World Corporate Top R&D Investors:

PAVING THE WAY FOR CLIMATE NEUTRALITY

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World Corporate Top R&D Investors:

PAVING THE WAY FOR CLIMATE NEUTRALITY

FOREWORD

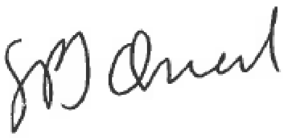
The transition towards a climate-neutral economy is one of the most significant challenges faced by our generation, and those that will follow. While the COVID-19 crisis led to a temporary drop in carbon dioxide emissions due to the resulting economic slowdown, greenhouse gas concentrations in the atmosphere continue to rise, with dangerous prospects for future warming.

Technology and innovation are major building blocks for achieving the deep cuts in carbon emissions that are required to enable the transition to a net-zero carbon world, as well as essential pillars of resilient economic growth. At a time when policymakers are seeking to re-ignite economic growth in a post-COVID era, integrating low-carbon innovation support into green recovery packages and making policy reforms to support innovation will be of utmost importance.

The current fourth edition of this biennial report on the innovative activity of the world's top corporate R&D investors is the result of a long-standing and fruitful collaboration between the European Commission's Joint Research Centre (EC-JRC) and the Organisation for Economic Co-operation and Development (OECD). It focuses on the role that these companies can play in reaching climate neutrality by developing, owning and commercialising low-carbon technologies. It does so by presenting and analysing data on their patent and trademark portfolios, with particular emphasis on intellectual property rights related to climate change mitigation and adaptation.

The report shows that the world's top R&D investors make a significant contribution to global climate-related innovation and associated goods and services: they own 70% of climate change mitigation or adaptation patents (compared to 63% of patents for all technologies) and more than 10% of global climate-related trademarks (compared to just over 6% of total trademarks). Thus, the report highlights the key role that top R&D investors can play in reaching climate neutrality objectives, even if some sectors such as information and communication technology, have growing impacts on global emissions and invest very little directly in low-carbon innovation. However, the report also suggests that while large corporate R&D investors produce large amounts of climate-related innovation, other inventors – such as young firms – develop more radical innovations and are therefore more likely to generate the breakthrough discoveries needed to achieve net-zero emissions.

By testing our resilience in responding to potential climate-related disasters, the COVID19 crisis has made it even more urgent to reconsider the way our societies operate and to reorient them towards sustainable pathways. As countries are slowly recovering from the pandemic, many governments are beginning to roll out recovery programmes which provide an opportunity to 'build back better' and reorient innovative activities towards less polluting technologies that can pave the way for a greener and more sustainable economy. This report and the related publicly available dataset are a testament to the commitment of both the EC-JRC and the OECD in providing solid data and analysis in support of evidence-based climate policy action.



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LIST OF ABBREVIATIONS

CCMA	*Climate change mitigation or adaptation*
CNIPA	*People's Republic of China National Intellectual Property Office*
CPC	*Cooperative Patent Classification*
EPO	*European Patent Office*
EU27	*European Union*
EUIPO	*European Union Intellectual Property Office*
GHG	*Greenhouse gases*
ICT	*Information and communication technology*
IP	*Industrial Property*
IP5	*Five IP offices (EPO, JPO, KIPO, USPTO and CNIPA)*
IPC	*International Patent Classification*
ISIC	*International Standard Industrial Classification of All Economic Activities*
JPO	*Japan Patent Office*
KIPO	*Korean Intellectual Property Office*
R&D	*Research and Development*
RTA	*Revealed technology advantage*
TM	*Trademark*
USPTO	*United States Patent and Trademark Office*
WIPO	*World Intellectual Property Organization*

COUNTRIES OR ECONOMIES, ISO CODES

ARG	Argentina	**AUS**	Australia	**AUT**	Austria
BEL	Belgium	**BRA**	Brazil	**BGR**	Bulgaria
CAN	Canada	**CHN**	China	**HRV**	Croatia
CYP	Cyprus	**CZE**	Czech Republic	**DNK**	Denmark
EST	Estonia	**FIN**	Finland	**FRA**	France
DEU	Germany	**GRC**	Greece	**HKR**	Hong Kong China
HUN	Hungary	**ISL**	Iceland	**IND**	India
IRL	Ireland	**ISR**	Israel	**ITA**	Italy
JPN	Japan	**KOR**	Korea	**LVA**	Latvia
LIE	Liechtenstein	**LTU**	Lithuania	**LUX**	Luxembourg
MYS	Malaysia	**MLT**	Malta	**MEX**	Mexico
NLD	Netherlands	**NZL**	New Zealand	**NOR**	Norway
PHL	Philippines	**POL**	Poland	**PRT**	Portugal
ROU	Romania	**RUS**	Russian Federation	**SAU**	Saudi Arabia
SGP	Singapore	**SVK**	Slovak Republic	**SVN**	Slovenia
ZAF	South Africa	**ESP**	Spain	**SWE**	Sweden
CHE	Switzerland	**TWN**	Chinese Taipei	**THA**	Thailand
TUR	Turkey	**UKR**	Ukraine	**ARE**	United Arab Emirates
GBR	United Kingdom	**USA**	United States	**VNM**	Vietnam

EXECUTIVE SUMMARY

This biennial report continues the joint JRC-OECD analysis of the Intellectual Property (IP) portfolios of the world's top 2 000 R&D investors and explores the pivotal role played by these companies in the development and commercialisation of new technologies, as reflected in their patenting and trademark filing activity. It provides a thematic focus on the contribution of the world's top 2 000 R&D investors to innovation in climate change mitigation and adaptation technologies as a response to the new climate neutrality objectives.

The report shows that global R&D and patenting activities remain highly concentrated within the world's top 2 000 R&D investors. These are responsible for 87% of global business R&D expenditure by the private sector and 63% of patent filings across all technologies. There is much less concentration at the commercialisation stage, with only 6% of all trademarks owned by the top R&D investors. Among the top R&D investors, R&D investments, patents and trademarks are highly concentrated within the hands of a few hundred companies. United States (US)-based firms lead the ranking in almost every sector. Companies located in Japan and in the European Union (EU27) have recently been losing ground to companies based in People's Republic of China (hereafter 'China'). A few sectors dominate both R&D investments and patent filings, including 'Computers & electronics', 'Pharmaceuticals' and 'Transport equipment'. Looking at the IP bundle, we observe key sectoral differences: companies in 'Transport equipment', 'Electrical equipment', 'Machinery' and 'Computers & electronics' primarily rely on patents to protect their products, while companies in 'Food products', 'Telecommunications' and 'Pharmaceuticals' use more trademarks than patents.

Countries representing more than 80% of the world economy (including the EU27) have announced targets of climate neutrality by mid-century in their policy agendas. Reaching this objective requires the development and large-scale diffusion of a wide set of new low-carbon technologies. The world's top R&D investors are key contributors to global climate-related innovation. They own 70% of global climate change mitigation or adaptation patents and over 10% of global climate-related trademarks, which is larger than their contribution to overall patents and trademarks across all fields. However, while top R&D investors produce large amounts of climate-related innovation, other inventors – such as young firms – develop more radical innovations and are therefore more likely to generate the breakthrough discoveries needed to achieve net-zero emissions.

Some disparities across sectors emerge: while the electricity production, transportation and construction sectors heavily invest in climate-related innovation, other sectors such as information and communication technology (ICT) invest little in low-carbon innovation but contribute by developing enabling technologies such as artificial intelligence (AI). Focusing on a few technologies that are key to reaching the climate neutrality objective (renewable energy, electric cars and hydrogen), companies headquartered in Asian countries exhibit clear specialisation patterns: Japanese firms lead in hydrogen technologies, Korean firms in electric cars and batteries and Chinese firms in renewable energy technologies. On the contrary, the EU27-headquartered companies do not exhibit such a pronounced specialisation pattern, but have a broad technological base contributing to all climate-related technologies in equal measure. Relative to firms in other regions, US-based firms are not specialised in this specific subset of key climate-related technologies.

Looking at the potential contribution of the digital revolution to climate-related innovation at the invention stage, 20% of climate-related patents have a digital component (compared to 33% for patents across all technological fields). This suggests further potential regarding the digital transformation enabling the green transition across many carbon-intensive sectors of the economy. However, 60% of climate-related trademarks are also ICT-related, which is much larger than for the average trademark filed (around 30%). Hence, the use of digital solutions to address climate-related issues seems especially widespread at the commercialisation stage.

Lastly, this edition of the report investigates – for the first time – the gender composition of the board of directors of the top 2 000 R&D investors and that of their R&D workforce. EU27 companies have, on average, more gender-balanced boards than the US and Asia, with female representation of at least 26%. The French companies included in the study have the most gender-balanced boards by far. A substantial gender gap is also observed for inventors listed in patent applications, with significant heterogeneity across countries and sectors. Companies with the highest shares of patents invented by women are located in Spain (37%), the United States (29%) and Belgium (26%). The 'Pharmaceuticals', 'Biotechnology' and 'Chemistry' sector employ the most gender-balanced teams of inventors. However, there is no evidence that 'green' firms (which lead in climate-related innovation) have more gender-balanced boards than 'brown' firms (who do not own any climate-related IP), or that climate-related technologies rely more heavily on female inventors.

1. INTRODUCTION

Countries representing more than 80% of the world economy (including the European Union) have announced targets for carbon neutrality by mid-century. Reaching carbon neutrality in 2050 will require a major structural transformation towards the use of low-carbon technologies. This includes the rapid deployment of currently available technologies, but also further innovation in breakthrough technologies that are not yet on the market. According to the International Energy Agency (IEA), half of the global reductions in energy-related CO2 emissions by 2050 will have to come from technologies that are currently at the demonstration or prototype phase (IEA, 2021). In heavy industry, the share of emission reductions from technologies that are still under development today is even greater. Therefore, technology and innovation are major building blocks in achieving the deep cuts in carbon emissions that are required to enable the transition to a net-zero carbon world.

Innovation is not only important because it can help reach climate change objectives: as the main source of modern economic growth, it can enable a greener future that goes hand in hand with new growth opportunities and strengthened productivity growth. This is particularly important as countries seek to recover from the COVID19 pandemic. In this respect, green recovery programmes provide an opportunity to 'build back better' and reorient innovative activities towards less polluting technologies that can pave the way for a greener and more sustainable economy.

The objective of this report is to document the role that top corporate R&D investors – which are key actors in the global innovation space –are playing in the development and commercialisation of new climate change or adaptation technologies. Information on patents and trademarks owned by the world's top 2 000 R&D investors is used to explore the new technologies and products introduced by world-leading corporations in key markets, including Europe, Japan, Korea, the People's Republic of China (hereafter 'China') and the United States. These intellectual property (IP) assets are also informative about which companies, countries and sectors are best positioned to seize the opportunity stemming from the green transition over the coming decades. They shed light on the innovative strategies of top R&D investors worldwide, and the way they contribute to shaping the development of future technologies.

To identify patents related to climate change mitigation and adaptation technologies, this report uses the classification scheme (known as Y02) developed by the European Patent Office (EPO) and applied to the near-population of worldwide patents available in the PATSTAT database. This tagging system has become the gold standard for monitoring progress on innovation in climate-related technologies worldwide. In addition, climate change-related trademarks were identified using a new classification based on textual analysis of trademark descriptions, developed in the framework of this report (Aristodemou et al., forthcoming).

This report, in its 4th edition, is a result of the long-lasting collaboration between the Joint Research Centre (JRC) of the European Commission (EC) and the Organisation for Economic Co-operation and Development (OECD). It reflects the joint effort to provide up-to-date comparable data and state-of-the-art indicators and analysis in support of an evidence base related to key policy issues. The sample of the top 2 000 R&D investors used for the report refers to those firms that invested the largest sums in R&D in 2018, as published in the EU Industrial R&D Scoreboard 2019 edition (Hernández et al., 2019).[1]

The remainder of this publication is articulated as follows:

- Section 2 offers an overview of the top corporate R&D investors worldwide. It presents their geographical and sectoral distribution, their workforce as well as a description of the gender composition of their leadership. It also looks at the extent to which the top 2 000 R&D investors have changed between 2012 and 2018, focusing in particular on the industrial and geographical differences that emerge.

- Section 3 analyses the contribution of the top R&D investors to intellectual property assets, with a focus on patents and trademarks. Evidence of the geographical and industrial specificities emerging across economies complements the picture. The section also analyses changes over time in the top R&D investors' contribution to patents and trademarks.

- Section 4 examines the innovation activities related to climate change mitigation and adaptation of top corporate R&D investors worldwide, as evidenced by their patent and trademark portfolios. It presents the contribution of the top R&D investors to global climate-related innovation and diffusion, and zooms in on three key technologies critical to climate neutrality (renewable energy, electric cars and hydrogen).

1 See https://iri.jrc.ec.europa.eu/scoreboard/2019-eu-industrial-rd-investment-scoreboard

2. OVERVIEW OF THE TOP R&D INVESTORS

This chapter presents the main characteristics of the the world's top corporate R&D investors. It presents the geographical and sectoral distributions of the companies analysed and the evolution of these distributions across the four editions of the report. It also considers the distribution of the workforce by sector and its changes over time. Finally, it introduces a focus on the topic of gender. For the first time in this report series, we present data on the gender composition of the board of directors, both by country and by sector. This helps to get a better 'identikit' of the companies with the largest investment in R&D worldwide.

HIGHLIGHTS

- The top 2 000 R&D-investing companies worldwide invested EUR 805.1 billion in R&D in 2018, which represents 87.7% of the estimated total R&D investment financed by the business sector globally.

- R&D is highly concentrated within a few economies and sectors. Four economies (the United States, EU27, China and Japan) collectively represent almost 85% of the total R&D invested. The United States is by far the largest R&D-investing economy. At sectoral level, the top three sectors ('Computers & electronics', 'Pharmaceuticals' and 'Transport equipment') account for 56.5% of the total R&D invested overall.

- Two of the top three sectors in terms of R&D investment – 'Computers & electronics' and 'Pharmaceuticals'– are dominated by US companies, while in 'Transport equipment' EU27 companies are the key players.

- Across the four editions of the report, China is the economy that has increased its presence most considerably within the top 2 000 R&D investors, in terms of both the number of companies (from 147 in 2012 to 365 in 2018) and the share of R&D (from 3.7% to 11.3%). This growth has occurred primarily to the detriment of Japan and the EU27. At sector level, 'Pharmaceuticals' increased its presence the most in terms of the number of companies, while 'IT services' is the sector that increased its share of R&D in the sample the most from 2012 to 2018.

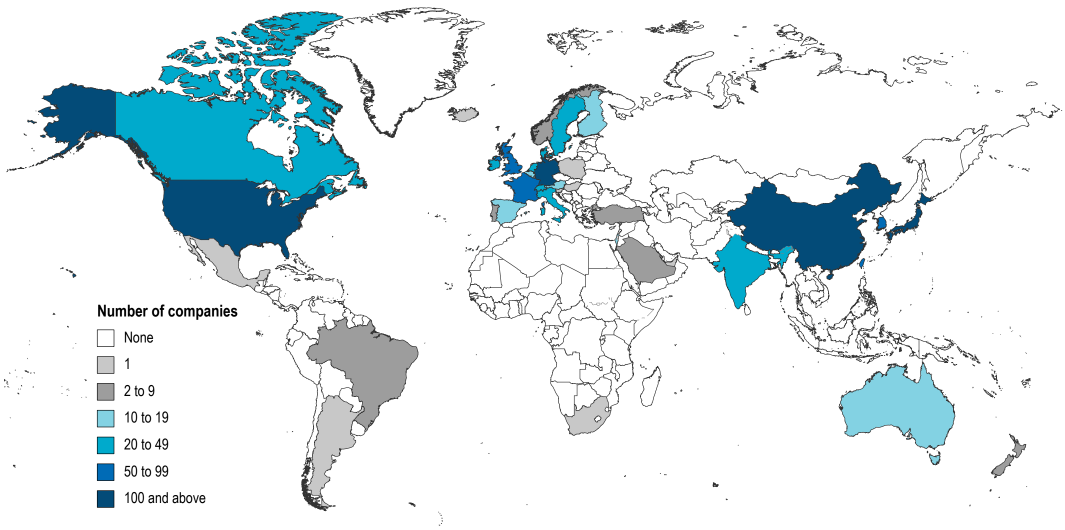
- Looking at the gender balance of board of directors in the top 2 000 R&D investors, EU27-companies have, on average, more gender-balanced boards than the US and Asian ones, with female representation of at least 26%. French companies have by far the most gender-balanced boards.

2.1. CORPORATE STRUCTURE AND GEOGRAPHICAL LOCATION

In 2018, the top 2 000 R&D investors worldwide invested a total amount of EUR 805.1 billion in R&D activities (Hernández et al, 2019). This represented 87.7% of the estimated total R&D investment financed by the business sector worldwide (BES-R&D, Grassano et al., 2020).

The world's top R&D investors are geographically concentrated: 75% of these companies are headquartered in only five economies. The sample of top R&D investors (as of 2018) comprises companies with headquarters in 38 countries, of which 16 are Member States of the EU27. More specifically, 636 companies are located in the United States, 365 in China, 263 in Japan, 118 in Germany and 96 in the United Kingdom (Figure 2.1). In total, 366 companies have their headquarters in the EU27, of which 57% are located in three countries: Germany, France and the Netherlands. The United States, China and Japan are home to 77% of the world's top R&D investors outside the EU27. Half of the sample consists of companies headquartered in the United States and China.

Figure 2.1. Location of headquarters of the world's top R&D investors, 2018



***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

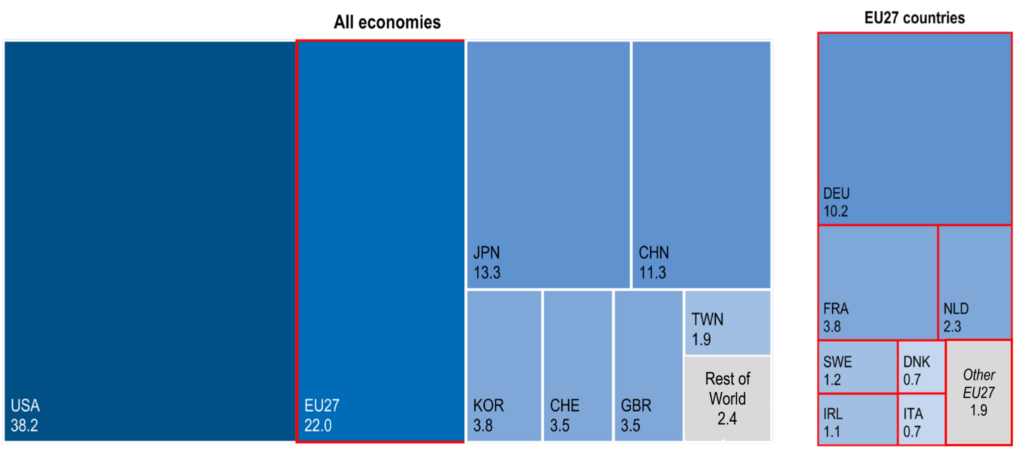
The number of companies in the sample headquartered in China is similar to the number of companies headquartered in the EU27. However, looking at the amount invested in R&D, we get a different picture. The distribution of R&D investments made by top R&D investors by country is shown in Figure 2.2. In 2018, around 38% of the total R&D investments of the top 2 000 investors were made by US-headquartered companies. Companies located in both the United States and the EU27 (22% of the overall R&D) invested much more than firms located in China (11%). Japanese companies in the sample contributed slightly more to R&D than Chinese ones: 263 companies headquartered in Japan accounted for 13% of R&D spending in the sample. The top three countries (Germany, France and the Netherlands) represented 74.5% of the R&D invested in the EU27, and Germany alone accounted for 46.6% of the R&D invested in the EU27. The United Kingdom, representing almost 5% of the companies, accounted for 3.5% of the total R&D investment.

In 2018, the average firm in the sample invested EUR 402.6 million in R&D. The average US firm and EU firm invested the same amount in R&D (EUR 483.7 million and EUR 483.7 million, respectively), while the average Chinese firm invested much less (EUR 250 million). The difference between the EU27 and China is apparent from the distribution of the firms in the sample: when dividing into quartiles, 58.5% of the EU firms were ranked in the first two quartiles (compared to 40.3% of the Chinese firms). US firms were evenly distributed across the four quartiles.

Looking at indicators other than R&D, the firms in the sample generated EUR 19.4 trillion in net sales, EUR 1 258.7 billion in capital expenditure and employed 52.2 million employees (in full time equivalent – FTE) in 2018. EU27 and US firms accounted for similar shares of the total net sales (23.9% and 23.7%) and capital expenditure (21.8% and 22.7%). The same is not true for employment, where the share of EU27 firms (31.4%) was considerably higher than that of companies headquartered in the United States (19.4%). Chinese and Japanese firms were comparable in terms of their shares of net sales (15.3% and 15.5%) and capital expenditure (16.6% and 15.9%), while China had the edge in terms of employment (19.4% versus 16.4%). It is worth noting how Chinese and US firms had the same number of workers overall (10.1 million FTE employees each), while the investment in R&D by US firms was more than three times the investment by Chinese firms.

