchange rates applied to *Scoreboard* data for companies reporting in different currencies (as of 31 Dec 2021)

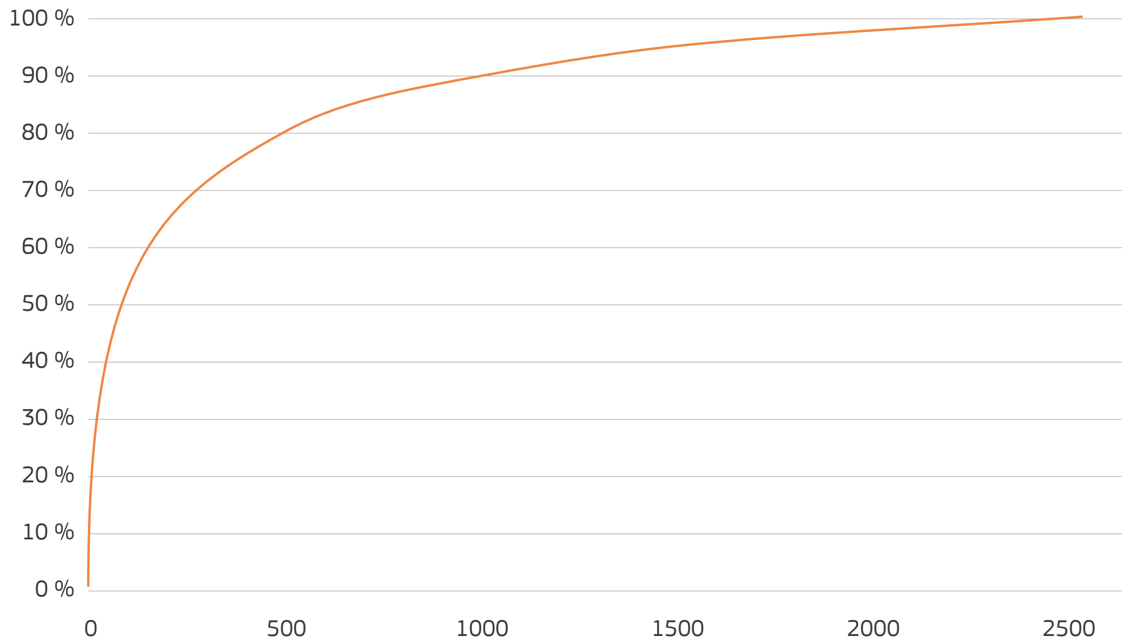
Country	As of 31 Dec 2020	As of 31 Dec 2021
Australia	$ 1.59	**$ 1.56**
Brazil	6.38 Brazilian real	**6.32 Brazilian real**
Canada	$ 1.58	**$ 146**
China	8.02 Renminbi	**7.22 Renminbi**
Czech Republic	26.24 Koruna	**24.86 Koruna**
Denmark	7.43 Danish Kronor	**7.43 Danish Kronor**
Hungary	364.83 Forint	**368.87 Forint**
Hong Kong	9.51 HKD	**8.83 HKD**
India	89.65 Indiana Rupee	**84.15 Indiana Rupee**
Israel	3.95 Shekel	**3.25 Shekel**
Japan	127.16 Yen	**129.35 Yen**
New Zealand	1.70 NZD	**1.66 NZD**
Norway	10.47 Norwegian Kronor	**9.99 Norwegian Kronor**
Poland	4.61 Zloty	**4.60 Zloty**
Russia	90.65 Rouble	**84.15 Rouble**
Singapore	1.62 SGD	**1.53 SGD**
South Korea	1335.11 Won	**1344.09 Won**
Sweden	10.03 Swedish Kronor	**10.24 Swedish Kronor**
Switzerland	1.08 Swiss Franc	**1.03 Swiss Franc**
Taiwan	$ 34.98 New dollar	**$ 31.36 New dollar**
Turkey	9.02 Turkish lira	**14.71 Turkish lira**
UK	£0.91	**£0.84**
US	$ 1.23	**$ 1.13**
United Arab Emirates	4.51 Dirham	**4.16 Dirham**

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

[170] 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).