Figure 2.2. R&D investment of the world's top R&D investors, by headquarters' location, 2018

Share of total R&D investments in the sample



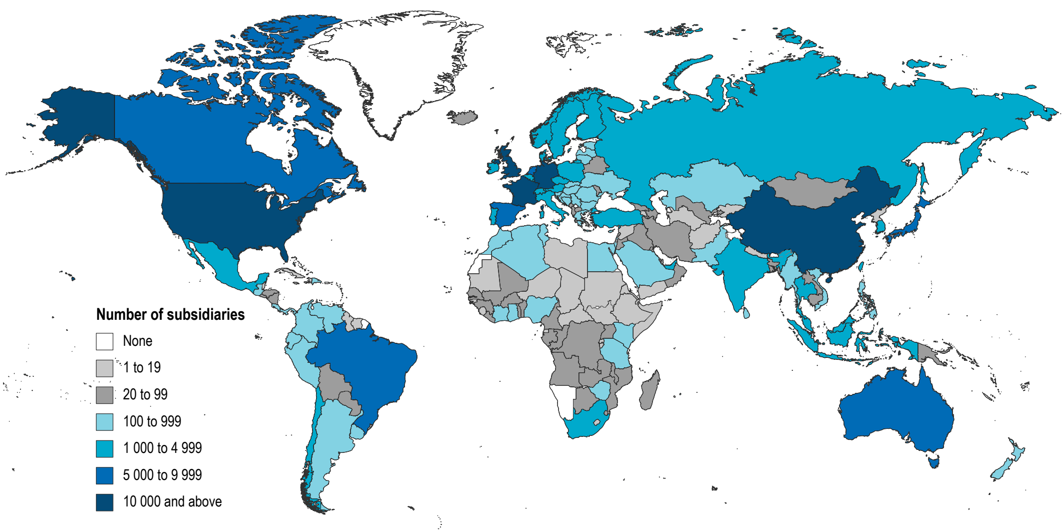
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

The world's top R&D investors control subsidiaries that are located all over the world, as shown in Figure 2.3. In 2018, the largest numbers of subsidiaries were found in the United States (87 547 firms), in Europe (71 171) and in China (29 654). The United States alone accounted for 29% of subsidiaries, while 10% of affiliates were located in China and 6% in the United Kingdom. Germany and France followed, hosting 5% and 4%, respectively, of the total number of subsidiaries.

Of the subsidiaries located in the United States, almost half (48.6%) were owned by parent companies headquartered in the United States, 26.6% were owned by EU27 parent companies, 9.4% by Japanese parent companies and only 1% by Chinese parent companies. The picture is similar for the subsidiaries located in the EU27, where 55.5% belonged to parent companies located within the EU27, 21.8% were owned by US-based firms, 6.8% by Japanese firms and a mere 2.0% by parent companies located in China.

The share of national subsidiaries – i.e. subsidiaries owned by companies located in the same country – was greater for China, where almost 60% of the subsidiaries were national, 12.3% were EU27 owned, 9.3% were controlled by US firms and 8.4% by Japan-based firms. National subsidiaries were even more common in Japan (81.8%), where only residual shares of subsidiaries were controlled by companies headquartered in the EU27, the United States or China (6.2%, 6.8% and 1.0%, respectively). In the United Kingdom, there were more subsidiaries controlled by EU27-based parent companies (29.2%) than by UK-based parent companies (27.6% of the total). There was also a substantial share of US-controlled subsidiaries (25.6%).

Figure 2.3. Location of subsidiaries of the world's top R&D investors, 2018



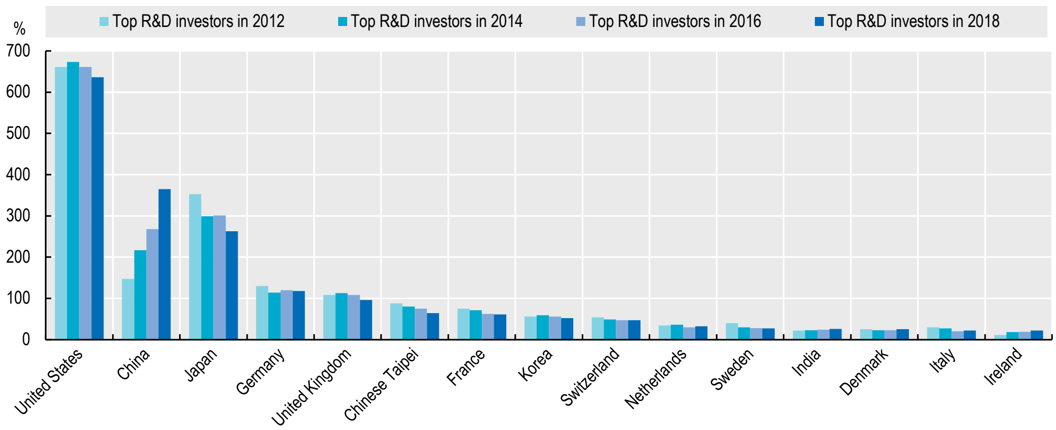
***Note**: Branches are excluded from the list of subsidiaries.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 2.4 presents the changes in the geographical distribution of the top R&D investors across the four editions of this report, based on the top R&D investment rankings observed in 2012, 2014, 2016 and 2018. The overall picture that emerges looking at the changes in number of firms and R&D shares across the four samples is characterised by the strengthening of US leadership, the growth of China and the weakening of Japan (predominantly) and the EU27, which remained led by Germany. US companies in the sample were slightly less present in 2018 than in 2012 (from 661 to 636) but their share of R&D increased from 35.6% to 38.2%.

The most striking variation is the astonishing growth in the number of Chinese firms in the top 2 000, which has more than doubled in the current edition compared to the first. This growth has been accompanied by a steady growth in the share of R&D conducted by the Chinese companies in the sample, which went from 3.7% in 2012 to 11.3% in 2018.

Figure 2.4. Changes in the geographical distribution of the world's top R&D investors, 2012-18

Number of companies by location of headquarters, top 15 economies



***Sources**: JRC-OECD, COR&DIP© databases v.0, v.1, v.2 and v.3, 2021.*

China's growth both in terms of number of companies and the share of R&D in the sample mainly occurred at the expense of Japanese and EU companies. The number of Japanese companies in the sample dropped from 353 to 263, and their share of R&D in the top 2 000 fell from 18.9% to 13.3%. For the EU27, the number of companies went from 419 to 366, and the share of R&D from 25.0% to 22.0%.

Looking inside the EU27 region, the top three countries in terms of number of companies were Germany, France and Sweden in 2012, while in 2018 the Netherlands reached third position. The number of German companies decreased (from 130 in 2012 to 118 in 2018), but their relative contributions to R&D investments increased, with shares of R&D in the EU27 sample rising from 42.0% to 46.6%.

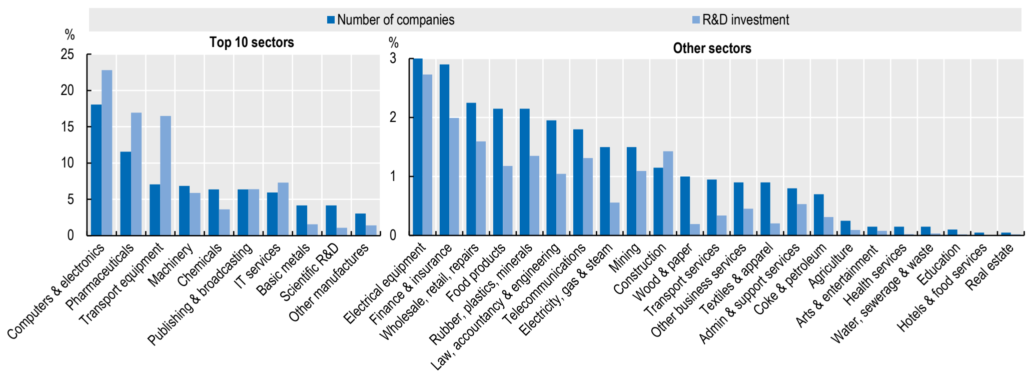
2.2. LEADING SECTORS IN R&D INVESTMENT

Top R&D investors worldwide operate in a variety of sectors, as identified by the main code of the International Standard Industrial Classification of All Economic Activities (ISIC, Rev. 4 – see the list of sectors in Annex A). According to Figure 2.5, the 'Computers & electronics' industry dominates with 18% of companies in the sample. In turn, 12% of companies operate in 'Pharmaceuticals'. The top 10 sectors accounted for more than 73% of the top R&D investors.

Considering shares of R&D investments instead of the number of firms, the top three sectors do not change, with 'Computers & electronics', 'Pharmaceuticals' and 'Transport equipment' accounting for 22.3%, 16.9% and 16.8%, respectively, of the total R&D in the sample. However, the fourth sector in terms of R&D share is 'IT services' (only seventh in terms of number of firms) with 7.3%, while 'Machinery' accounts for only 5.9%, also below 'Publishing & broadcasting' (6.4% of the total R&D in the sample). The top 10 sectors in terms of number of firms are responsible for 83.4% of the R&D in the sample, suggesting an (even higher) concentration of R&D.

Figure 2.5. World's top R&D investors by sector, 2018

Distribution of companies and R&D investments, ISIC Rev. 4

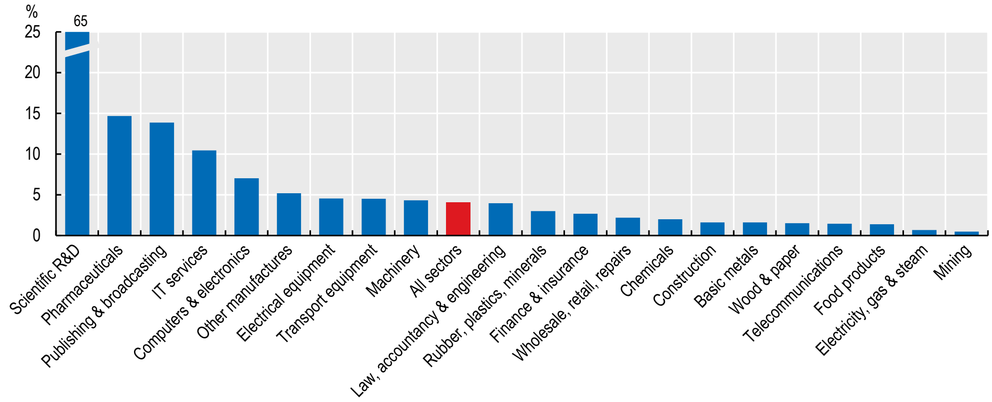


***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 2.6 shows the ranking of sectors in terms of R&D intensity (R&D over net sales) instead of the number of firms. The top sector in terms of R&D intensity is by far 'Scientific R&D', with 64.8% of net sales spent on R&D. Second and third are 'Pharmaceuticals' (14.7%) and 'Publishing & broadcasting' (13.9%). The top five are completed by 'IT services' (10.5%) and 'Computers & electronics' (7.1%). Only 'Pharmaceuticals' and 'Computers & electronics' are in the top five sectors in terms of both number of firms and R&D intensity.

Figure 2.6. R&D intensity by sector, 2018

R&D investments of firms over net sales, ISIC Rev. 4

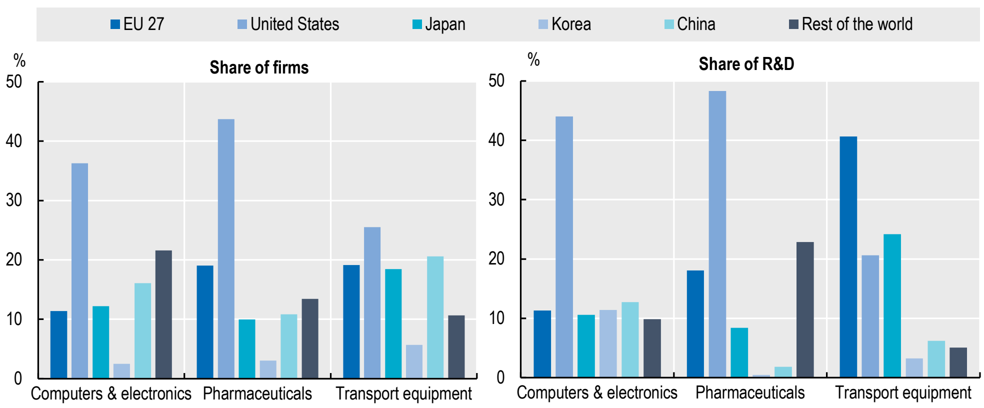


***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 2.7 shows the geographical composition of the companies in the top three sectors in terms of number of firms and R&D shares. The 'Computers & electronics' sector is dominated by US companies. They represent 36.3% of the firms and 44% of the R&D invested by this sector. Not surprising given what we have seen so far, China is second in this sector both in terms of the share of firms (16.1%) and R&D (12.8%). The four main Asian players in this sector (China, Korea, Japan and Chinese Taipei) together account for a share of R&D invested in this sector (42.3%) similar to that of the United States. EU27 is a marginal player in this field, with around 11% of both the number of firms and R&D invested by the sector.

Figure 2.7. Share of firms and R&D by sector and headquarters' location, top 3 sectors, 2018

Distribution of companies, ISIC Rev. 4



***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

The situation is to some extent similar in the Pharmaceuticals sector. US companies also dominate in this sector, with 43.7% of the firms and 48.3% of the R&D invested. However, second here is the EU27, which accounts for 19.0% of the firms and 18.1% of the R&D investment undertaken in the sector. It is worth noting Switzerland, whose five firms in the sector are all top players and together invest 13.4% of the R&D in the sector. Overall, Europe (grouping the EU27; the United Kingdom and Switzerland) would account for 38.3% of the sector's R&D. It would still remain behind the United States in terms of both number of firms and R&D invested in Pharmaceuticals, but would be much closer.

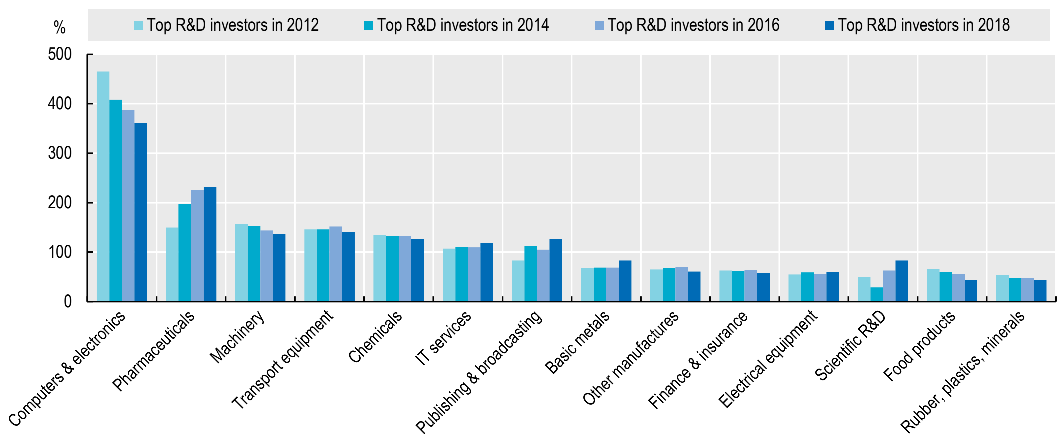
In contrast, EU27 firms are responsible for 40.6% of the R&D invested in the 'Transport equipment' sector, notwithstanding that only one in every five firms in this sector is headquartered in the EU27 (19.1%). Japan is also a relevant player in this sector, with 18.4% of the firms and 24.2% of the R&D invested. US firms are also the relative majority in this sector (25.5%) but they invest much less in R&D (20.6%) than both their EU27 and Japanese competitors.

Figure 2.8 shows how the sectoral distribution of companies has evolved across the four editions of this report. The top 10 sectors in 2012 in terms of number of firms are still the top 10 sectors of 2018, with the only exception being the 'Food producers' exit and the entry of 'Scientific R&D'.

There are now fewer firms in the 'Computers & electronics' sector compared to 2012 (from 22.8% to 18.1%), but their share of R&D did not fall as much as their number (from 23.4% to 22.8%). The United States is now leading this sector and was also leading it in 2012. The main difference is that China – which was a marginal player behind Japan, Korea and Chinese Taipei – is now a regional leader in the sector.

Figure 2.8. Changes in the sectoral distribution of the world's top R&D investors, 2012-2018

Number of companies, top 15 sectors, ISIC Rev. 4



***Sources**: JRC-OECD, COR&DIP© databases v.0, v.1, v.2 and v.3, 2021.*

In 'Pharmaceuticals', the growth in terms of number of firms (from 8.7% to 11.6%) between 2012 and 2018 was not accompanied by a similar increase in the share of R&D in the sector, which altogether saw a slight decrease (from 17.2% to 16.9%). US companies strengthened their position as R&D investment leaders in the sector, increasing their share from 44 % in 2012 to 48.3% in 2018. Europe as a geographical region (EU27, the United Kingdom and Switzerland) has lost ground compared to the United States, its share falling from a combined 41.6% to 38.3%. Chinese companies in this sector were and still are marginal players.

'Transport equipment', which ranked fourth in terms of number of firms in 2021 and is now third, registered a decrease in both number of firms and R&D shares. The country composition of firms belonging to this sector has not changed significantly. Among the sectors on the rise, 'IT services' is the one that increased its share of R&D in the sample the most (from 3.7% to 7.3%), although the growth in terms of number of firms has not been as sharp as that of the R&D share. The same dynamic can be observed in the 'Publishing & broadcasting' sector. Both sectors were – and still are – heavily dominated by US firms, especially in terms of the share of R&D invested.

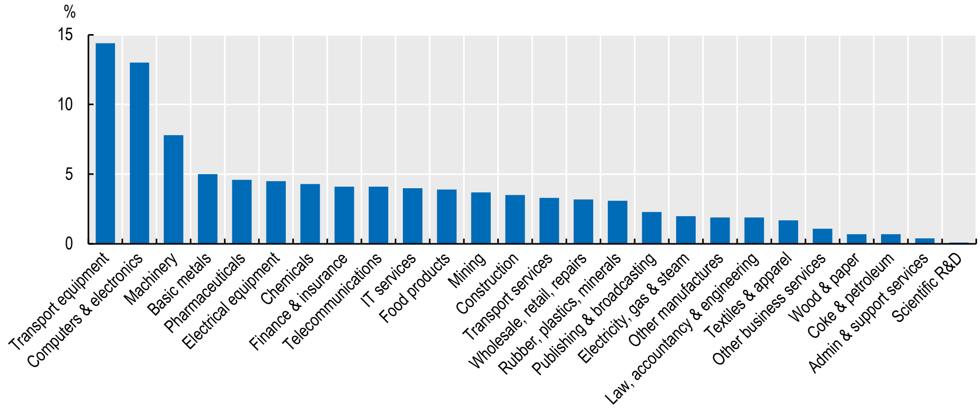
2.3. WORKFORCE AND GENDER LEADERSHIP

This subsection explores the composition of the corporate boards and employment of top R&D companies and their relationship with R&D investment. Employment is less concentrated compared to the number of firms or the R&D investment in the sample. The top 10 sectors in terms of employment account for 66.1% of the overall employment in the sample.

While the 'Transport equipment' sector ranked third in terms of the number of corporations, this sector was responsible for the highest share of employment (14.6%) in 2018, as shown in Figure 2.9. 'Computers & electronics' followed, accounting for 13.0% of the workforce of the world's top 2 000 R&D investors. In distant third is 'Machinery', with 7.9% of the total workforce of the sample. The first two sectors switched position compared to 2012, when 'Computers & electronics' was accounting for 13.9% of the employment versus the 13.3% of 'Transport equipment'. 'Machinery' also ranked third in 2021 (7.2%).

Figure 2.9. Workforce of the world's top R&D investors, by sector, 2018

Distribution of employment in sectors and share of sectors in the total workforce, ISIC Rev. 4



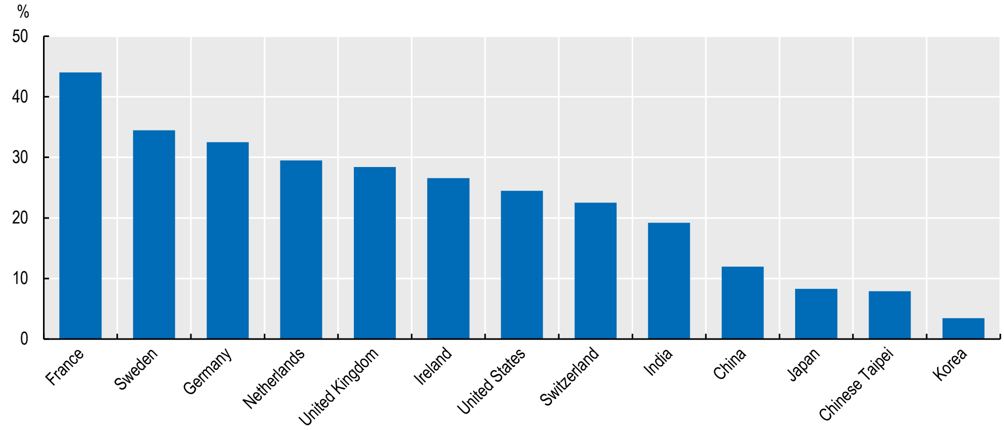
***Note**: Data refer to employment figures for 2018 or the closest available year. Employment figures are missing for 92 companies.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

In 2018, the average firm in the sample employs 27 790 employees in full-time equivalent (FTE). The average EU27 firm in the sample employs 44 975 employees, which is also almost three times more than the average US firm's 16 023 employees. In the top three sectors in terms of total employment, EU27 firms are on average bigger (meaning they have more employees) than their US competitors. This is also the case in the 'Computers & electronics' sector, dominated by US firms, both in terms of numbers and R&D.

Figure 2.10 reports the share of women on the board of directors for 1 584 companies out of the top 2 000 corporate R&D sample, by location of the headquarters (see Box 2.1 for further details on the data source). Note that due to data limitations, a few leading R&D companies, such as Bosch and Huawei, are not included in the Figure. In general, European companies have more gender-balanced boards than US and Asian counterparts, with female representation of at least 26%. The sample of French companies indicated the most gender-balanced boards by far. This could be the result of the European Commission's proposed legislation to increase the number of women on corporate boards by 40% by 2020 in publicly listed companies. In many other economies (India, the United States, for example), the law is laxer as it imposes a quota of at least one female director on the board of listed companies. For the most part, there is no evident association between the representation of women on boards and the R&D efforts by economy.

Figure 2.10. Gender leadership of the world's top R&D investors, by headquarters' location, 2018

Average share of women on the board of directors



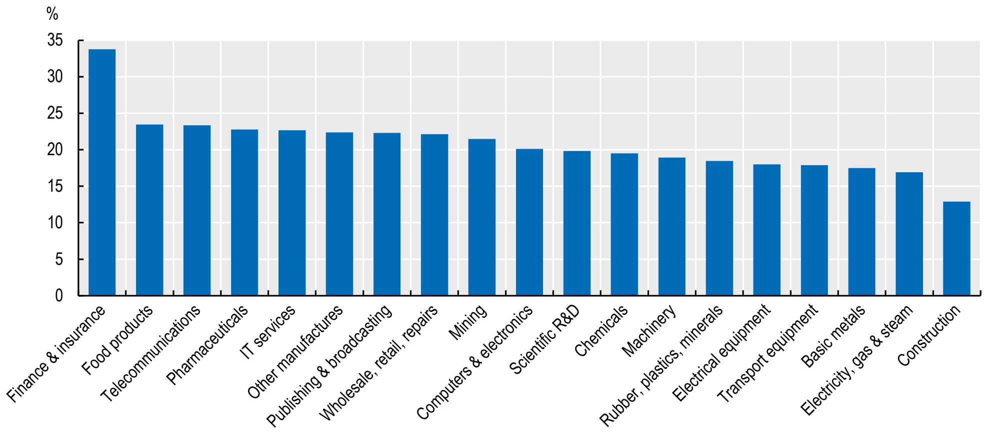
***Note**: Data relate to economies with at least 20 company headquarters in the top 2 000 corporate R&D sample.*
***Source**: Covalence SA and JRC-OECD, COR&DIP© database v.3, 2021.*

From a sectoral perspective (Figure 2.11), companies in the sectors of financial and insurance services have a greater gender balance in their leadership than other sectors. On average, one in three board members of a company operating in the 'Finance and insurance' sector is a woman. The most gender-balanced companies in this sector are the Korean NXC (55%), Commonwealth Bank of Australia (55%), the French Scor (50%) and the Swedish Svenska HandelsBanken (50%). In the rest of the sectors, there is little variation, as the percentage of women on boards ranges from 17% to 23%. The 'Construction' sector has the lowest share of women per corporate board (less than 13%).

A significant positive correlation between the share of women on boards and R&D investment is found for 'Pharmaceuticals', 'Publishing and broadcasting' and 'Transport equipment' companies (see correlation coefficients in Annex B).

Figure 2.11. Gender leadership of the world's top R&D investors, by sector, 2018

Average share of women on the board of directors, ISIC Rev.4



***Note**: Data relate to sectors with at least 20 company headquarters in the top 2 000 corporate R&D sample.*
***Source**: Covalence SA and JRC-OECD, COR&DIP© database v.3, 2021.*

Box 2.1.

WOMEN ON THE BOARD OF DIRECTORS – COVALENCE DATABASE

Covalence SA, based in Geneva (Switzerland) since 2001, is specialised in environmental, social and governance (ESG) research and ratings. The data gathered by Covalence only relates to ESG issues, sustainability, corporate social responsibility and business ethics. It does not cover purely economic or financial information. Covalence's data is articulated in two dimensions: disclosure and reputation. For more information, please visit https://www.covalence.ch/.

Disclosure covers ESG data published by companies such as the percentage of women among board members (other indicators include CO2 emissions, water consumption, anti-corruption policy, etc.) and is sourced from Refinitiv (formerly Thomson Reuters). The composition of the workforce within a company can be roughly grouped into 4 categories: board members, executives, managers and employees. The largest gender gaps are generally found between board members and executives (Refinitiv, 2020). A board of directors is an elected group of people that represent shareholders and may or may not have executive roles. One of the main tasks of the board of directors is the appointment of a chief executive officer, who belongs to the executive group in a company's organisation.

3. THE INNOVATIVE ACTIVITIES OF THE WORLD'S TOP R&D INVESTORS

This chapter describes in detail the innovative activities of the top R&D investors as measured by their intellectual property. In particular, it presents the geographical and sectoral distribution of patents and trademarks and analyses on how companies bundle these IP tools. The chapter also looks into changes over time within the IP bundle composition and their technological specialisations. Lastly, it examines the contribution of female inventors to the patent portfolios of R&D investors.

HIGHLIGHTS

- R&D, patents and trademarks are highly concentrated in the hands of a few hundred companies, with a clear prevalence of Asian companies. R&D investors owned 63% of all 'IP5' patents filed during 2016-18. Their share of trademarks is considerably lower, with only 6% of the total trademarks filed at the European Union Intellectual Property Office (EUIPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO).

- 60% of the patent families owned by R&D investors are concentrated within three sectors: 'Computer electronics', 'Transport equipment' and 'Machinery'. Similarly, more than 50% of trademarks are owned by R&D investors operating in three sectors: 'Computer electronics', 'Chemicals' and 'Pharmaceuticals'.

- The top five economies in terms of the location of inventive activity are Japan, the United States, the EU27, Korea and China. Germany accounts for more than 50% of the patents invented in the EU.

- The gender gap in patent applications is very large. Companies with the highest shares of patents invented by women are located in Spain (37%), the United States (29%) and Belgium (26%). Fields with the highest shares (around and above 50%) of women's inventions are in 'Pharmaceuticals', 'Biotechnology' and 'Chemistry'.

- The United States' considerable technological advantage in 'Pharmaceuticals', 'Biotechnology' and 'Organic chemistry' explains, in part, the higher-than-average share of patents invented by women in US-based firms.

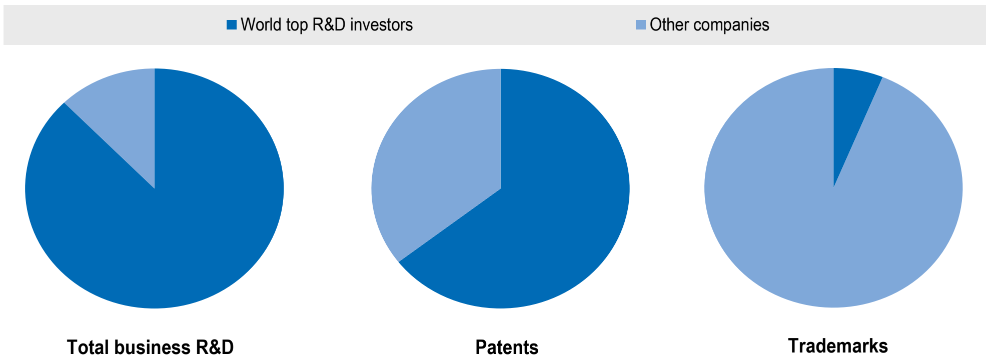
- Bundles of trademark and patent portfolios differ between sectors: companies in 'Transport equipment', 'Electrical equipment', 'Machinery' and 'Computers & electronics' primarily rely on patents to protect their products, while companies in 'Food products', 'Telecommunications' and 'Pharmaceuticals' use more trademarks than patents. R&D companies in the 'Chemicals' sector have a more balanced IP bundle.

3.1 TOP INNOVATORS

Worldwide R&D investment is highly concentrated within the top 2 000 R&D investors, and so are the outputs of R&D activities, as measured by patented inventions owned by companies. As shown in Figure 3.1, top R&D investors owned 63% of patents protected in the five largest markets worldwide during 2016-18, as measured by what are known as IP5 patent families (see Box 3.1 for further details on the data sources and methodology). Those companies, in turn, represent a much smaller share of trademarks: they are responsible for approximately 6% of trademarks registered at the European Union Intellectual Property Office (EUIPO), the Japan Patent Office (JPO) and the United States Patent and Trademark Office (USPTO).

Figure 3.1. R&D, patents and trademarks of the world's top R&D investors, 2016-18

As a percentage of the world's business-funded R&D, patents and trademarks, respectively

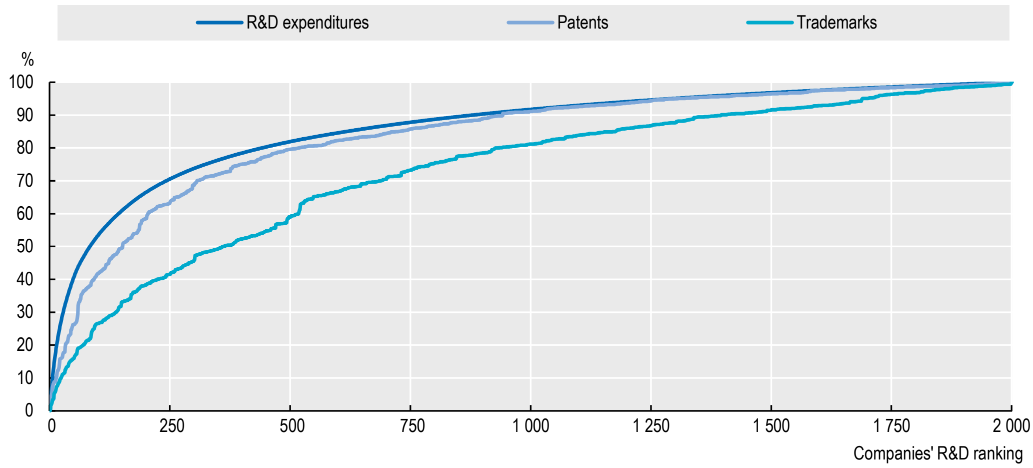


Note: *Data refer to the estimated total world business R&D investments for the year 2018, the total number of IP5 patent families filed between 2016 and 2018 and the total number of trademarks filed at the EUIPO, JPO and USPTO during the same period.*
Source: *JRC-OECD, COR&DIP© database v.3, 2021.*

R&D and innovative activities are highly concentrated within the top 2 000 R&D investors worldwide. In 2016-18, the top 250 companies contributed to almost 71% of R&D investments in the sample (Figure 3.2). This subset of companies was in turn responsible for 64% of patents owned by the sample – as measured by the number of IP5 patent families – and for 42% of trademarks registered in Europe, the United States or Japan.

Figure 3.2. Distribution of R&D investments and the IP bundle of the world's top R&D investors, 2016-18

Cumulative percentage shares within the top 2 000 R&D companies



__Note__: Data relate to companies in the top 2 000 corporate R&D sample, ranked by R&D investment in 2018. The IP bundle refers to the number of patents and trademarks filed in 2016-18, owned by the top R&D companies, using fractional counts.
__Source__: JRC-OECD, COR&DIP© database v.3, 2021.

Box 3.1.

INTELLECTUAL PROPERTY (IP) RIGHTS OF THE WORLD'S TOP R&D INVESTORS – THE PORTFOLIO OF PATENTS AND TRADEMARKS

The intellectual property (IP) bundle of the world's top R&D investors presented in the report includes patents filed by companies and their subsidiaries to protect inventions at the five largest IP offices worldwide, and trademarks registered in three of the largest IP offices to protect goods and services on key economic markets. The data derives from the IP data of the OECD Science, Technology and Innovation (STI) Micro-data Lab and the Worldwide Patent Statistical Database maintained by the European Patent Office (EPO), also known as PATSTAT Global, in its Spring 2021 edition.

PATENTS

The report focuses on a set of patents filed at the five largest IP offices (IP5) to better reflect the inventive activities of top corporate R&D investors worldwide. These cover the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (CNIPA) and the United States Patent and Trademark Office (USPTO). Unless otherwise specified, all statistics presented in the report rely on IP5 patent families. IP5 patent families are defined as sets of patent applications filed in several IP offices to protect the same invention, covering at least one of the IP5, provided that another family member has been filed in any other office worldwide (see Dernis et al., 2015, and Daiko et al., 2017, for further discussion on the use of IP5 families). Patent families are reported according to the earliest filing date. The International Patent Classification (IPC) is used to allocate patents to technological fields (see Schmoch, 2008, **http://www.wipo.int/classifications/ipc** and Annex C).

TRADEMARKS

Data on trademark applications relate to trademarks registered at the European Union Intellectual Property Office (EUIPO), the JPO and the USPTO. The EUIPO administers EU trademarks (EUTMs – formerly known as Community trademarks, CTMs), which are valid throughout the European Union and coexist with nationally granted trademarks. The JPO and the USPTO guarantee protection on their national markets only. For more details on USPTO trademark data, see Graham et al. (2013). Trademarks are filed in accordance with the International Classification of Goods and Services, also known as the Nice Classification (see **https://www.wipo.int/classifications/nice/en**, and Annex D).

THE IP PORTFOLIO OF TOP R&D INVESTORS

The characterisation of the IP portfolio of companies requires patent and trademark records to be linked to enterprise-level data in the absence of detailed information on the owners of IP rights. For this purpose, the names of the top corporate R&D investors and their subsidiaries were matched to the applicant names provided in published patent and trademark documents, as described in Annex E. It should be noted that the data sources exploited for this report do not allow to track changes in patent ownership over time. Throughout the report, discussions about the ownership of patents refer to ownership at the time of filing. For this reason, the expressions 'patent owner' and 'patent applicant' are used here as synonyms.

The geographical attribution relies on the information about the country in which each company has its headquarters; in the case of patent families or trademarks containing applications filed by multiple companies, an equal share is attributed to each one. As an example, a patent co-owned by three of the top R&D investors, of which one has headquarters in France, one in Germany and one in the United Kingdom, will be counted as one third of a patent family to each company. The attribution of patents to technologies or to goods and services classes follows the same fractional counting procedure mentioned above.

Table 3.1 dives deeper into the output of the patenting and trademarking activities of the top R&D-investing companies. In particular, the table consists of two panels, each of them zooming into the top 50 companies in terms of the number of patents (left panel) and the number of trademarks (right panel) filed over the period 2016-18. It gives the reader a glimpse into the geographical and sectoral concentrations, as well as an idea of the distribution of the activities in question within this group of influential players.

Table 3.1. Top 50 patenting and trademarking companies, 2016-18

IP5 patent families and trademarks at the EUIPO, JPO and USPTO

Patenting companies		Sector, ISIC Rev.4	*Share*	*Rank*
Samsung Electronics	KOR	Computers & electronics	3.6	*(1)*
Canon	JPN	Machinery	2.5	*(2)*
Huawei Investment & Holding Co	CHN	Computers & electronics	1.7	*(3)*
Boe Technology Group	CHN	Computers & electronics	1.6	*(4)*
Ford Motor	USA	Transport equipment	1.5	*(5)*
Robert Bosch	DEU	Machinery	1.5	*(6)*
Panasonic	JPN	Electrical equipment	1.4	*(7)*
United Technologies	USA	Transport equipment	1.4	*(8)*
Sumitomo Electric	JPN	Basic metals	1.4	*(9)*
Hitachi	JPN	Electrical equipment	1.3	*(10)*
General Electric	USA	Machinery	1.2	*(11)*
Denso	JPN	Transport equipment	1.1	*(12)*
Siemens	DEU	Machinery	1.1	*(13)*
IBM	USA	IT services	1.1	*(14)*
Toyota Motor	JPN	Transport equipment	1.1	*(15)*
Ricoh	JPN	Machinery	1.0	*(16)*
Qualcomm	USA	Computers & electronics	1.0	*(17)*
LG Electronics	KOR	Computers & electronics	1.0	*(18)*
Seiko Epson	JPN	Computers & electronics	1.0	*(19)*
Fujifilm	JPN	Computers & electronics	0.9	*(20)*
Toyota Industries	JPN	Transport equipment	0.9	*(21)*
LG Chem	KOR	Chemicals	0.9	*(22)*
Volkswagen	DEU	Transport equipment	0.8	*(23)*
Taiwan Semiconductor	TWN	Computers & electronics	0.8	*(24)*
Intel	USA	Computers & electronics	0.8	*(25)*
Mitsubishi Electric	JPN	Electrical equipment	0.7	*(26)*
Denka	JPN	Chemicals	0.7	*(27)*
Sony	JPN	Computers & electronics	0.7	*(28)*
Fujitsu	JPN	Computers & electronics	0.7	*(29)*
Ericsson	SWE	Computers & electronics	0.7	*(30)*
Kyocera	JPN	Computers & electronics	0.7	*(31)*
SK Hynix	KOR	Computers & electronics	0.6	*(32)*
Honda Motor	JPN	Transport equipment	0.6	*(33)*
STMicroelectronics	NLD	Computers & electronics	0.6	*(34)*
Alphabet	USA	IT services	0.6	*(35)*
Sumitomo Chemical	JPN	Chemicals	0.5	*(36)*
BMW	DEU	Transport equipment	0.5	*(37)*
NEC	JPN	Computers & electronics	0.5	*(38)*
Konica Minolta	JPN	Computers & electronics	0.5	*(39)*
Murata Manufacturing	JPN	Computers & electronics	0.5	*(40)*
Nidec	JPN	Computers & electronics	0.5	*(41)*
Advanced Micro Devices	USA	Computers & electronics	0.5	*(42)*
Alibaba Group Holding	CHN	Wholesale, retail, repairs	0.5	*(43)*
Fanuc	JPN	Machinery	0.4	*(44)*
Airbus	NLD	Transport equipment	0.4	*(45)*
Hyundai Motor	KOR	Transport equipment	0.4	*(46)*
HP	USA	Computers & electronics	0.4	*(47)*
Boeing	USA	Transport equipment	0.4	*(48)*
Kia Motors	KOR	Transport equipment	0.4	*(49)*
Continental	DEU	Rubber, plastics, minerals	0.4	*(50)*

Trademarking companies		Sector, ISIC Rev.4	*Share*	*Rank*
Shiseido	JPN	Chemicals	1.7	*(1)*
Johnson & Johnson	USA	Pharmaceuticals	1.4	*(2)*
Kao	JPN	Chemicals	1.4	*(3)*
AT&T	USA	Telecommunications	1.3	*(4)*
L'Oréal	FRA	Chemicals	1.3	*(5)*
LG Electronics	KOR	Computers & electronics	1.2	*(6)*
Samsung Electronics	KOR	Computers & electronics	1.2	*(7)*
Aristocrat Leisure	AUS	Arts & entertainment	1.0	*(8)*
NTT	JPN	Telecommunications	1.0	*(9)*
Bandai Namco	JPN	Other manufactures	1.0	*(10)*
Procter & Gamble	USA	Chemicals	0.9	*(11)*
Panasonic	JPN	Electrical equipment	0.8	*(12)*
Huawei Investment & Holding Co	CHN	Computers & electronics	0.8	*(13)*
Novartis	CHE	Pharmaceuticals	0.8	*(14)*
Sony	JPN	Computers & electronics	0.8	*(15)*
Fujitsu	JPN	Computers & electronics	0.8	*(16)*
Meiji	JPN	Food products	0.7	*(17)*
Mattel	USA	Other manufactures	0.7	*(18)*
BAT	GBR	Food products	0.6	*(19)*
Mitsubishi Electric	JPN	Electrical equipment	0.6	*(20)*
Pepsico	USA	Food products	0.6	*(21)*
GlaxoSmithKline	GBR	Pharmaceuticals	0.6	*(22)*
Christian Dior	FRA	Textiles & apparel	0.6	*(23)*
Anheuser-Busch Inbev	BEL	Food products	0.6	*(24)*
International Game Technology	GBR	Arts & entertainment	0.6	*(25)*
Kobayashi Pharmaceutical	JPN	Wholesale, retail, repairs	0.6	*(26)*
Ezaki Glico	JPN	Food products	0.6	*(27)*
Hasbro	USA	Other manufactures	0.6	*(28)*
Bayer	DEU	Pharmaceuticals	0.6	*(29)*
Eli Lilly	USA	Pharmaceuticals	0.6	*(30)*
Lixil Group	JPN	Basic metals	0.6	*(31)*
Taisho Pharmaceutical	JPN	Pharmaceuticals	0.5	*(32)*
Nissin Food Holdings	JPN	Food products	0.5	*(33)*
Bristol-Myers Squibb	USA	Pharmaceuticals	0.5	*(34)*
Merck US	USA	Pharmaceuticals	0.5	*(35)*
Pfizer	USA	Pharmaceuticals	0.5	*(36)*
Scientific Games	USA	IT services	0.5	*(37)*
Nintendo	JPN	Other manufactures	0.5	*(38)*
Siemens	DEU	Machinery	0.5	*(39)*
Novomatic	AUT	Law, accountancy & engineering	0.5	*(40)*
Coty	USA	Chemicals	0.5	*(41)*
Toyota Motor	JPN	Transport equipment	0.5	*(42)*
Otsuka	JPN	Pharmaceuticals	0.4	*(43)*
Hitachi	JPN	Electrical equipment	0.4	*(44)*
Alphabet	USA	IT services	0.4	*(45)*
Volkswagen	DEU	Transport equipment	0.4	*(46)*
BASF	DEU	Chemicals	0.4	*(47)*
Asahi Group	JPN	Food products	0.4	*(48)*
Reckitt Benckiser	GBR	Chemicals	0.4	*(49)*
Nippon Steel	JPN	Basic metals	0.4	*(50)*

***Note**: Data relate to the share of patents (respectively trademarks) owned by companies in total patents (respectively trademarks) filed by the top 2 000 corporate R&D sample in 2016-18.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Looking at the patent side (left panel), as in the previous editions of this report (Dernis et al., 2019), Samsung Electronics, which alone owns 3.5% of the IP5 patent families globally owned by the top 2 000 R&D investors, dominates the ranking. Next is Canon, which, with a 2.5% share of patent families, holds a sizeably larger share of patents than the companies further down in the ranking. Proceeding further down the table, patent ownership shares tend to stabilise. For instance, more than half of the companies in the table display an ownership share between 0.5% and 1%.