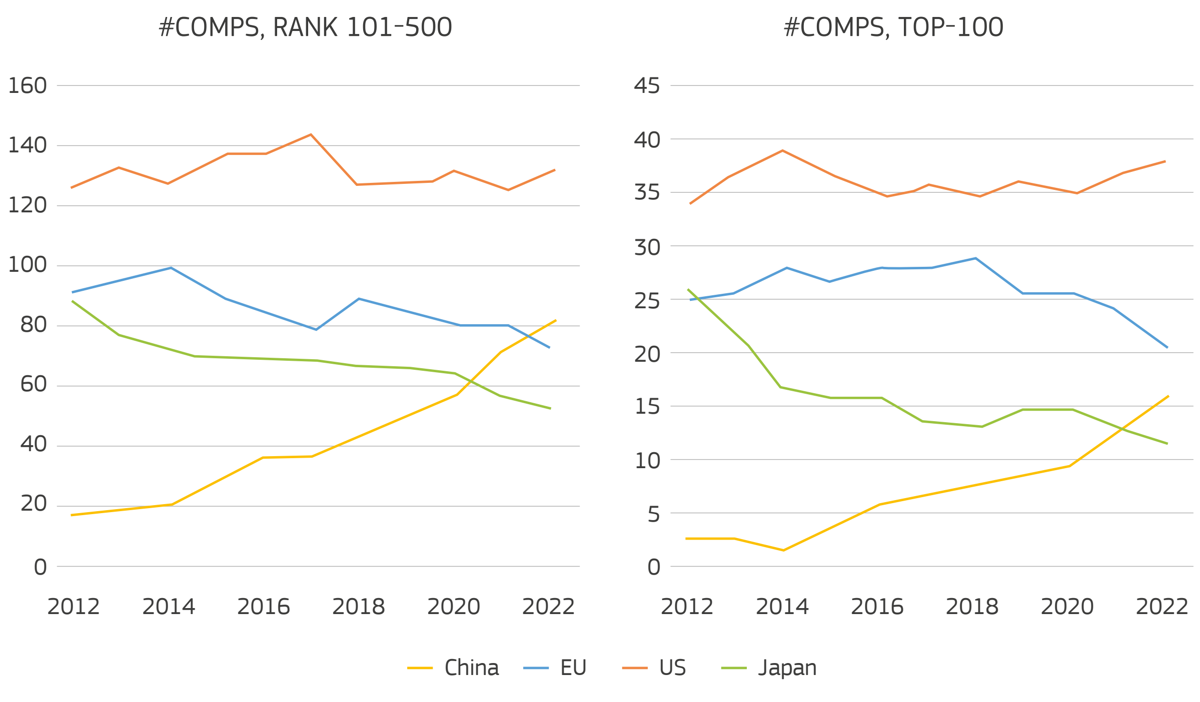
Annex 3: Chapter 3 - additional tables

Figure A.1: Average of the cumulated shares of R&D investments companies of *Scoreboard* 2012 and 2022



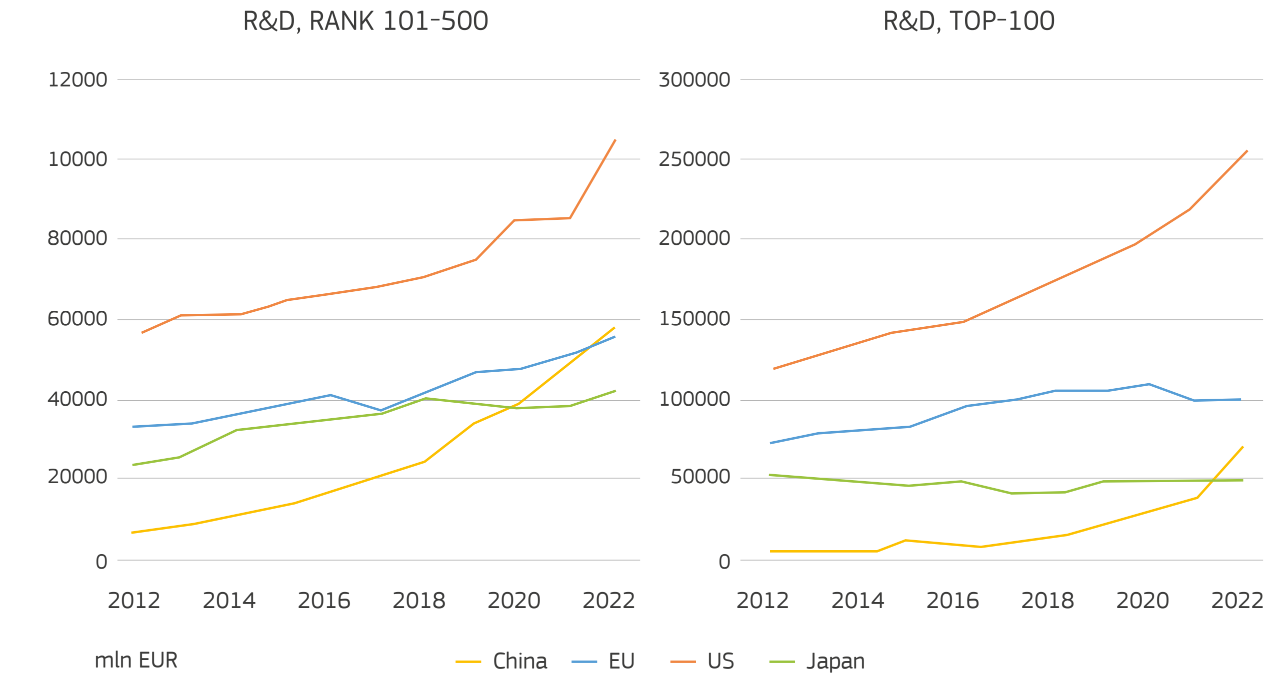
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A.2: Main developments in the number of companies in the *Scoreboard* by the four main geographical regions



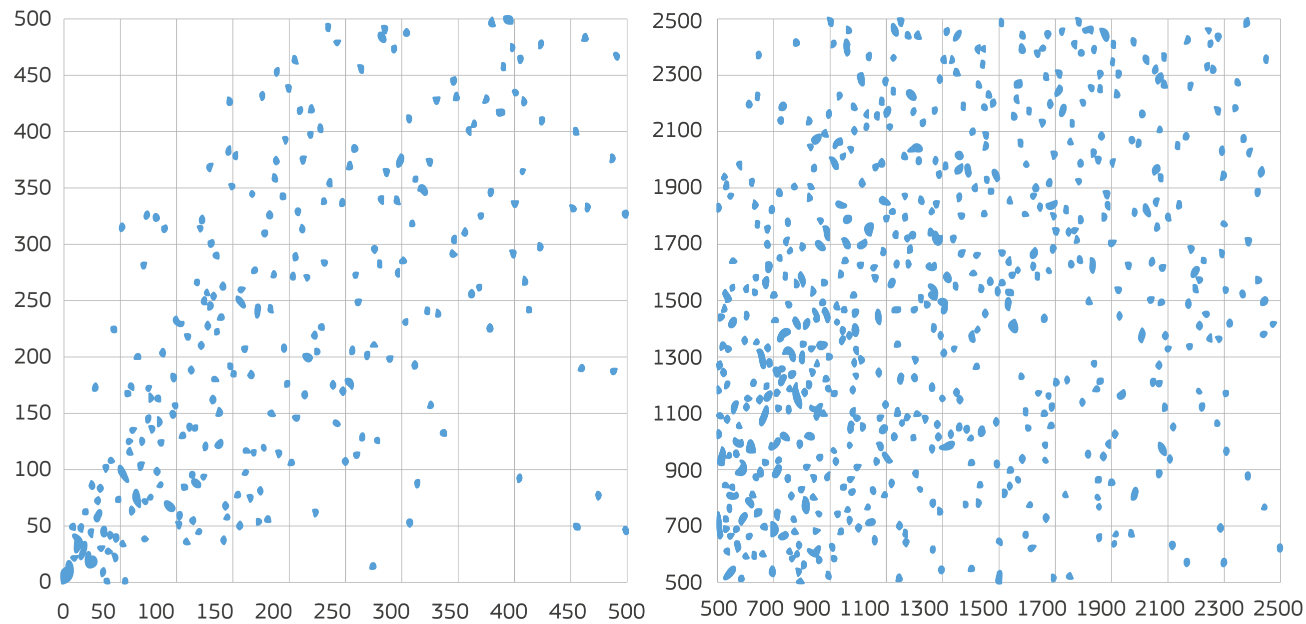
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A.3: Main developments in R&D investment in the *Scoreboard*'s four main geographical regions, EUR million