From the geographical concentration angle, there is a clear prevalence of companies based in Asia (mainly Japan, China and Korea) both at the very top of the table and throughout the top 50, with Japan taking the lion's share in terms of the number of represented companies. The highest-ranking US-based company is Ford Motor, in fifth place, followed by German machinery manufacturer Robert Bosch. Globally, US-based companies account for 20% of the companies listed in Table 3.1, while EU-based companies account for 16% (i.e. 8 out of 50), of which 5 have headquarters located in Germany. From a sectoral standpoint, the 'Computers and electronics' sector is by far the most represented with over 40% of the companies and 40% of the total patent families owned.

Of the top 50 patenting companies, 21 are also among the top 50 R&D investors. In this 'top 50 patenting-top 50 R&D-investing companies' club there are 7 EU27 firms (5 of which are German), 6 US firms, 5 Japanese firms, 2 Chinese firms and 1 Korean firm. The three main sectors in which they operate are 'Transport equipment', 'Computers and electronics' and 'Machinery' (7, 6 and 3 firms, respectively).

Looking now at the trademark side (right panel), the leading company in the sample is Shiseido, which was third in the ranking in the last edition of the report (Dernis et al., 2019). Former leader LG Electronics now ranks sixth in terms of share of trademarks in the sample. The two companies ranking second and third in this year's report (Johnson & Johnson and Kao) made a considerable improvement compared to the last edition, where they ranked eighth and nineth, respectively.

As for the location of the top trademarking companies, there is a relative majority of Asian companies (mainly represented by Japanese companies), but less pronounced than in the case of patents. There are more US companies in the top 50 trademarking companies (13) than in the top 50 patenting companies (10). EU27-based companies have the same share of trademarking and patenting companies in the respective top 50, although only two of them are present in both rankings (Siemens and Volkswagen).

In general, top trademarking companies appear less geographically concentrated than top patenting companies. The same is true at sector level: companies in the top 50 trademarking companies belong to 15 different sectors, while only 9 sectors are represented in the top 50 patenting companies list. The relative majority of companies belong to the 'Pharmaceuticals' sector (10). The 'Chemicals' and 'Food producers' sectors also have a significant representation (7 companies each).

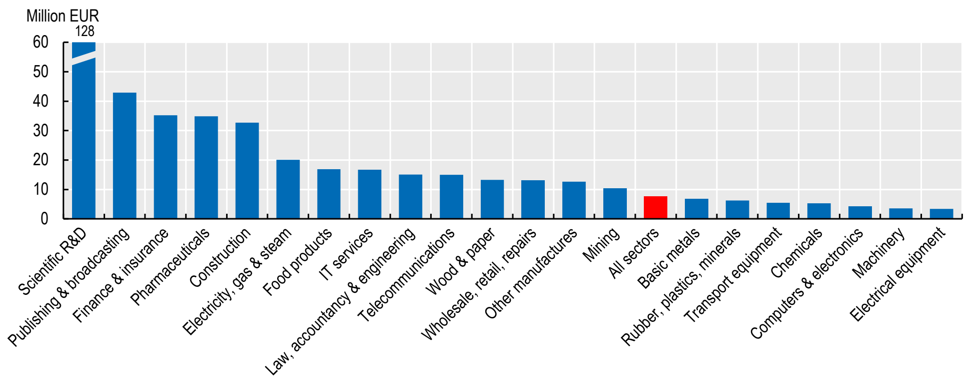
The 'top 50 trademarking-top 50 R&D-investing companies' club is much more exclusive than the 'top 50 patenting-top 50 R&D-investing companies' one, with only 12 members, half of which being Japanese (the rest are 2 German companies, 2 Korean companies, 1 Chinese company and 1 US company). The even more exclusive 'top 50 patenting-top 50 trademarking-top 50 R&D-investing companies' club has only 8 members (Alphabet, Samsung Electronics, Volkswagen, Huawei, Toyota Motor, Siemens, Panasonic and Sony).

As an indication of the effort put into the production of patents, Figure 3.3 presents the average R&D investment per patent by sector. This measure needs to be interpreted with caution, as not all R&D investment translates directly into patents. A company may invest substantially in R&D and not protect the results of its research with a patent, either because it prefers to protect it via other channels (i.e. trade secrets) or simply because the research did not produce an output that is worth patenting or is not patentable at all. Secondly, R&D investment and patent production are not simultaneous. There is a time lag between the R&D invested and the eventual patent (or patents) that comes out of that investment. It is virtually impossible to directly link a specific R&D investment done in time *t* to a specific patent filed in time *t+x*. Nevertheless, the indicator is meaningful in that it conveys the idea of the ease with which R&D activity within an industry leads to patentable outputs. Roughly speaking, the lower the cost per patent, the higher the returns on the scope of R&D investment in terms of the generation of protected intellectual property.

Taking R&D investments per patent as a measure of the R&D cost, 'Scientific R&D' is – with EUR 128 million spent per patent – the sector that undoubtedly leads in this area, to the point that it is literally off the chart in Figure 3.3. The majority of companies in this sector are performing research in biotechnology. The 'Publishing and broadcasting' sector comes in second with just over EUR 40 million, closely followed by 'Finance & insurance', 'Pharmaceuticals' and 'Construction', all of which record one patent for around every EUR 35 million declared in R&D. At the opposite end of the spectrum, sectors like 'Chemicals' and 'Machinery' record well under EUR 5 million spent per patent family.

Figure 3.3. R&D investment per patent of the world's top R&D investors by sector, 2016-18

Million EUR per IP5 patent family, ISIC Rev. 4

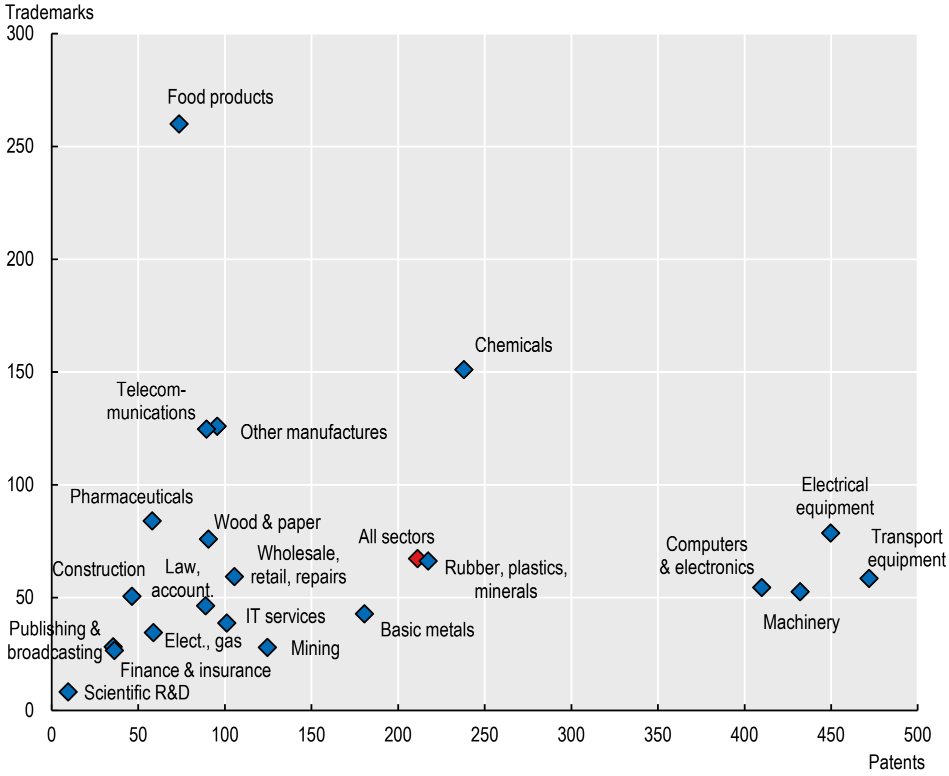


***Note**: Data relate to industries with at least 20 company headquarters in the top 2 000 corporate R&D sample.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

The way in which the top R&D investors bundle the two types of IP assets in their portfolios differs between sectors. Figure 3.4 shows the average number of patents (x-axis) and trademarks (y-axis) per firm across sectors. Technical sectors tend to rely more on patents to protect newly developed inventions than on trademarks: companies performing in 'Transport equipment', 'Electrical equipment', 'Machinery' and 'Computers & electronics' own, on average, more than 400 IP5 patent families filed in 2016-18, and only 50 to 100 trademarks. At the other end of the spectrum, companies in 'Food products' mainly rely on trademarks to signal their presence on the market, with 260 trademarks on average per company, and seldom protect new technologies with patents (around 70 patents per company). Top R&D investors from 'Telecommunications' and 'Other manufactures' also heavily rely on trademarks to protect their products (around 125 trademarks on average per company), followed by 'Pharmaceuticals' (84 trademarks on average). 'Chemicals' companies rely on a more balanced bundle of IP, owning on average 238 IP5 patent families and 151 trademarks filed in 2016-18.

Figure 3.4. IP bundle owned by the world's top R&D investors, by sector, 2016-18

Average number of patents and trademarks per company, ISIC Rev.4



***Note**: Data relate to industries with at least 20 company headquarters in the top 2 000 corporate R&D sample.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

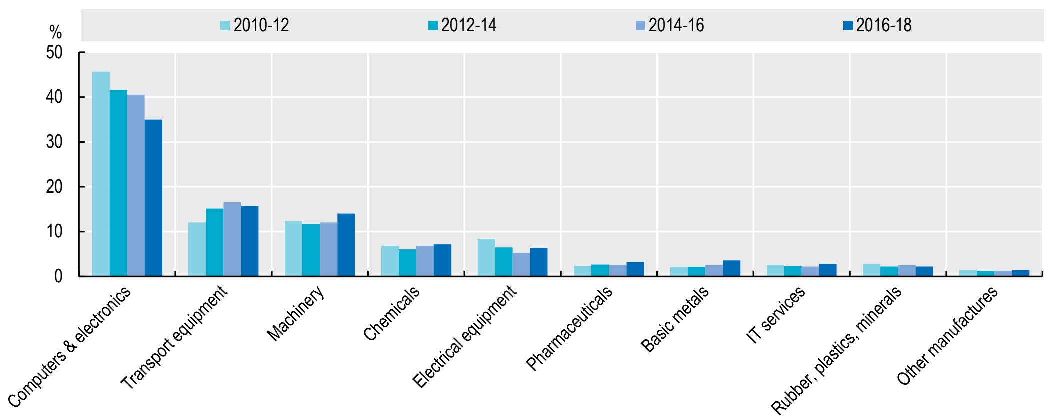
3.2 DYNAMICS OF INNOVATIVE ACTIVITIES

This section presents the changes in the sectoral distribution of the IP bundle owned by top R&D investors throughout the different editions of the 'IP bundle of top corporate R&D investors' database (*JRC-OECD COR&DIP© database*), based on the top 2 000 R&D investors sample in 2012, 2014, 2016 and 2018.

Figure 3.5 focuses on the top 10 sectors in terms of the volume of patents produced. The most recent data from the 2016-18 period show a clear prevalence of the 'Computers & electronics' sector, which has produced around twice as many patents (around 35% of the total patent volume) as 'Transport equipment', the next sector in the ranking. Overall, patent output is quite concentrated, as the top three sectors account for over 60% of the patent families owned by the top R&D investors. Turning to the evolution over time, the chart suggests that the situation has remained qualitatively stable since 2010. The most noteworthy change concerns 'Computers & electronics', which was even more prevalent in the past than it is in 2018. In fact, its share of the total patents has noticeably and steadily reduced since the first version of the JRC-OECD COR&DIP© database was published.

Figure 3.5. Patents portfolio of the world's top R&D investors, by sector, 2010-18

Top 10 patenting sectors, share of total IP5 patent families, ISIC Rev.4



***Note**: Data refer to four vintages of the world's top 2 000 R&D investors (2012, 2014, 2016 and 2018) matched to IP data in the neighbouring 3-year periods. Figures are ordered according to the average values observed in the four different time periods.*

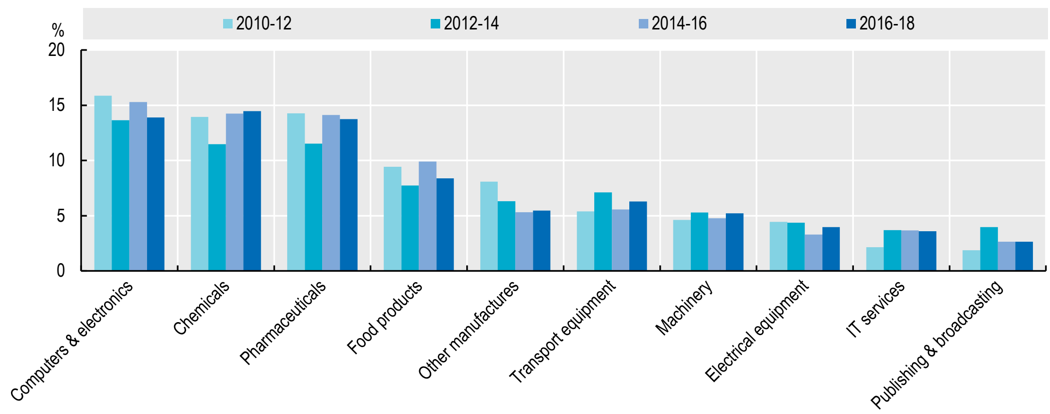
***Sources**: JRC-OECD, COR&DIP© databases v.0, v.1, v.2 and v.3, 2021.*

Temporal trends in terms of trademark production by sector across the four different editions of this report are reported in Figure 3.6. The top three sectors in the current edition are the same as in the first edition, but the ranking has changed. 'Computers and electronics' is now second in terms of the share of trademarks in the sample (it was first in the previous three editions), while ''Chemicals' ranks first (it was third in 2010-12) and 'Pharmaceuticals' (second in the first edition) becomes third.

Given that the number of companies in 'Chemicals' in the sample represents a third of the number of companies in the 'Computer and electronics' sector (as shown in Figure 2.5), the similarity of their trademark shares is remarkable (in fact, 'Chemicals' owns more trademarks). It signals a much higher propensity to use trademarks by the 'Chemicals' sector than most other sectors in the sample. Among other sectors, the share of trademarks for 'Transport equipment' has increased (compared to the first edition) and the sector now ranks fifth, just behind 'Food producers'. This last sector is also quite trademark-intensive (similar to 'Chemicals') since only 43 firms (see Figure 2.5) own 8.9% of the trademarks in the sample.

Figure 3.6. Trademark portfolio of the world's top R&D investors, by sector, 2010-18

Top 10 trademarking sectors, share of total trademarks, ISIC Rev.4



***Note**: Data refer to four vintages of the world's top 2 000 R&D investors (2012, 2014, 2016 and 2018) matched to IP data in the neighbouring 3-year periods. Figures are ordered according to the average values observed in the four different time periods.*

***Sources**: JRC-OECD, COR&DIP© databases v.0, v.1, v.2 and v.3, 2021.*

3.3. THE GEOGRAPHY OF INNOVATIVE OUTPUT

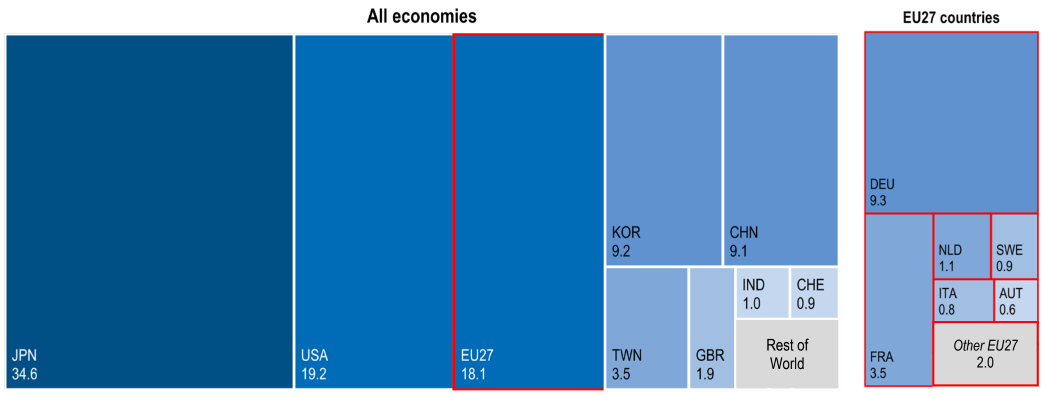
The corporate structure of most top R&D investors consists of multiple subsidiaries located in different countries. Consequently, the inventors and the research facilities involved in developing inventions may be located in other countries. Figure 3.7 shows the distribution of the location of inventors[2] of patents owned by the top R&D investors across countries and regions. The location of inventors is determined by the address of the inventor as reported in published patent documents. Fractional counts are used in such a way that if a patent is filed by inventors located in different countries, an equal share of the patent is attributed to each inventor before aggregating at country level.

2 Contrary to applicant's location, inventor's location is not affected by strategic decisions of the companies on how to distribute intellectual property between subsidiaries.

The top five economies in terms of location of inventive activity are Japan (34.6% of patents), the United States (19.2%), the EU27 (18.1%), Korea (9.2%) and China (9.1%). Germany accounts for more than 50% of patents invented in the EU.

Figure 3.7. Location of inventors, 2016-18

Economies' share of patents owned by the world's top R&D investors

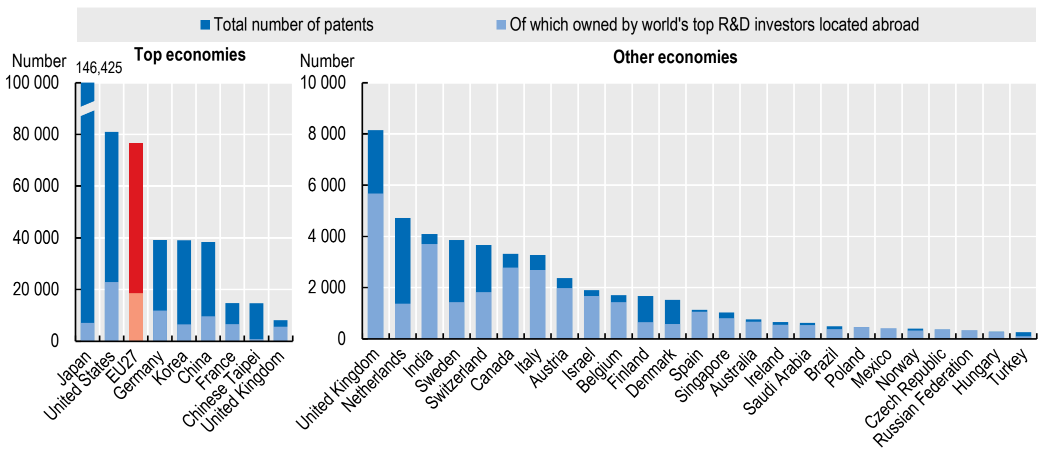


Source: *JRC-OECD, COR&DIP© database v.3, 2021.*

The world's top R&D investors tap into knowledge in both economies where they are headquartered and abroad. Figure 3.8 shows the number of patents developed within economies, broken down between patents owned by domestic firms and foreign-based companies. Japanese companies are those that rely most heavily on research conducted domestically: only 5% of patents invented in Japan belong to the world's top R&D investors headquartered abroad. The share is larger in the case of the United States, where 28% of patents invented in the United States belong to the portfolio of companies headquartered outside the United States. Overall, around 24% of patents invented in the EU27 are owned by top R&D investors located in non-EU27 economies.

Figure 3.8. Internationalisation of inventions, 2016-18

Total patents invented in economies and location of the owner's headquarters



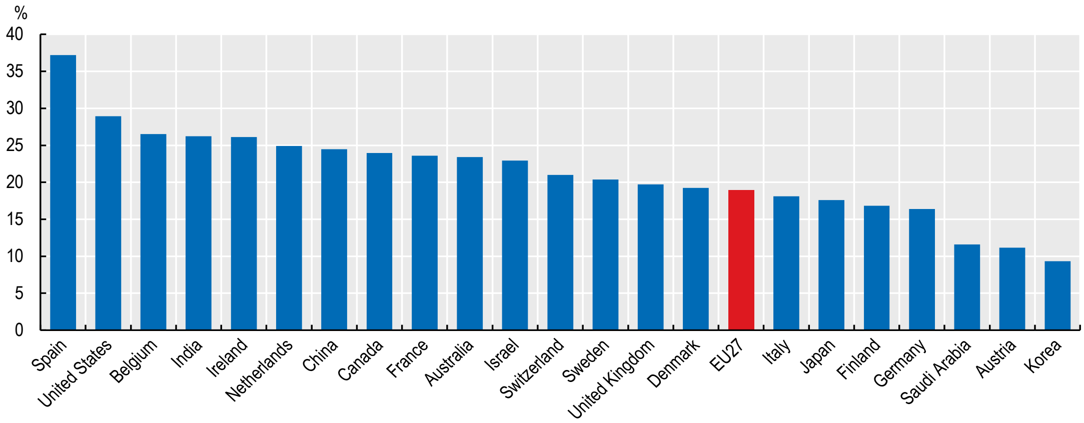
Note: *Intra-EU27 ownership is excluded.*
Source: *JRC-OECD, COR&DIP© database v.3, 2021.*

3.4. GENDER OF INVENTORS

Innovation is the result of teamwork and gender diversity within the team has received increasing attention. The gender gap in patent applications, while narrowing (WIPO, 2020), is still very large. Figure 3.9 reports on the contribution of female inventors to the patent portfolios of top R&D investors by country (see Box 3.2 for details on the data sources and methodology), as measured by the share of patents with at least one a woman on the team of inventors for the total patents invented domestically. Less than 20% of all patents of European top R&D investors were invented by at least one woman. Spanish R&D companies have the most gender-balanced innovation teams, with a share of female-invented patents of 37%. US companies also have a reasonable proportion of their patent portfolio invented by women (29%). Overall, the distribution of the shares of patents invented by women does not mirror any socio-economic and cultural traits, such as how middle-income countries have fewer gender-balanced societies, higher wage gaps, reduced female participation in the workforce, etc. Indeed, German companies have a representation of female inventors of approximately 15% in terms of patents protected, while Indian and Chinese companies see female inventors contributing to around 25% of patents invented domestically. The country distribution of such shares could be, of course, the result of country-specific technological specification (see Section 3.4).