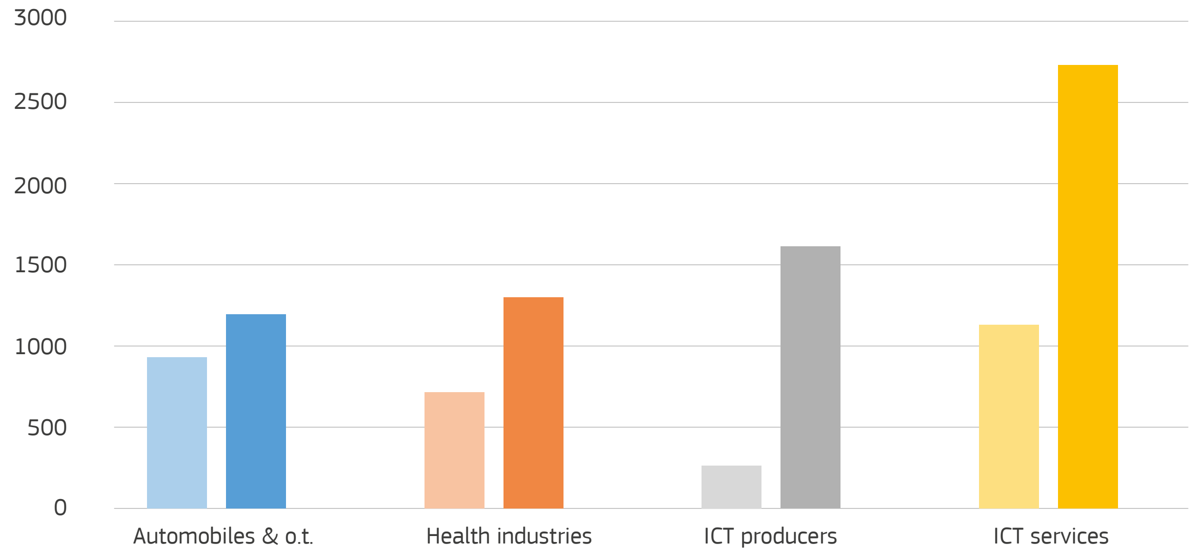
Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A.4: Scatterplot of rankings in *Scoreboard* 2012 and 2022 (horizontal: ranking in 2012, vertical: ranking in 2022)



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Figure A.5: Average R&D of companies improving (rise) and worsening (fall) their ranking



Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A.2: Number of companies by region and by sector of activity between *Scoreboard* 2012 and 2022

number of companies	SB2012						SB2021					
	EU	Japan	China	US	RoW	Total	EU	Japan	China	US	RoW	Total
Aerospace & Defence	13	1	0	21	18	53	10	0	5	15	14	44
Automobiles & other tr	**44**	**52**	**19**	**37**	**29**	**181**	**34**	**28**	**54**	**37**	**27**	**180**
Chemicals	23	55	4	38	28	148	16	28	33	21	17	115
Construction	21	27	11	7	10	76	9	10	35	4	7	65
Energy	32	18	5	12	24	91	26	10	20	10	14	80
Financial	31	0	0	9	17	57	22	0	12	9	18	61
Health industries	**82**	**44**	**13**	**185**	**65**	**389**	**68**	**31**	**92**	**309**	**67**	**567**
ICT producers	**65**	**98**	**53**	**226**	**157**	**599**	**42**	**45**	**153**	**112**	**102**	**454**
ICT services	**44**	**15**	**18**	**129**	**53**	**259**	**30**	**6**	**83**	**203**	**40**	**362**
Industrials	92	87	36	55	58	328	57	36	99	35	35	262
Others	72	83	17	77	70	319	47	39	92	67	65	310
Total	**519**	**480**	**176**	**796**	**529**	**2500**	**361**	**233**	**678**	**822**	**406**	**2500**

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A.3: Top 50 R&D investment per company in *Scoreboard* 2012 and 2022, EUR million

	2012						2022					
	EU	US	JP	CN	RoW	Total	EU	US	JP	CN	RoW	Total
Automotive	4 616	5 926	3 916			4 600	8 729	6 843	6 303			7 624
Health industries	3 452	5 478	2 179		6 086	4 982	5 110	7 876	4 065		8 464	7 266
ICT producers	3 721	4 434	2 784	3 122	5 550	4 032	4 441	8 969		1 9534	10 395	8 955
ICT services		5 508	1 957			4 324	5 168	1 4474	5 732	7 439		11 262
Others	3 249	3 614	3 322			3 407			4 902	5 509		5 206

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A.4: R&D invested by region and by sector of activity between *Scoreboard* 2012 and 2022, EUR million

number of companies	SB2016						SB2021					
	EU	JP	CN	US	RoW	Total	EU	US	JP	CN	RoW	Total
Aerospace & Defence	7 618	16	0	7 666	3 248	18 548	6 359	0	587	7 640	3 114	17 699
Automobiles & o.t.	3 6343	23 385	3 017	20 076	5 321	88 141	62614	33 189	18 037	27 588	10 979	152 407
Chemicals	4 356	6 460	97	6 660	2 682	20 255	5 346	7 848	3 787	4 733	3 425	25 138
Construction	1 453	1 211	2 730	672	647	6 714	2 910	1 374	24 750	590	1 228	30 852
Energy	4 365	1 134	2 691	3 641	4 649	16 480	5 550	991	6 792	2 477	3 688	19 498
Financial	3 861	0	0	557	4 898	9 316	7 095	0	2 014	3 511	6 525	19 145
Health industries	19 305	10 386	397	55 611	2 8815	114 515	38 599	15 349	13 783	123 897	43 712	235 339
ICT producers	23 137	20 392	6 961	56 969	2 8120	135 579	28 578	20 962	52 016	97 438	47 814	246 808
ICT services	7 487	5 435	1 381	37 138	4 410	55 852	14 821	9 498	34 732	145 501	11 709	216 260
Industrials	10 446	9 189	2 643	9 820	4 444	36 543	11 474	8 831	20 328	8 339	5 825	54 797
Others	7 722	13 998	719	13 544	7 830	43 814	9 411	15 763	19 032	17 965	13 745	75 916
Total	**126 096**	**91 606**	**20 637**	**212 355**	**95 064**	**545 757**	**192 756**	**113 802**	**195 858**	**439 680**	**151 763**	**1 093 860**

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Table A.5: Structure of company presence in *Scoreboard* industrial sectors by main geographical regions – # of companies included (orange = lower than the Scoreboard average, blue=higher than the *Scoreboard* average)

SB Sectors	SB Average		EU		Japan		China		US	
	2012	2022	2012	2022	2012	2022	2012	2022	2012	2022
Aerospace & Defence	2.1%	1.8%	2.5%	2.8%	0.2%	0.0%	0.0%	0.7%	2.6%	1.8%
Automobiles & other transport	7.2%	7.2%	8.5%	9.4%	10.8%	12.0%	10.8%	8.0%	4.6%	4.5%
Chemicals	5.9%	4.6%	4.4%	4.4%	11.5%	12.0%	2.3%	4.9%	4.8%	2.6%
Construction	3.0%	2.6%	4.0%	2.5%	5.6%	4.3%	6.3%	5.2%	0.9%	0.5%
Energy	3.6%	3.2%	6.2%	7.2%	3.8%	4.3%	2.8%	2.9%	1.5%	1.2%
Financial	2.3%	2.4%	6.0%	6.1%	0.0%	0.0%	0.0%	1.8%	1.1%	1.1%
Health industries	15.6%	22.7%	15.8%	18.8%	9.2%	13.3%	7.4%	13.6%	23.2%	37.6%
ICT producers	24.0%	18.2%	12.5%	11.6%	20.4%	19.3%	30.1%	22.6%	28.4%	13.6%
ICT services	10.4%	14.5%	8.5%	8.3%	3.1%	2.6%	10.2%	12.2%	16.2%	24.7%
Industrials	13.1%	10.5%	17.7%	15.8%	18.1%	15.5%	20.5%	14.6%	6.9%	4.3%
Others	12.8%	12.4%	13.9%	13.0%	17.3%	16.7%	9.7%	13.6%	9.7%	8.2%

Source: The 2022 EU Industrial R&D Investment Scoreboard, European Commission, JRC/DG R&I.

Annex 4: Access to the dataset

The 2022 *Scoreboard* comprises two data samples:

- The world's top 2500 companies that invested more than EUR 48.5 million in R&D in 2021
- The top 1000 R&D investing companies based in the EU with R&D investment exceeding EUR 3.1 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 link provides access to the page of the two *Scoreboard* data samples, which contain the main economic and financial indicators and main statistics:

https://iri.jrc.ec.europa.eu/scoreboard/2022-eu-industrial-rd-investment-scoreboard

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