Figure 3.9. Patents invented by women, by location of inventor, 2016-18

Share of IP5 patent families owned by the world's top R&D investors involving female inventors



***Note**: Only inventors' economies with at least 500 patent families are included. Figures for Korea and China are based on a subset of IP5 families.*

***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Box 3.2.

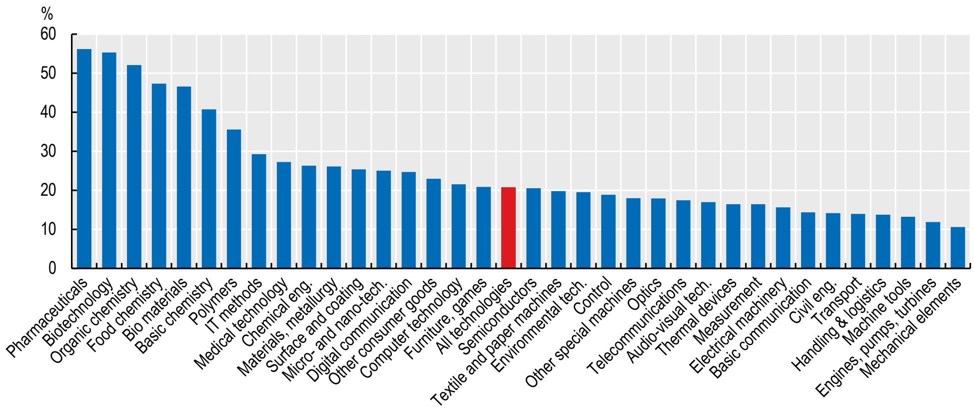
IDENTIFYING THE GENDER OF INVENTORS

Inventors' genders were identified using gender-name dictionaries based on the first names by country, following the methodology described in Lax Martínez, Raffo and Saito (2016). The gender allocation builds on the latest dictionaries published by the Intellectual Property Office of the United Kingdom (Intellectual Property Office, 2019) and the 'World Gender Name Dictionary' (WGND) developed by the World Intellectual Property Organization (Raffo, 2021). It was complemented by the recent work by the USPTO for US-based inventors (USPTO, 2020), as well as that of the Instituto Nacional de Propiedad industrial of Chile (INAPI) for Spanish inventors (INAPI, 2020).

For most countries, the share of inventors for whom the gender is identified is above 80%. For countries where many first names can indistinctively relate to female or male (this is particularly the case in Asian countries such as Korea or China), the UK IPO dataset was used as a priority, even though the proportion of identified genders using that dictionary was lower. Therefore, the results for some countries (China, Korea) should be considered with caution. Work is underway to improve dictionaries and overcome this issue.

Figure 3.10. Patents invented by women, by technology, 2016-18

Share of IP5 patent families owned by the world's top R&D investors involving female inventors



***Note**: IP5 patent families are allocated to technology fields using the taxonomy developed by the WIPO, as described in Annex C.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 3.10 shows the share of patents invented by women broken down by technology fields. Fields with the highest shares (around and above 50%) of female inventions are *Pharmaceuticals*, *Biotechnology* and *Chemistry* (*Organic, Food,* and *Basic*). On the other hand, female inventors are heavily under-represented in patent-intensive fields such as *Computer technology*, *Machinery* and *Transport*. The high revealed technological advantage (RTA) of the United States in *Pharmaceuticals*, *Biotechnology* and *Organic chemistry* (Table 3.2) would explain, in part, the higher-than-average share of female-invented patents owned by US companies. Likewise, the high level of technological specialisation of Korean companies in male over-represented technologies such as *Computer technology* and high RTAs in *Transport equipment* within European and Japanese companies could reflect the low share of female innovation in Japan, Korea and the EU27.

3.5. TECHNOLOGICAL SPECIALISATION OF MAJOR ECONOMIC REGIONS

The technological strengths of the top R&D investors are depicted with indicators of specialisation, looking at the relative distribution of the patent portfolio (respectively trademark portfolio) across 35 technology fields (respectively goods and service categories for trademarks). Table 3.2 presents indices of the revealed technological advantage (RTA) for the top R&D investors across six geographical regions: the EU27 (Europe in the table), the United States, Japan, Korea, China and the rest of the world. The RTA index is defined as the share of patents in a particular technological field in the patent portfolio of a given country or geographical area over the share of patents in the same technological field globally. As such, the RTA captures a region's specialisation in a particular technology, controlling for the effect of the region's size. Further details on RTA computation are provided in Box 3.3.

Table 3.2 reports RTA indices compiled for all combinations of the regions and technology fields, as identified using the WIPO concordance table between the International Patent Classification (IPC) and technology domains (see Annex C). For better readability, the table cells containing RTA values equal to or greater than one, i.e. technologies, in which a region has a relative specialisation over the 2016-18 period are highlighted in blue. Europe displays a positive specialisation in 25 technology fields out of 35, a broader set of technologies than all other regions; the United States and Japan follow, featuring a specialisation in 18 and 19 fields, respectively, before Korea (13 fields) and China (9).

Table 3.2. Revealed technology advantage (RTA) of the world's top R&D investors, 2016-18

RTA and changes compared with 2010-12 levels, by field of technology and geographical location of headquarters

Field of technology	Europe	United States	Japan	Korea	China	Rest of the World
Electrical machinery	1.0 ↗	0.6 ↘	1.2 ↗	1.4 ↗	0.6 ↗	0.9 ↘
Audio-visual tech.	0.4 ↗	0.6 ↗	1.1 ↘	1.6	2.0 ↗	1.2 ↘
Telecommunications	0.7	0.9 ↗	1.0	1.1 ↘	1.6 ↘	0.9 ↘
Digital communication	1.0 ↘	1.2 ↗	0.5 ↘	1.1 ↘	2.9 ↘	0.8 ↘
Basic communication	1.0 ↗	1.2 ↗	0.8 ↘	1.2 ↗	0.8 ↘	1.2 ↘
Computer technology	0.6 ↗	1.4 ↗	0.7 ↘	1.4	1.6 ↗	1.0 ↘
IT methods	0.6 ↘	1.4 ↘	0.9 ↗	0.5 ↘	2.0 ↗	0.8 ↘
Semiconductors	0.5	0.8 ↗	0.9 ↘	1.9 ↘	1.4 ↗	1.7 ↗
Optics	0.4 ↗	0.5 ↗	1.5 ↘	0.9 ↘	1.5 ↗	0.9 ↗
Measurement	1.3	1.0 ↘	1.0 ↗	0.5	0.6 ↗	1.1 ↘
Bio materials	0.9 ↘	1.3 ↘	1.0 ↗	0.3 ↘	0.2 ↗	1.9 ↗
Control	1.1 ↘	1.0 ↘	1.2 ↗	0.4 ↘	0.7 ↗	0.9 ↘
Medical technology	1.1 ↘	1.5 ↘	0.9	0.3	0.2 ↗	1.6 ↗
Organic chemistry	1.5 ↘	1.1 ↘	0.7	1.2 ↗	0.4 ↘	1.7 ↗
Biotechnology	1.1 ↘	1.3 ↘	0.8 ↗	0.4 ↘	0.2 ↗	2.3 ↗
Pharmaceuticals	0.8 ↘	1.6 ↘	0.7 ↗	0.3 ↗	0.4 ↗	2.5 ↗
Polymers	1.1 ↘	0.6 ↘	1.3 ↗	1.4 ↗	0.2 ↘	0.9 ↗
Food chemistry	1.4 ↘	0.9 ↘	0.7 ↗	0.7 ↗	0.1 ↗	2.7 ↗
Basic chemistry	1.0 ↘	1.1 ↘	1.1 ↗	0.9 ↗	0.2 ↘	1.1 ↗
Materials, metallurgy	1.1 ↘	0.7	1.3	1.2 ↗	0.4 ↗	0.7 ↗
Surface and coating	0.8	0.9 ↘	1.4 ↗	0.8 ↗	0.6 ↗	0.6 ↘
Micro- and nano-tech.	2.0 ↗	0.8 ↘	0.6 ↘	0.3 ↘	0.9 ↗	1.6 ↗
Chemical eng.	1.4 ↘	1.1 ↘	0.9 ↗	0.7 ↗	0.5 ↗	1.3 ↗
Environmental tech.	1.8 ↗	1.0 ↘	0.9 ↘	0.5 ↗	0.5 ↗	0.6 ↗
Handling & logistics	1.0 ↘	0.9 ↗	1.4 ↗	0.3 ↗	0.3 ↘	0.9 ↗
Machine tools	1.4 ↘	0.9 ↘	1.2 ↗	0.3 ↗	0.5 ↗	0.6 ↘
Engines, pumps, turbines	1.4 ↘	1.5 ↘	0.8	0.6 ↗	0.3 ↗	0.8 ↗
Textile and paper machines	0.6 ↗	0.5	2.0 ↗	0.1 ↘	0.1 ↘	0.4 ↗
Other special machines	1.5	1.2 ↗	1.0 ↘	0.4 ↗	0.2 ↗	0.8 ↗
Thermal devices	1.2 ↘	0.7 ↘	1.2 ↗	1.0 ↗	0.8 ↗	0.5 ↘
Mechanical elements	1.8	0.9 ↘	1.0 ↗	0.7 ↗	0.3 ↗	0.6 ↘
Transport	1.6 ↘	1.0	1.1 ↗	0.8 ↗	0.4 ↗	0.3 ↗
Furniture, games	1.3 ↘	0.6 ↘	1.0	1.0 ↗	1.5 ↗	1.0 ↘
Other consumer goods	1.4 ↘	0.9	0.7	1.7 ↗	1.0 ↗	1.1 ↗
Civil eng.	1.1 ↘	1.8	0.7 ↗	0.3 ↗	0.4	1.5 ↘

***Note**: IP5 patent families are allocated to technology fields using the taxonomy developed by the WIPO, as described in Annex C. The revealed technology advantage is defined in Box 3.3. Arrows denote more than 5% changes in the RTAs when compared with the 2010-12 levels.*

***Source**: JRC-OECD, COR&DIP© databases v.0 and v.3, 2021.*

Another striking feature of Table 3.2 concerns the distribution of RTA values in the different regions. For instance, top R&D investors based in Europe predominantly seem, as a whole, to be lacking technological specialisation in digital and related technologies, as suggested by low RTA values observed in *Telecommunications*, *Computer technologies*, *IT methods* and *Semiconductors*. Europe's strengths appear in *Micro- and nano-technologies* (RTA=2.0), *Environmental technologies* (1.8), *Transport* (1.6), and chemicals – e.g. *Organic* *chemistry* (1.5), *Food chemistry* (1.4), *Chemical engineering* (1.4). In turn, companies located in the United States are relatively more specialised in *Civil engineering* (1.8), *Pharmaceuticals* (1.6) and in ICT-related fields such as *Computer technology* and *IT methods* (1.4 each). On the other hand, Korea and China – both of which display a much narrower specialisation profile than Europe – concentrate most of their RTA in digital (and related) technologies. In particular, companies located in China specialise in *Digital communication* (2.9), the largest RTA in the five main regions.

In addition to displaying the RTA values of each region-technology pair for the 2016-18 period, Table 3.2 also allows a comparison with the technological specialisation profile of regions compared against that observed during the 2010-12 period. An arrow pointing upwards means that the region has increased its specialisation in a technology; conversely, an arrow pointing downwards tells us that RTA has decreased in a particular technology within a specific region. The cells in which no arrow appears mean that the RTA value for 2016-18 has remained within 5% of the value measured in 2010-12.

Table 3.3 reports the same indicator for trademarks, the trademark specialisation index, and compares the values of the specialisation index compiled for the different regions to those derived from the first edition of the JRC-OECD COR&DIP© database. Instead of looking at the technological specialisation of regions, this index reveals the specialisation in the different categories of goods and services protected by trademarks. On the one hand, Europe has the broader variety of trademark specialisations, having an index greater than 1 in 9 for the 13 goods and services categories. Japan shows a similar variety, with an index value greater than 1 in 8 categories. On the other hand, China, Korea and the United States appear to be specialised in fewer fields.

The largest trademark specialisations in Europe are observed in products related to *Transport* (1.7), *Chemicals* (1.4) and *Tools and machines* (1.4). In the United States, top R&D investors show the largest specialisation in trademarking products related to *Health, pharmaceuticals and cosmetics* (1.4). The portfolio of trademarks registered by Korean companies shows the largest specialisation in all region-product pairs, in particular *Tools and machines* (3.4), *Furniture and households goods* (3.1) and *ICT and audio-visual* (2.8). It is worth noting that China tends to register for almost three times more trademarks in *ICT and audio visual* than the world's average, featuring a specialisation index of 2.9 in that product group.

Table 3.3. Trademark specialisation of the world's top R&D investors, 2016-18

Trademark specialisation in goods and services and changes compared with 2010-12 levels, by groups of goods and services and geographical location of headquarters

Goods and services	Europe	United States	Japan	Korea	China	Rest of the World
Chemicals	1.4 ↗	1.0	0.9 ↘	0.1 ↘	0.1 ↘	1.2 ↗
Transport	1.7 ↘	0.6 ↘	0.9 ↘	0.9 ↘	1.3	0.7 ↗
Construction	1.1 ↘	0.6 ↘	1.3	0.1 ↘	0.5 ↘	0.5 ↘
Clothes, textiles and accessories	1.0 ↗	0.8 ↗	1.0 ↘	1.7 ↗	0.9 ↗	1.2 ↗
Tools and machines	1.4 ↗	0.9	0.8 ↘	3.4 ↗	1.2 ↗	0.6 ↘
Advertising and business services	1.1	0.7 ↘	1.1 ↗	0.4 ↘	1.2 ↗	1.0 ↘
Agricultural products	0.4	0.6 ↘	1.3 ↘	0.4 ↗	0.1 ↗	1.4 ↗
R&D	1.0 ↘	1.1 ↘	1.0 ↗	0.4 ↗	1.6 ↗	0.7 ↘
Health, pharmaceuticals and cosmetics	1.1 ↗	1.4 ↗	0.9 ↗	0.1	0.1 ↗	1.1 ↘
Furniture and household goods	1.0 ↘	0.5 ↘	1.2	3.1 ↗	0.9 ↗	0.4 ↘
ICT and audio-visual	0.9	1.1 ↗	0.8 ↘	2.8 ↘	2.9 ↘	0.8 ↘
Leisure and education	0.7 ↘	1.1 ↘	1.0 ↗	0.1 ↘	0.9 ↗	1.5 ↗
Hotels, restaurants and other services	0.8 ↘	0.5 ↘	1.4 ↗	0.1 ↘	0.7 ↗	0.6 ↘

Note: *Goods and services categories are described in Annex D. The trademark specialisation index is defined in Box 3.3. Arrows denote more than 5% changes in the trademark specialisation when compared with the 2010-12 levels.*
Source: *JRC-OECD, COR&DIP© databases v.0 and v.3, 2021.*

Box 3.3.

REVEALED TECHNOLOGICAL ADVANTAGE (RTA) AND TRADEMARK SPECIALISATION

Revealed technological advantage (RTA) indicators have been compiled at country or regional level to highlight the technological specialisation of top R&D investors (OECD, 2009). The RTA index is defined as the share of patents in a particular technological field in the patent portfolio of a given country or area over the total share of patents in the same technological field:

$$RTA_{it} = \frac{ps_{it} / \sum_t ps_{it}}{\sum_i ps_{it} / \sum_i \sum_t ps_{it}}$$

where ps_{it} represents the number of patents in a country or area i in technological field t, using fractional counts (see Box 3.1).

The index equals 0 when the country or area where the headquarters is based holds no patent in a given technology. Positive RTA values below 1 signal that the country or area does not display a strong specialisation in the technology (the share of the technology in the patent portfolio of the country is lower than that observed at global level). RTAs above 1 signal that the country or area is relatively specialised in the technology in question.

The trademark specialisation index follows the same definition, looking at the number of trademarks for a country or area i in product group t, using fractional counts.

4. THE ROLE OF THE WORLD'S TOP R&D INVESTORS IN CLIMATE-RELATED INNOVATION

This chapter discusses the role of the world's top R&D investors in climate-related innovation (measured by patent filings) and in the commercialisation of climate-related goods and services (measured by trademark filings). It reports the proportion of global climate-related innovation produced by top R&D investors and analyses which countries and sectors are most specialised in climate-related activities. It analyses the relationship between the digital and the green transition and presents a focus on key technologies for climate neutrality: renewable energy, electric vehicles and hydrogen.

HIGHLIGHTS

- The world's top R&D investors greatly contribute to global climate-related innovation: they are responsible for 70% patent applications in climate change mitigation or adaptation technologies (compared to 63% of patents in all technologies) and for more than 10% of global climate-related trademark applications (compared to just over 6% of total trademarks).

- The top R&D investors are clearly specialised in climate-related innovation and diffusion: more than 11% of their patents and 7% of their trademarks cover climate-related technologies or goods and services. These shares amount to 8% and 4%, respectively, for other applicants.

- While the top R&D investors apply for the vast majority of global climate-related patents, their innovations appear relatively more focused in terms of the spectrum of technologies they tackle compared to other applicants. Top R&D investors are key to maintaining the global pace of climate-related innovation, but breakthrough inventions have likely benefit substantially also from the complementary effort of other inventors, such as young firms.

- While some sectors have started to direct significant innovation efforts towards climate-related technologies (including electricity production, transportation and construction sectors), other sectors with growing impacts on global emissions, such as IT, still invest little in low-carbon innovation despite their large overall investment in R&D.

- Globally, some countries appear to be specialised in climate-related innovation (e.g. Denmark), while others specialise in the commercialisation of climate-related goods and services (e.g. China).

- Based on inventor location, Japan exhibits global leadership in low-carbon innovation. The EU27 and Korea clearly specialise in low-carbon innovation: their contribution to global low-carbon innovation is higher than their contribution to total innovation.

- Focusing on a specific subset of key technologies for climate neutrality, (i.e. renewable energy, electric cars, and hydrogen), the EU27 does not appear to be strongly specialised in any of these. Similarly, US-based firms are not specialised in any of the above climate-related technologies. In contrast, several Asian countries exhibit clear specialisation patterns resulting in the leaderships of Japan in hydrogen technologies, of Korea in electric cars and batteries and of China in renewable energy technologies.

- Looking at the potential contribution of digital technologies to the green transition, 20% of climate-related patents have a digital component (compared to 33% for patents across all technological fields). Most energy-intensive sectors make little use of ICT in their climate-related inventions, suggesting that there is untapped potential in the digital transformation to enable the green transition across many carbon-intensive sectors of the economy.

- More than 60% of climate-related trademarks are also ICT-related, which is much larger than for the average trademark filed (around 30%). Hence, while the combination of climate-related and ICT-related technologies is relatively rare as far as new patent filings are concerned, the use of digital solutions in addressing climate-related issues seems widespread at the commercialisation stage.

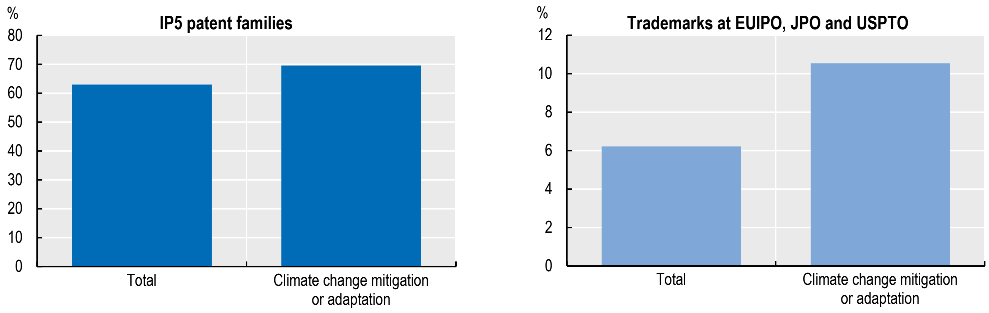
4.1 CONTRIBUTION TO GLOBAL CLIMATE-INNOVATION EFFORTS

Figure 4.1 shows the share of patents and trademarks applied for by the top 2 000 corporate R&D investors worldwide in 2016-18, both in general and for climate-related technologies, goods and services. The data clearly shows that the top R&D investors significantly contribute to climate-related innovation and activities. While they are responsible for filing 63% of the total IP5 patent families globally, this proportion reaches 70% for climate change mitigation or adaptation (CCMA) patents.[3] Similarly, the world corporate top 2 000 R&D investors own more than 10% of the CCMA trademarks[4], compared to just over 6% of the total trademarks.

The higher percentage ownership for CCMA than for total patents and trademarks indicates a specialisation towards climate-related technologies, goods and services. The concentration of global patenting activity in climate change mitigation or adaptation among the top R&D investors worldwide is particularly striking. This finding underlines the importance of technology diffusion towards other firms in the economy, particularly those located in low- and middle-income economies, where most of the increase in CO2 emissions is set to occur in the coming decades.

Figure 4.1. Share of patents and trademarks owned by the world's top R&D investors, 2016-18

In total patents and trademarks, and in climate change mitigation or adaptation



***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 4.2 confirms the specialisation towards climate-related technologies, goods and services of the top R&D investors by showing the percentage share of climate change

3 The analysis of innovation in climate change and mitigation or adaptation technologies presented in this chapter focuses on the patent portfolios of the top R&D investing companies and on the technological content of such portfolios. Related, though complementary issues, such as an estimate of the amount invested in specific technologies within a company or a region (see e.g. Fiorini et al., 2017; Pasimeni et al., 2019) are beyond the scope of the present analysis.

4 The study of "green trademarks" is a relatively new field, for a resent overview see Ghisetti. et al 2021.

mitigation and adaption patents and trademarks for the period 2016-18 for both the top R&D investors and other applicants. Among all IP5 patent applications globally, around 10% of patents concern climate change mitigation and adaptation technologies. This share is higher for the top 2 000 R&D investors, with more than 11% of their patents covering climate-related technologies. The top R&D performers' specialisation in climate-related technologies is apparent when comparing them with other applicants, who only dedicate around 8% of their patent portfolio to climate-related technologies.

This specialisation is also apparent when looking at climate-related trademarks. While the share of climate change mitigation and adaptation trademarks, across three major intellectual property offices (the EUIPO, JPO and USPTO), is around 4%, it is 7% for the top 2 000 R&D investors (and slightly less than 4% for other applicants).

Figure 4.2. Patents and trademarks for climate change mitigation and adaptation, 2016-18

Share in total IP5 patent families and trademarks at the EUIPO, JPO and USPTO,
world's top R&D investors and other applicants

***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Box 4.1.

CLIMATE CHANGE MITIGATION OR ADAPTATION (CCMA) PATENTS AND TRADEMARKS

CCMA PATENTS

The European Patent Office has developed a dedicated classification scheme for climate change mitigation and adaptation (CCMA) technologies (referred to as the Y02 tagging scheme of the Cooperative Patent Classification - CPC) to identify relevant inventions in global patent databases such as the EPO PATSTAT Global database (Angelucci, Hurtado-Albir & Volpe, 2018). This classification system is the result of an unprecedented effort by the EPO whereby patent examiners specialised in each technology, with the help of external experts, developed a tagging system for all patents ever filed at the EPO and in other patent offices that are related to CCMA technologies. It classifies millions of patent documents across a wide variety of climate change mitigation or adaptation technologies, including, to name a few examples, electric cars, renewable energy technologies, efficient combustion technologies (e.g. combined heat and power generation), carbon capture and storage, efficient electricity distribution (e.g. smart grids), hydrogen, energy-efficient lighting, energy storage (batteries, fuel cells), etc. It has become a widely used international standard for monitoring progress in climate-related technologies across the world.

The Y02 tagging system for 'Technologies or applications for mitigation or adaptation against climate change' comprises the following categories:

- Y02A – Technologies for adaptation to climate change,
- Y02B – Climate change mitigation technologies related to buildings, e.g. housing, house appliances or related end-user applications,
- Y02C – Capture, storage, sequestration or disposal of greenhouse gases [GHG],
- Y02D – Climate change mitigation technologies in information and communication technologies (ICT), i.e. information and communication technologies aiming at the reduction of their own energy use,
- Y02E – Reduction of greenhouse gas (GHG) emissions, related to energy generation, transmission or distribution,
- Y02P – Climate change mitigation technologies in the production or processing of goods,
- Y02T – Climate change mitigation technologies related to transportation,
- Y02W – Climate change mitigation technologies related to wastewater treatment or waste management.

The detailed breakdown of the Y02 class is available at:
https://worldwide.espacenet.com/patent/cpc-browser#!/CPC=Y02

CCMA TRADEMARKS

To identify and extract climate change mitigation or adaptation (CCMA) trademarks, the OECD has used a suitable CCMA vocabulary based on natural language processing (NLP) which is then used to extract the related trademarks. A comprehensive vocabulary consisting of terms related to CCMA was developed using (i) the descriptive content of the Y02 patent classification at subgroup level; (ii) a selective number of keywords and phrases from published academic literature (Garcia-Valero et al., 2021); (iii) the Elsevier list of Sustainable Development Goal (SDG) terms (Jayabalasingham et al., 2019); and (iv) topic model analyses from the description of the start-up activity operating in climate change-related sectors. The final vocabulary of relevant CCMA terms is then translated into the Japanese language, allowing CCMA trademarks from the EUIPO, JPO and USPTO to be classified.

In a final stage, trademarks are grouped into categories that match those available from the Y02 patent classification scheme described above. Further details on the construction of the CCMA vocabulary, including the trade-off faced between accuracy and recall, are described in Aristodemou et al. (forthcoming).

CCMA TECHNOLOGIES IN FOCUS

The three CCMA technologies in focus are: electric cars and batteries, renewables and hydrogen. These are composed of the following CPC classification codes:

- Electric cars and batteries – Y02E60/10, Y02T10/64, Y02T10/70, Y02T10/7072, Y02T10/72, Y02T90/10, Y02T90/12, Y02T90/14, Y02T90/16, Y02T90/167.
- Renewable energy – Y02E10.
- Hydrogen – Y02E60/30, Y02E60/32, Y02E60/34, Y02E60/36, Y02E60/50, Y02T90/40, Y02P90/40, Y02P90/45.

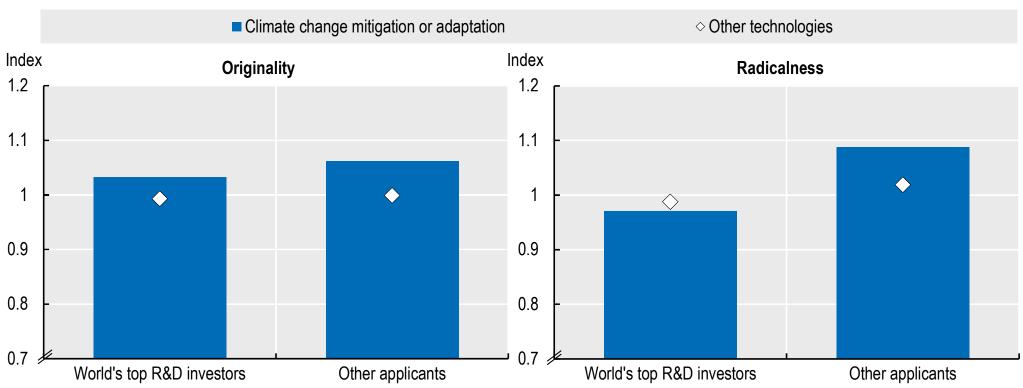
For further information on the CPC classification, see:
https://www.cooperativepatentclassification.org/index.

As shown in Figures 4.1 and 4.2, the world's corporate top R&D investors contribute to a large majority of climate-related innovation, as measured by patent filings. But do they file the same type of patents as other applicants? To investigate this, Figure 4.3 shows the average 'originality' and 'radicalness' of climate-related patents filed by top R&D investors and by other applicants in the economy. Originality and radicalness are formally defined in Box 4.2, but in a nutshell, the index of patent originality refers to the breadth of the technology fields on which a patent relies, with more original patents combining knowledge from a more diverse set of existing technological fields. The index of patent radicalness is a related concept and focuses on the use of 'external' knowledge in the creation of a patent (for example, a chemical patent building on previous non-chemical inventions).

Figure 4.3 shows that climate-related patents filed by the top corporate R&D investors score lower in terms of both the originality and the radicalness indexes than climate-related patents filed by other applicants in the economy. This suggests that top R&D investors may target a more focused, perhaps incremental, kind of innovation compared to other applicants who, on average, produce more radically new innovations, i.e. innovations drawing on a broader spectrum of technologies. Hence, while top R&D investors are key in terms of ensuring high rates of climate-related innovation, other applicants – in particular young and small firms – will be important for the emergence of potentially breakthrough inventions for the green transition to emerge. Different policies are needed to support these two very different groups of inventors.

Figure 4.3. Originality and radicalness of patents in climate change mitigation or adaptation technologies, 2016-18

Average values based on EPO and USPTO patents owned by the world's top R&D investors and by other companies



Note: *Data refer to originality and radicalness indices compiled on EPO and USPTO patents that are members of IP5 patent families owned by top R&D investors. To minimise IP office effects due to different citation procedures, indices for each patent set were normalised according to the average value of the indices observed in the two datasets.*
Source: *JRC-OECD, COR&DIP© database v.3, 2021.*

Box 4.2.

ORIGINALITY AND RADICALNESS OF PATENTS

The notions of originality and radicalness of patents reflect the extent to which the technological composition of patents differs from the prior art cited in patents. Two sets of indicators were constructed using information on cited patents provided in published patent documents (see Squicciarini, Dernis and Criscuolo (2013) for further methodological details). Citation measures are constructed on EPO patents and USPTO patents separately – to account for different citation procedures observed at the two offices. To minimise IP office-specific effects due to different citation procedures, indices for each patent set were normalised according to the average value of the indices observed in the two datasets.

ORIGINALITY INDEX

The patent originality index refers to the breadth of the technology fields on which a patent relies, using a measure first proposed by Trajtenberg et al. (1997) and expanded by Hall et al. (2001). It builds on the assumption that inventions relying on diversified knowledge sources may lead to original results (i.e. on patents belonging to a wide array of technology fields).

The originality index is constructed as:

$$Originality_P = 1 - \sum_{j}^{n_p} s_{pj}^{\;2}$$

where $\boldsymbol{s_{pj}}$ is the percentage of citations made by patent $\boldsymbol{p}$ to patent class $\boldsymbol{j}$ out of the $\boldsymbol{n_p}$ IPC codes contained in the patents cited by patent $\boldsymbol{p}$.

RADICALNESS INDEX

The radicalness index derives from the definition by Shane (2001). The radicalness of a patent is measured by the number of technology classes of cited patents in which the citing patent itself is not classified. The radicalness indicator is compiled as follows:

$$Radicalness_P = \sum_{J}^{n_p} CT_J / n_p \; ; \; IPC_{pJ} \neq IPC_p$$

where $\boldsymbol{CT_j}$ denotes the count of IPC subclasses $\boldsymbol{IPC_{pj}}$ of patent $\boldsymbol{j}$ cited in patent $\boldsymbol{p}$ that is not allocated to patent $\boldsymbol{p}$, out of $\boldsymbol{n}$ IPC subgroups in the backward citations counted. The higher the ratio, the more diversified the array of technologies upon which the patent relies.

4.2 TOP FIRMS AND SECTORS

Table 4.1 shows the top 50 patenting and trademarking companies for climate change mitigation and adaptation technologies and goods and services. It follows on from Table 3.1 and provides a glimpse into geographical and sectoral concentrations. The top 50 companies together account for more than 62% of climate change-related patents, and for more than 47% of climate change-related trademarks filed by the top 2 000 R&D investors globally. 19 companies own more than 1% of the total climate-related patents of the top R&D investors (shown in column "Share"), of which more than 60% operate in the 'Transport equipment' sector, suggesting the prominence of large automotive firms in CCMA innovation. The top five patenting companies each own more than 3% of the total climate-related patents of the top R&D investors. LG Chem (a company principally producing batteries) ranks first.

Looking at climate-related trademarks, 14 companies own more than 1% each of the total climate-related trademarks of the top R&D investors, with the top three owning more than 2%. LG Electronics is the highest-ranking climate-related trademarking company, followed by Mitsubishi Electric and Tata Motors.

Looking at the geographical spread, 62% of the top 50 patenting companies are located in Asia (with Japan representing 40% of the headquarters, followed by Korea with 12% and China with 10%), 18% are in the EU27 (with 10% in Germany alone) and 18% in the United States. Among the top 50 climate-related trademarking companies, 60% are located in Asia (with 42% in Japan alone and 12% in China), followed by 18% in Germany and 6% in the United States.

From a sectoral standpoint, the 'Transport equipment' sector is by far the most represented with 40% of the top 50 patenting companies (and 45% of patents owned by companies in the top 50), followed by the 'Computers & electronics' sector with 22%. Green trademark companies are more evenly spread between sectors, with 24% in 'Transport equipment', followed by 16% in 'Computers & electronics' and 12% in 'Electrical equipment.

Table 4.1. Top 50 patenting or trademarking companies in climate change mitigation and adaptation, 2016-18

IP5 patent families and trademarks at the EUIPO, JPO and USPTO

Patenting companies		Sector, ISIC Rev.4	Share	Rank
LG Chem	KOR	Chemicals	3.7	(1)
Ford Motor	USA	Transport equipment	3.5	(2)
General Electric	USA	Machinery	3.4	(3)
Toyota Motor	JPN	Transport equipment	3.2	(4)
Samsung Electronics	KOR	Computers & electronics	3.0	(5)
United Technologies	USA	Transport equipment	2.9	(6)
Toyota Industries	JPN	Transport equipment	2.9	(7)
Panasonic	JPN	Electrical equipment	2.6	(8)
Robert Bosch	DEU	Machinery	2.4	(9)
Volkswagen	DEU	Transport equipment	2.3	(10)
Sumitomo Electric	JPN	Basic metals	2.0	(11)
Denso	JPN	Transport equipment	1.9	(12)
Siemens	DEU	Machinery	1.7	(13)
Hitachi	JPN	Electrical equipment	1.2	(14)
BMW	DEU	Transport equipment	1.2	(15)
Hyundai Motor	KOR	Transport equipment	1.2	(16)
Rolls-Royce	GBR	Transport equipment	1.2	(17)
Kia Motors	KOR	Transport equipment	1.2	(18)
Honda Motor	JPN	Transport equipment	1.1	(19)
STMicroelectronics	NLD	Computers & electronics	0.9	(20)
Safran	FRA	Transport equipment	0.9	(21)
LG Electronics	KOR	Computers & electronics	0.9	(22)
Samsung SDI	KOR	Computers & electronics	0.9	(23)
Airbus	NLD	Transport equipment	0.9	(24)
Huawei Investment & Holding Co	CHN	Computers & electronics	0.9	(25)
Contemporary Amperex Technology	CHN	Electrical equipment	0.8	(26)
Qualcomm	USA	Computers & electronics	0.8	(27)
Canon	JPN	Machinery	0.7	(28)
Boeing	USA	Transport equipment	0.7	(29)
Boe Technology Group	CHN	Computers & electronics	0.7	(30)
IBM	USA	IT services	0.7	(31)
Mitsubishi Electric	JPN	Electrical equipment	0.6	(32)
Denka	JPN	Chemicals	0.6	(33)
Mitsubishi Heavy	JPN	Machinery	0.6	(34)
Sumitomo Chemical	JPN	Chemicals	0.6	(35)
General Motors	USA	Transport equipment	0.6	(36)
Honeywell	USA	Transport equipment	0.6	(37)
Intel	USA	Computers & electronics	0.6	(38)
Mazda Motor	JPN	Transport equipment	0.6	(39)
Shanghai Prime Machinery	CHN	Machinery	0.5	(40)
Continental	DEU	Rubber, plastics, minerals	0.5	(41)
Fanuc	JPN	Machinery	0.5	(42)
TDK	JPN	Computers & electronics	0.5	(43)
Nissan Motor	JPN	Transport equipment	0.5	(44)
Vestas Wind Systems	DNK	Electricity, gas & steam	0.5	(45)
GS Yuasa	JPN	Electrical equipment	0.4	(46)
Murata Manufacturing	JPN	Computers & electronics	0.4	(47)
TCL	CHN	Computers & electronics	0.4	(48)
Subaru	JPN	Transport equipment	0.4	(49)
Mitsubishi Motors	JPN	Transport equipment	0.4	(50)

Trademarking companies		Sector, ISIC Rev.4	Share	Rank
LG Electronics	KOR	Computers & electronics	6.7	(1)
Mitsubishi Electric	JPN	Electrical equipment	2.2	(2)
Tata Motors	IND	Transport equipment	2.1	(3)
Lixil Group	JPN	Basic metals	1.8	(4)
Volkswagen	DEU	Transport equipment	1.6	(5)
Panasonic	JPN	Electrical equipment	1.3	(6)
Baidu	CHN	IT services	1.3	(7)
Huawei Investment & Holding Co	CHN	Computers & electronics	1.2	(8)
Hitachi	JPN	Electrical equipment	1.2	(9)
Philips Lighting	NLD	Electrical equipment	1.2	(10)
Yamaha Motor	JPN	Transport equipment	1.0	(11)
Siemens	DEU	Machinery	1.0	(12)
Sekisui Chemical	JPN	Construction	1.0	(13)
Nio	CHN	Transport equipment	1.0	(14)
Tokyo Gas	JPN	Electricity, gas & steam	0.9	(15)
Sharp	JPN	Computers & electronics	0.9	(16)
Sky	GBR	Publishing & broadcasting	0.9	(17)
Koc	TUR	Finance & insurance	0.9	(18)
Daimler	DEU	Transport equipment	0.9	(19)
Nissan Motor	JPN	Transport equipment	0.9	(20)
Nippon Steel	JPN	Basic metals	0.8	(21)
Toyota Motor	JPN	Transport equipment	0.8	(22)
Nintendo	JPN	Other manufactures	0.8	(23)
Samsung Electronics	KOR	Computers & electronics	0.8	(24)
Osram Licht	DEU	Electrical equipment	0.7	(25)
Continental	DEU	Rubber, plastics, minerals	0.7	(26)
Sony	JPN	Computers & electronics	0.7	(27)
NTT	JPN	Telecommunications	0.7	(28)
Mitsubishi Heavy	JPN	Machinery	0.7	(29)
ABB	CHE	Electrical equipment	0.6	(30)
Peugeot (PSA)	FRA	Transport equipment	0.6	(31)
Koenig & Bauer	DEU	Machinery	0.6	(32)
Geely Automobile	CHN	Publishing & broadcasting	0.6	(33)
Chongqing Sokon Industry	CHN	Transport equipment	0.5	(34)
Durr	DEU	Machinery	0.5	(35)
Toshiba	JPN	Computers & electronics	0.5	(36)
Ford Motor	USA	Transport equipment	0.5	(37)
Kyocera	JPN	Computers & electronics	0.5	(38)
Electricité de France	FRA	Electricity, gas & steam	0.5	(39)
Fujitsu	JPN	Computers & electronics	0.5	(40)
Saint-Gobain	FRA	Rubber, plastics, minerals	0.5	(41)
General Motors	USA	Transport equipment	0.5	(42)
Vaillant	DEU	Law, accountancy & engineering	0.5	(43)
Vestas Wind Systems	DNK	Electricity, gas & steam	0.5	(44)
Mitsubishi Chemical	JPN	Chemicals	0.5	(45)
Alphabet	USA	IT services	0.5	(46)
Osaka Gas	JPN	Electricity, gas & steam	0.5	(47)
Mitsubishi Motors	JPN	Transport equipment	0.5	(48)
Vodafone	DEU	Telecommunications	0.4	(49)
Techtronic Industries	CHN	Machinery	0.4	(50)

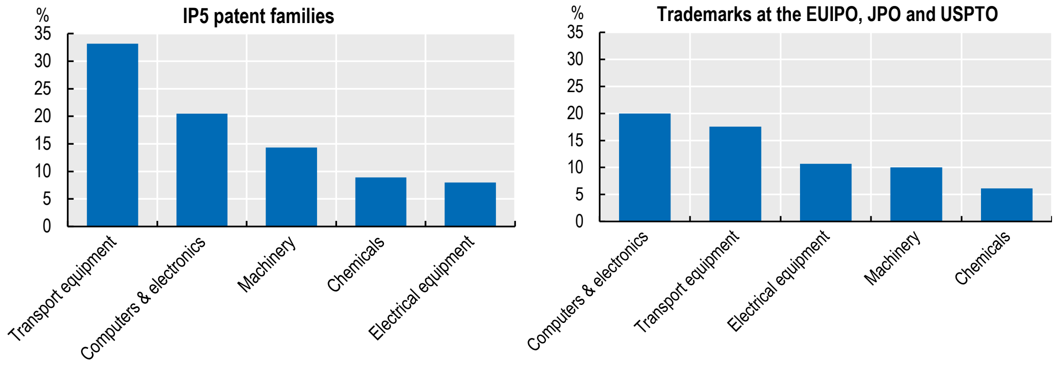
***Note**: Data relate to the share of the patents (respectively trademarks) related to climate change mitigation and adaptation owned by companies in total patents (respectively trademarks) in that domain owned by the top 2 000 corporate R&D sample in 2016-18.*

***Source**: JRC/OECD COR&DIP© database, v.3 2021.*

The ranking of sectors that emerges from the analysis of the top 50 firms shown in Table 4.1 is confirmed when looking at the whole sample. This suggests that the focus on the top companies in the sample produces a reasonable birds-eye view regarding the overall behaviour in the climate-related patenting and trademarking of top R&D investors across sectors. Figure 4.4 shows the distribution of climate-related patents and trademarks between the top five sectors for the period 2016-18. For patents, ‘Transport equipment’ ranks first, followed by ‘Computers & electronics’ and ‘Machinery’. For trademarks, ‘Computers & electronics’ ranks first, closely followed by ‘Transport equipment’ and ‘Electrical equipment’. The top five sectors are the same for both patents and trademarks, reflecting that firms innovating in these fields simultaneously file patents and trademarks to protect their inventions, goods and services.

Figure 4.4. Top five sectors with patents or trademarks for climate change mitigation or adaptation technologies, 2016-18

Share of sectors in patents or trademarks in the field, ISIC Rev. 4

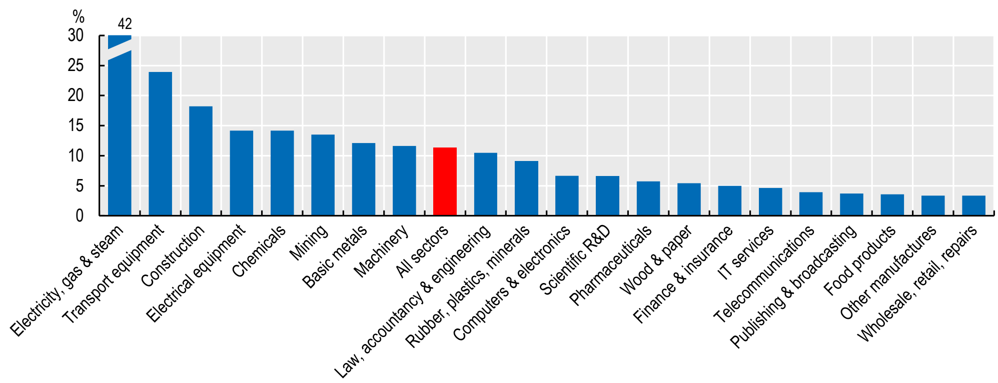


__Source__: JRC-OECD, COR&DIP© database v.3, 2021.

Figure 4.5 shows the proportion of climate-related patents in all IP5 patent families by sector. Compared with the total number of climate-related patents filed, the share of climate-related patents within each industry allows controlling for sector size. Figure 4.5 shows vast heterogeneity across sectors: while climate-related patents account for 42% of patents in the 'Electricity, gas & steam' sector and 24% of patents in the 'Transport equipment' sector, and 18% of patents in the 'Construction' sector, climate-related patenting represents less than 5% of the total patents in six sectors including 'IT services' and 'Telecommunications'. This shows that, while some sectors started to direct significant innovation efforts towards climate-related technologies following recent policy developments (with renewable energies and electric vehicles at the forefront of the policy agenda), other sectors with growing impacts on global emissions, such as IT (digital technologies, analytics and connectivity consume large amounts of energy), have yet to invest in low-carbon innovation.

Figure 4.5. Patents in technologies related to climate change mitigation or adaptation technologies, 2016-18

Share of total IP5 patent families by sector, ISIC Rev. 4



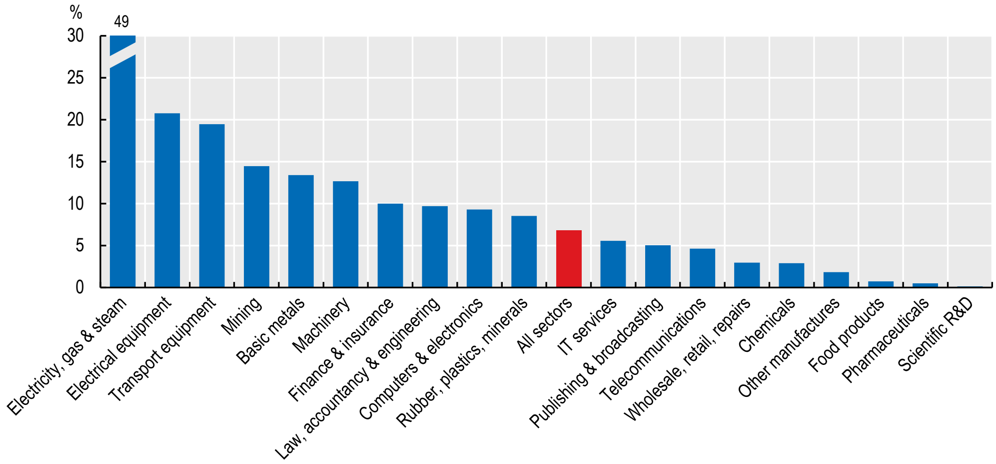
__Note__: Data relate to sectors with at least 20 company headquarters in the top 2 000 corporate R&D sample with patents in 2016-18.

__Source__: JRC-OECD, COR&DIP© database v.3, 2021.

Akin to Figure 4.5, Figure 4.6 shows the proportion of climate change mitigation or adaptation trademarks in the trademark portfolio of top R&D investors by sector. The 'Electricity, gas & steam' sector again ranks first, with close to 50% of the sector's trademark portfolio dedicated to climate-related goods and services. This sector is followed by the 'Electrical equipment' and 'Transport equipment' sectors with a share of around 20% of the total trademarks with a climate-related dimension. The focus on the development and deployment of renewable energy and electric vehicle technologies is again apparent from this figure.

Figure 4.6. Trademarks for climate change mitigation or adaptation goods and services, by sector, 2016-18

Share of total trademarks by sector, ISIC Rev. 4, EUIPO, JPO, and USPTO



***Note**: Data relate to sectors with at least 20 company headquarters in the top 2 000 corporate R&D sample with trademarks in 2016-18.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

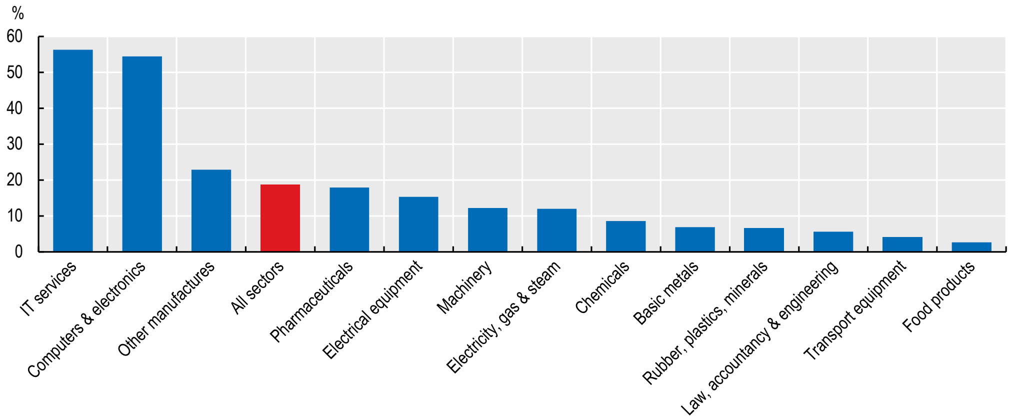
4.3 THE TWIN GREEN AND DIGITAL TRANSITIONS

While the high energy consumption associated with the use of digital technologies is a cause of legitimate concern, digital transformation has also been presented as a possible solution to the climate challenge. Information and communication technologies hold the promise of increasing energy and resource efficiency, both in electricity production and distribution (e.g. thanks to smart grids) as well as in industrial production. For example, smart manufacturing systems, additive manufacturing (3D printing), Internet of Things and artificial intelligence can all improve energy and material efficiency and contribute to the circularity of the manufacturing life cycle. In several industries, smart appliances, energy consumption feedback devices and energy management are already effectively reducing energy demand and associated carbon emissions.

In an attempt to investigate the potential contribution of digital technologies to the green transition, Figure 4.7 shows the share of climate-related patents by sector that rely on ICT-related technologies, as identified by previous OECD work (see Annex F). Averaging across all sectors, we find that almost 20% of climate-related patents have a digital component. For comparison, over the period 2013-16, digital-related patents accounted for around 33% of all IP5 patent families filed by OECD countries (OECD, 2019), suggesting that climate-related technologies are relatively less ICT-related than the average patent. The proportion of climate-related patents that are also ICT-related is unsurprisingly highest in IT sectors ('IT services' and 'Computers & electronics'), since these sectors are naturally providers of ICT-based low-carbon technologies for other sectors. This proportion is lower than 20% in other sectors, including 'Pharmaceuticals', 'Electrical equipment', 'Machinery', and electricity production. Highly energy-intensive sectors such as 'Chemicals', 'Basic metals' and 'Rubber, plastics, minerals' make little use of digital technologies in the new climate-related technologies they develop, suggesting that the digital transformation is not yet being put at the service of the green transition within many carbon-intensive sectors of the economy.

Figure 4.7. ICT-embedded in climate change mitigation or adaptation patents, by sector, 2016-18

Share of patents combining ICT and CCMA technologies in CCMA patents owned by the world's top R&D investors, ISIC Rev.4

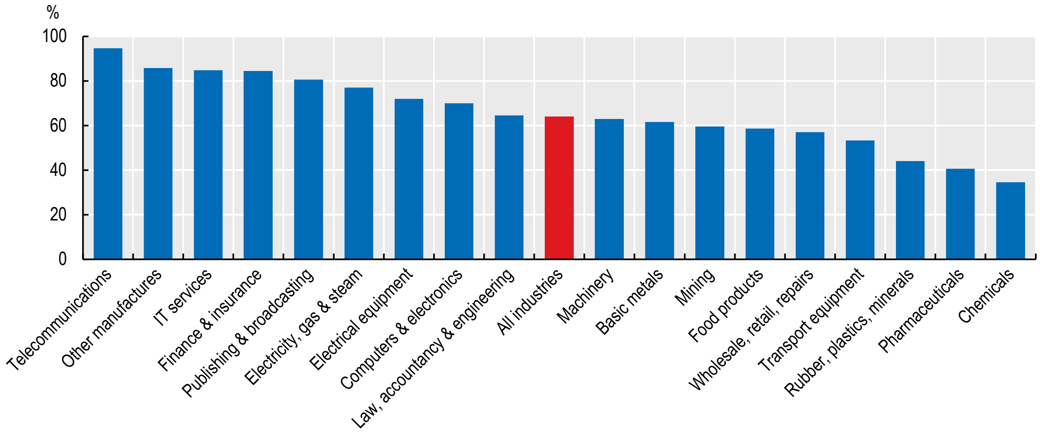


***Note**: Data relate to sectors with at least 20 company headquarters in the top 2 000 corporate R&D sample having filed for more than 50 patents in climate change mitigation or adaptation technologies in 2016-18. ICT-related technologies are defined using IPC codes listed in patents, following the taxonomy provided in Inaba and Squicciarini (2017). ICT-embedded in climate change mitigation or adaptation patents is identified by looking at the IPC codes in which Y02-tagged patents are also classified.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 4.8 shows the share of climate-related trademarks by sector that are also ICT-related. ICT-related trademarks are identified using a methodology developed by the OECD (OECD, 2019). On average, more than 60% of climate-related trademarks are also ICT-related. Not surprisingly, this share is highest in ICT-related sectors such as 'Telecommunications' or 'IT services', but it is also very high within most sectors. As a comparison, across all trademarks (not only climate-related) and all trademark applicants (not only the top R&D investors), ICT-related trademarks represent 37%, 24% and 36%, respectively, of all trademarks filed at the EUIPO, USPTO and JPO (OECD, 2019). Hence, while the combination of climate-related and ICT-related technologies is relatively rare as far as new patent filings are concerned (Figure 4.7), the use of digital solutions to address climate-related issues seems widespread at the commercialisation stage.

Figure 4.8. Trademarks combining ICT with climate change mitigation or adaptation, by sector, 2016-18

Share of trademarks for ICT and CCMA goods and services
in CCMA trademarks owned by the world's top R&D investors, ISIC Rev.4



***Note**: Data relate to sectors with at least 20 company headquarters in the top 2 000 corporate R&D sample with at least 50 trademarks in climate change mitigation or adaptation in 2016-18. ICT-related trademarks are defined using ICT-related trademarks referring to trademark application designating classes 9, 28, 35, 38, 41 and/or 42 of the Nice Classification, and containing ICT-related keywords in the goods and services description.*

***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

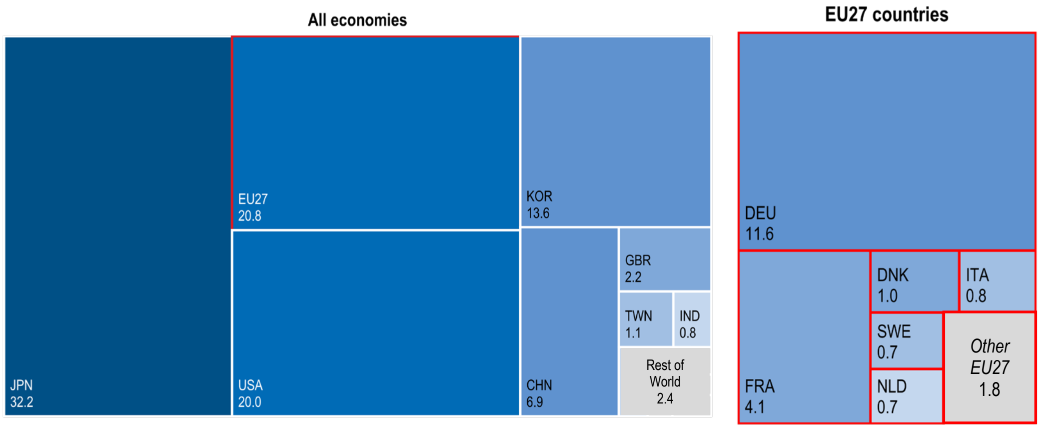
4.4 NATIONAL AND REGIONAL SPECIALISATION

Figure 4.9 shows the distribution of the location of inventors of climate-related patents filed by the top R&D investors between countries and regions. As in Figure 3.7, the location of inventors is determined by the address of the inventor as reported in published patent documents and fractional counts are used to assign patents to inventors located in different countries.

The top five economies in terms of location of inventive activity are Japan (32.2% of patents), the EU27 (20.8%), the United States (20.0%), Korea (13.6%) and China (6.9%). Germany accounts for over 50% of the inventor locations within the EU. Compared to the distribution of innovation activity shown in Figure 3.7, the EU makes a slightly larger contribution to global climate-related patents, but the main difference appears in Korea, whose contribution is 50% greater than that for patents across all technologies. China, on the contrary, appears relatively less specialised in climate-related innovation. The next figures explore this specialisation directly.

Figure 4.9. Location of inventors of climate change mitigation or adaptation technologies, 2016-18

Share of economies in patents owned by the world's top R&D investors



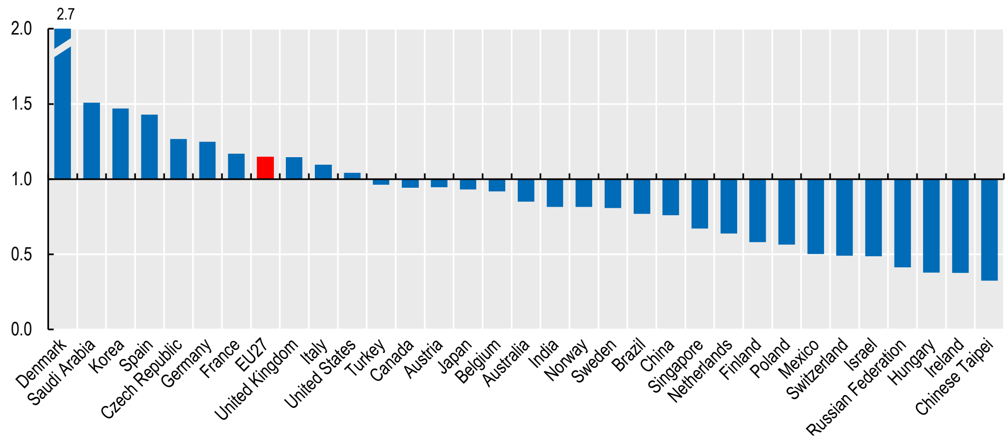
***Note**: Data relate to economies in which at least 250 patents owned by the world's top R&D investors were invented in 2016-18.*

***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 4.10 presents the revealed technological advantage (RTA) of economies in climate change mitigation or adaptation technologies (see Box 3.3 for the definition of RTA). Denmark ranks first, featuring a far higher RTA index value than all other economies. This reflects Denmark's strong specialisation in wind power innovation: wind power patents represent two thirds of all climate-related patents filed by top R&D investors headquartered in Denmark. Denmark is followed by Saudi Arabia, which primarily specialises in carbon emission reduction technologies in the chemicals sector and in hydrogen and battery technologies. Note, however, that despite an interesting specialisation, the contribution of top R&D investors located in Saudi Arabia to climate-related innovation remains marginal, with only 0.2% of global climate-related patents in the sample. Korea, Spain and the Czech Republic are next in the top 5 most specialised economies in climate-related innovation, thanks to specialisations in electric cars and batteries (Korea), renewables (Spain) and electric vehicles (Czech Republic). Among the major economic areas, the EU27 appears highly specialised in climate-related innovation, with an RTA above that of the United States, Japan, and China. This however hides heterogeneity within Europe, where Denmark, Spain, Germany, France and Italy are relatively specialised in climate-related innovation, while other countries (including Sweden, Finland, Poland, Hungary and Ireland) are not.

Figure 4.10. Revealed technological advantage in climate change mitigation or adaptation, 2016-18

Index based on inventor's location of patents

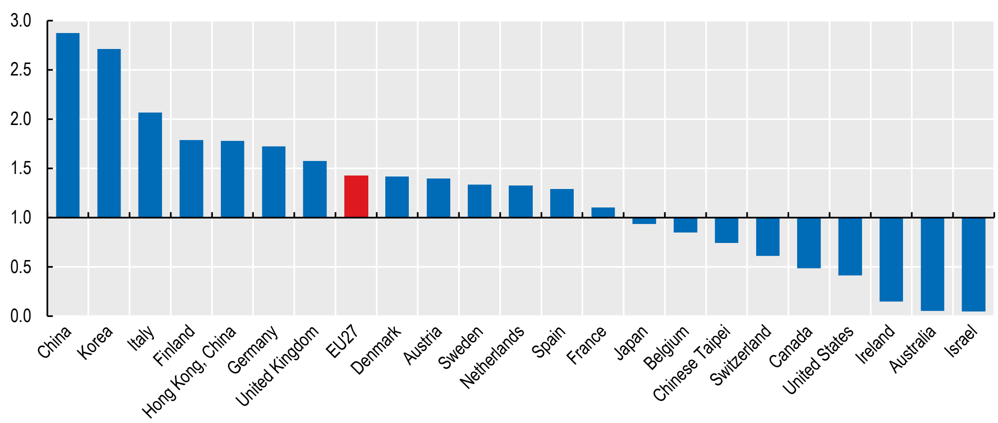


__Note__: Data relate to economies in which at least 250 patents owned by the world's top R&D investors were invented in 2016-18. The revealed technology advantage is defined in Box 3.3.
__Source__: JRC-OECD, COR&DIP© database v.3, 2021.

Figure 4.11 presents a trademark specialisation index for climate-related goods and services (see Box 3.3). This indicator is similar to the revealed technological advantage indicator for patents and indicates whether companies located in a particular economy file a greater (index >1) or smaller (index <1) proportion of climate-related trademarks than the global average. China ranks first, with a proportion of climate-related trademarks close to three times the global average. China-based companies appear relatively specialised in the commercialisation of electric cars and batteries (which represent almost 70% of climate-related trademarks filed by Chinese applicants). Korea-based firms clearly focus on renewable energy-related trademarks. Firms based in Italy and Hong Kong also specialise in electric vehicles, while Finnish firms focus on recycling and other goods and services related to the circular economy.

Figure 4.11. Trademark specialisation towards climate change mitigation or adaptation, 2016-18

Index based on EUIPO, JPO and USPTO trademarks, by location of applicants

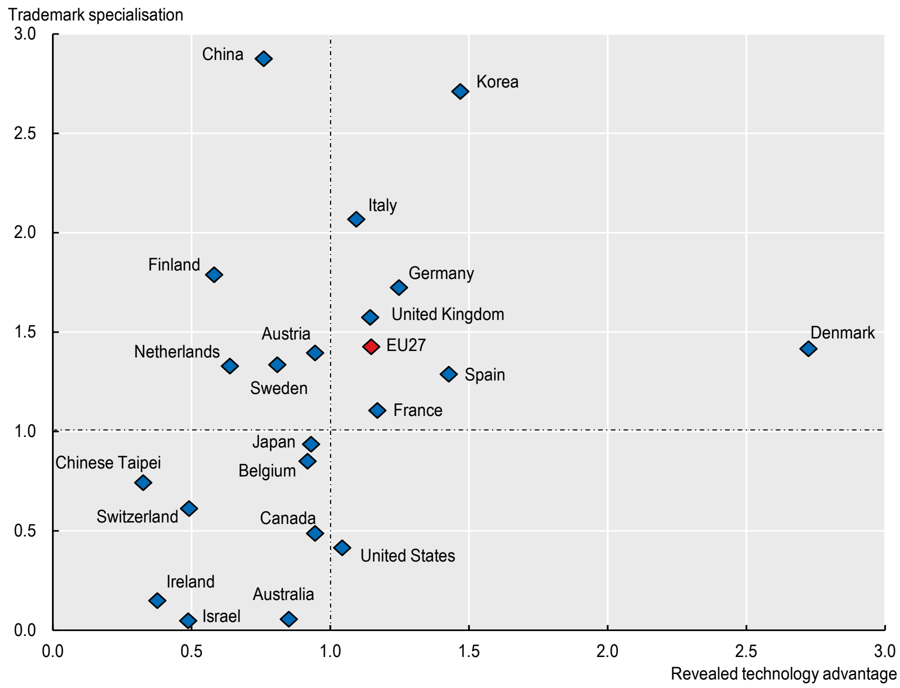


__Note__: Data relate to economies in which at least 250 trademarks owned by the world's top R&D investors were filed in 2016-18. The trademark specialisation index is defined in Box 3.3.
__Source__: JRC-OECD, COR&DIP© database v.3, 2021.

Comparing Figure 4.10 with Figure 4.11 suggests that some countries which appear to be specialised in climate-related innovation (as measured by patenting activity and the revealed technological advantage) are not specialised in technology commercialisation (as measured by trademarks and the trademark specialisation index), and vice versa. Figure 4.12 explores this further by plotting the relative technological advantage (x-axis) against the trademark specialisation index (y-axis). Overall, the figure shows a positive correlation between the two indices but also reveals considerable heterogeneity across countries. For example, companies based in China, Finland or Italy do not exhibit a strong innovation specialisation in climate-related technologies but they thrive in the commercialisation of climate-related goods and services, with a much higher-than-average rate of trademark filing. In contrast, companies based in Australia, Denmark and the United States enjoy a much better position on the innovation front than the commercialisation front.

Figure 4.12. Revealed technology advantage and trademark specialisation towards climate change mitigation or adaptation, 2016-18

Indices based on IP5 patent families and EUIPO, JPO and USPTO trademarks by location of patent inventors and trademark applicants



__Note__: Data relate to economies in which at least 250 patents and 250 trademarks owned by the world's top R&D investors were filed in 2016-18. The revealed technology advantage and trademark specialisation index are defined in Box 3.3.
__Source__: JRC-OECD, COR&DIP© database v.3, 2021.

4.5 A FOCUS ON SELECTED KEY TECHNOLOGIES

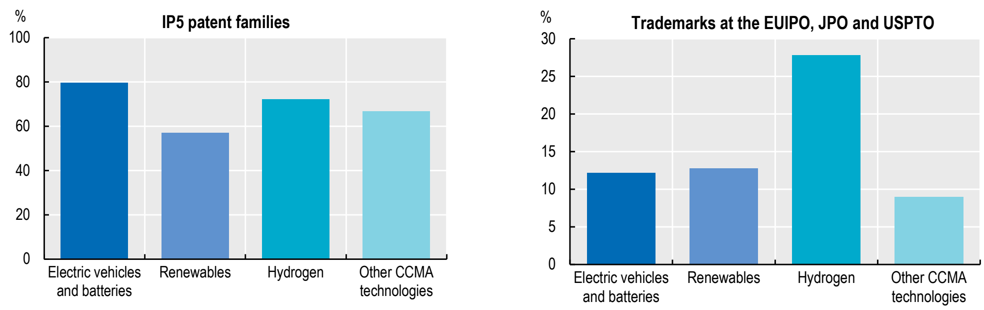
Section 4.2 suggests that the 'Electricity, gas and steam' and the 'Transport equipment' sectors are heavily engaged in climate-related innovation. This section dives deeper into the two technologies that are behind this trend: renewable energy technologies – electric vehicles and batteries. In addition, it provides a look into an additional technology that shows great promise for climate neutrality and has been the subject of recent policy attention: hydrogen. These three technologies account for the main mitigation measures in net-zero scenarios (IEA, 2021).

Figure 4.13 shows the share of patents and trademarks owned by the world's corporate top 2 000 R&D investors in 2016-18 in the three climate-related areas of focus. On average across all climate-related technologies, the top R&D investors represent 70% of climate-related patents (Figure 4.1). Figure 4.13 shows that this proportion reaches 80% for electric vehicles and batteries, and 72% for hydrogen patents. The contribution of the top R&D investors, however, is lower in renewable energies, where they own 57% of global patents.

Looking at trademarks, the top R&D investors' focus on those three promising technologies is visible. In electric vehicles and renewables, the share of global trademarks owned by the top R&D investors is close to the average across all climate-related technologies (10%), but the concentration is striking in hydrogen (28%). This finding may be related to the nature of hydrogen technologies, which are characterised by large economies of scale, critical infrastructure requirements and network effects.

Figure 4.13. Share of patents and trademarks owned by the world's top R&D investors in three technology focus areas, 2016-18

In total patents and trademarks in three focus technologies

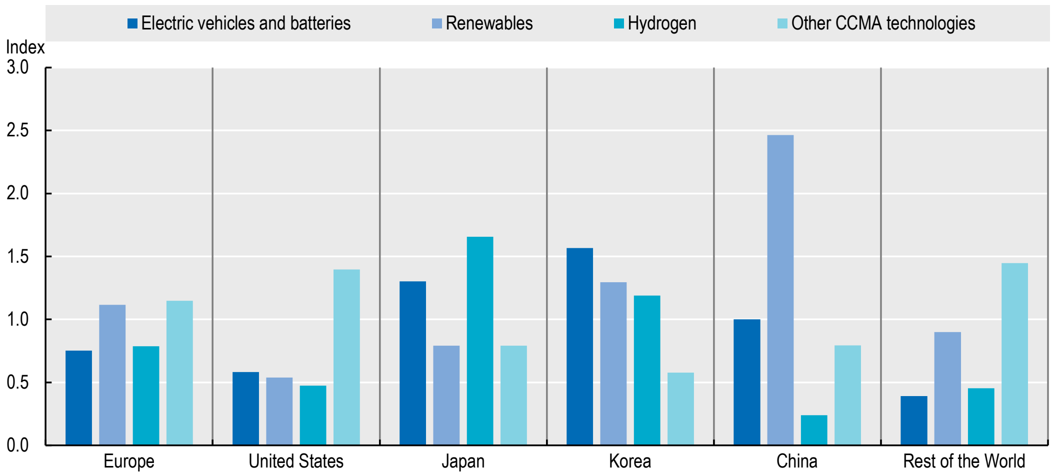


***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 4.14 focuses on relative regional specialisation in patenting by the top R&D investors in electric vehicles and batteries, renewables, hydrogen and all other climate-related technologies. We benchmark climate-related technologies against non-climate-related technologies. Alongside the three key technologies, we also add another category including all other climate-related technologies. The most specialised economy in terms of electric vehicles and batteries innovation is Korea, followed by Japan and China. China-based companies are the most specialised in renewable energy, followed by Korea and the EU27. Japan has the highest RTA index for hydrogen technologies, followed by Korea. In general, the European Union has a broad technological base contributing to these key technologies in equal measure. Relative to firms in other regions, US-based firms are not specialised in these key climate-related technologies.

Figure 4.14. Revealed technological advantage of regions, by specific technology areas, 2016-18

Index based on IP5 patent families in climate change mitigation or adaptation (CCMA), by location of inventors



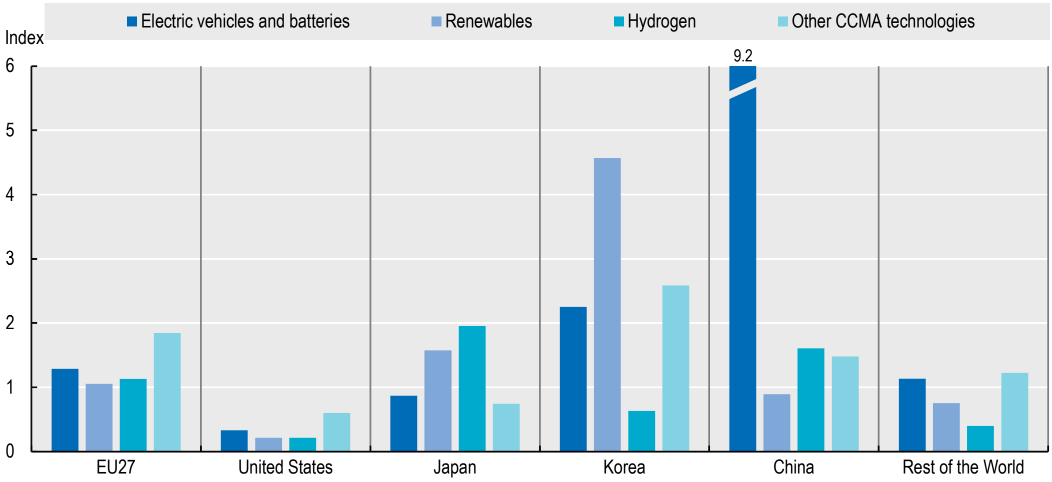
***Note**: Data refer to fractional counts of IP5 patent families in climate change mitigation or adaptation owned by the top R&D investors in 2016-18, according to the location of inventors. The revealed technology advantage is defined in Box 3.3.*
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

Figure 4.15 presents a trademark specialisation index focusing on the three key technologies and the main economies. Significant differences appear between countries. The focus of China-based firms on the commercialisation of electric vehicles (likely encouraged by strong policy support in this area) is striking from the figure, as is the focus of Korea-based firms on renewable energy. Meanwhile, Japan-based firms have a clear advantage in the commercialisation of hydrogen-based solutions. In contrast, Europe as a whole appears very balanced across all technologies, as do US-based firms (although these are, on average, not specialised in climate-related goods and services, as previously shown).

Comparing Figure 4.14 with Figure 4.15 again suggests interesting differences between countries, with Chinese firms filing large numbers of trademarks in electric vehicles compared to patents in this area; similarly, Korean firms are investing more heavily in the commercialisation stage of renewable energy compared to the innovation stage.

Figure 4.15. Trademark specialisation of regions, by specific technology areas, 2016-18

Index based on trademarks in climate change mitigation or adaptation (CCMA), by location of applicants



***Note**: Data refer to fractional counts of trademarks in climate change mitigation or adaptation owned by the top R&D investors in 2016-18, according to the location of applicants. The trademark specialisation index is defined in Box 3.3.*

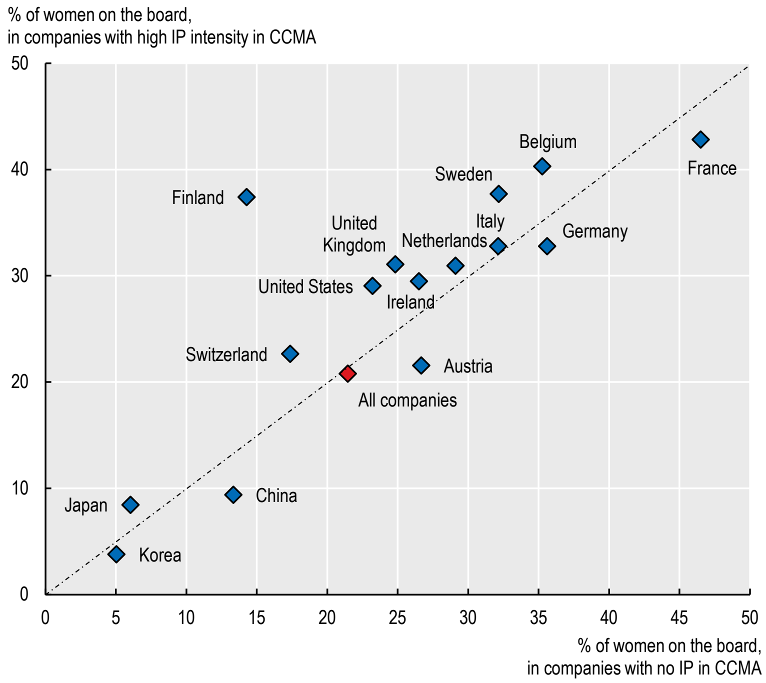
***Source**: JRC-OECD, COR&DIP© database v.3, 2021.*

4.6 GREEN AND GENDER – IS THERE A LINK?

CEOs and board of directors have a central role in shaping environmental strategy, and previous evidence has shown that higher shares of women on corporate boards and leadership teams correspond to better environmental practices at company level (Glass et al., 2016). Figure 4.16 reports on the share of women on boards of directors for two sets of firms: 'green' firms, which exhibit high intensity in the use of climate-related intellectual property assets (patents and trademarks), and 'brown' firms, which do not own any intellectual property assets in climate-related technologies, goods and services. In general, there is no systematic evidence that there are more women in the boardrooms of green firms compared to brown firms. Indeed, in only half of the countries – notably the Netherlands, Ireland, Sweden, the United Kingdom, the United States, Canada and India – the share of women in leadership positions is higher in green firms than in brown. The opposite is true in other countries.

Figure 4.16. Gender leadership in green vs brown companies, 2018

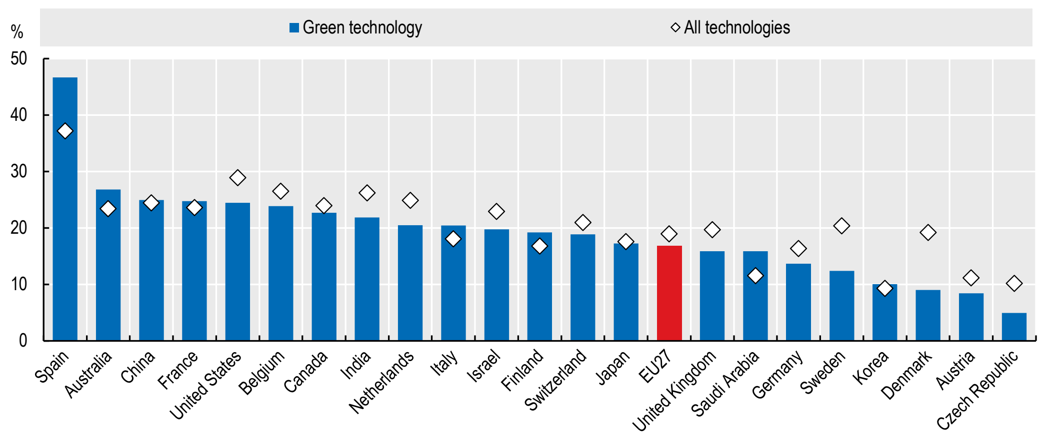
Average share of women on the board of directors, by country



Note: Data relate to countries with the largest number of companies with high IP intensity (patents and trademarks) relating to climate change mitigation or adaptation in 2016-18.
Source: Covalence SA and JRC-OECD, COR&DIP© database v.3, 2021.

Figure 4.17. Female inventorship of the world's top R&D investors in climate change mitigation or adaptation technologies, 2016-18

Share of IP5 patent families involving female inventors, by location of inventor



Note: Data relate to countries with at least 50 IP5 patent families in climate change mitigation or adaptation technologies. Figures for Korea and China are based on a subset of IP5 families (see Box 3.2).
Source: JRC-OECD, COR&DIP© database v.3, 2021.

Similarly, there is no strong evidence of a greater implication of female inventors in CCMA patents than in other technologies across countries. Figure 4.17 shows the proportion of patents with at least one female on the team of inventors for the total number of patents invented in a given country. In the United States and the EU27, the percentage computed for CCMA patents is lower than that observed for all technologies – although there is heterogeneity within the EU, with a higher proportion of female inventors in climate-related technologies observed in Spain and Italy. In other major economies – China, Japan and Korea – the proportion of female inventors in climate-related patents is similar to the proportion observed across all technologies.

LEARNING MORE

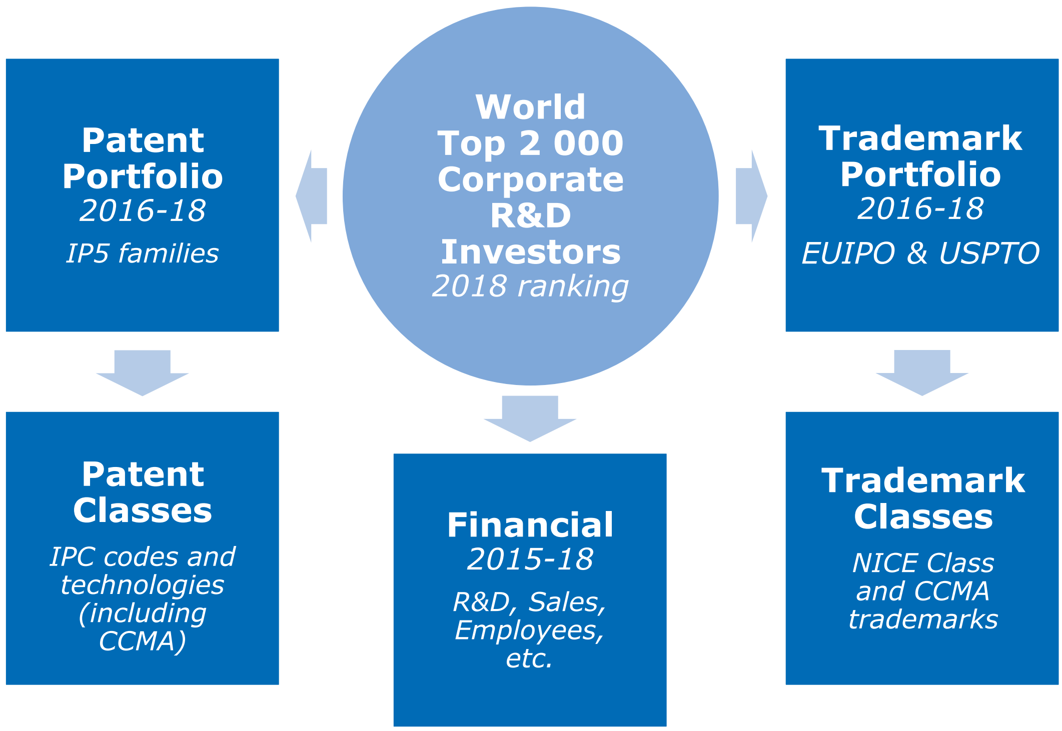
This fourth report on the innovative activity of the world's top 2 000 R&D investors is accompanied by the database on the IP bundle of top corporate R&D investors (*JRC-OECD, COR&DIP© database, v.3, 2021*).

The database (as well as its previous versions) is made available to researchers for free, upon request, to allow for further analysis in support of evidence-based policy-making.

The JRC-OECD COR&DIP© v.3 database contains information about the R&D activity and IP assets (i.e. patents and trademarks) of the top 2 000 corporate R&D investors worldwide. Information about the R&D investors comes from the 2019 *EU Industrial R&D Investment Scoreboard* (Hernández et al., 2019). Industrial property (IP) records are extracted from the EPO's *Worldwide Patent Statistical Database* (also known as PATSTAT, Spring 2021) in the case of patents, and from the EUIPO and the USPTO in the case of trademarks (note that raw data on JPO trademarks cannot be disseminated).

Raw data are made available on a secure server through the OECD website at http://oe.cd/ipstats, and are accompanied by a short technical document.

The structure of the JRC-OECD COR&DIP© database v.3, 2021 is detailed below.



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APPENDIX

ANNEX A. LIST OF INDUSTRIES

38 industries, ISIC Revision 4	
01-03	Agriculture
05-09	Mining
10-12	Food products
13-15	Textiles & apparel
16-18	Wood & paper
19	Coke & petroleum
20	Chemicals
21	Pharmaceuticals
22-23	Rubber, plastics, minerals
24-25	Basic metals
26	Computers & electronics
27	Electrical equipment
28	Machinery
29-30	Transport equipment
31-33	Other manufactures
35	Electricity, gas & steam
36-39	Water, sewerage & waste
41-43	Construction
45-47	Wholesale, retail, repairs
49-53	Transport services
55-56	Hotels & food services
58-60	Publishing & broadcasting
61	Telecommunications
62-63	IT services
64-66	Finance & insurance
68	Real estate
69-71	Law, accountancy & engineering
72	Scientific R&D
73-75	Other business services
77-82	Admin & support services
84	Public admin and defense
85	Education
86	Health services
87-88	Care & social work
90-93	Arts & entertainment
94-96	Other services

Source: OECD, STAN industry list, http://oe.cd/stan*, 2012.*

ANNEX B. R&D EXPENDITURE AND WOMEN ON BOARDS OF DIRECTORS

Pearson's correlation coefficients	
Basic metals	-0.104
Chemicals	0.109
Computers & electronics	0.096
Construction	-0.315
Electrical equipment	0.028
Electricity, gas & steam	0.180
Finance & insurance	0.124
Food products	0.220
IT services	0.085
Machinery	0.123
Mining	-0.002
Other manufactures	0.135
Pharmaceuticals	0.197 *
Publishing & broadcasting	0.245 *
Rubber, plastics, minerals	0.323
Scientific R&D	0.180
Telecommunications	0.127
Transport equipment	0.236 *
Wholesale, retail, repairs	-0.148

** statistically significant at $p < 0.05$*

Source: Covalence SA and JRC-OECD, COR&DIP© database v.3, 2021.

ANNEX C. LIST OF WIPO TECHNOLOGY FIELDS

Electrical engineering	
1	Electrical machinery, apparatus, energy
2	Audio-visual technology
3	Telecommunications
4	Digital communication
5	Basic communication processes
6	Computer technology
7	IT methods for management
8	Semiconductors
Instruments	
9	Optics
10	Measurement
11	Analysis of biological materials
12	Control
13	Medical technology
Chemistry	
14	Organic fine chemistry
15	Biotechnology
16	Pharmaceuticals
17	Macromolecular chemistry, polymers
18	Food chemistry
19	Basic materials chemistry
20	Materials, metallurgy
21	Surface technology, coating
22	Micro-structural and nano-technology
23	Chemical engineering
24	Environmental technology
Mechanical engineering	
25	Handling
26	Machine tools
27	Engines, pumps, turbines
28	Textile and paper machines
29	Other special machines
30	Thermal processes and apparatus
31	Mechanical elements
32	Transport
Other fields	
33	Furniture, games
34	Other consumer goods
35	Civil engineering

Source: WIPO, IPC concordance table, http://www.wipo.int/ipstats/en/index.html*, February 2016.*

ANNEX D. AGGREGATION OF NICE CLASSES BY FIELDS

1. Chemicals	
	1. Chemical goods
	2. Paints and colorants
	4. Oils and fuels
2. Transport	
	12. Vehicles
	39. Transport and packaging
3. Construction	
	1. Metals
	17. Rubber and plastics
	19. Building materials
	27. Carpets and floor covers
	37. Building services
4. Clothes, textiles and accessories	
	22. Fibrous products
	23. Yarns and threads
	24. Textiles
	25. Clothing and footwear
	26. Decorations
5. Tools and machines	
	7. Machineries
	8. Hand tools
6. Advertising and business services	
	35. Business and advertising
	36. Insurance and finance
	45. Legal and personal services
7. Agricultural products	
	29. Food
	30. Condiments and cereals
	31. Animals and grains
	32. Low and non alcohol drinks
	33. Alcoholic drinks
	34. Tobaccos
8. R&D	
	42. R&D and software
9. Health, pharmaceuticals and cosmetics	
	3. Cleaning products
	5. Pharmaceutical products
	10. Medical instruments
	44. Medical and hygiene services

10. Furniture and household goods	
	11. Lightening and heating
	20. Furniture
	21. House utensils
11. ICT and audio-visual	
	9. Instruments & computers
	38. Telecommunications
12. Leisure and education	
	13. Firearms
	15. Musical instruments
	16. Papers and packaging
	28. Games
	41. Education and sport
13. Hotels, restaurants and other services	
	40. Treatment of materials
	43. Food, drink and accommodation

Source: OECD, groupings based on WIPO, Nice classification, http://www.wipo.int/classifications/nice/en/

ANNEX E. LINKING COMPANY DATA TO IP DATA: A MATCHING APPROACH

Characterising the portfolio of IP rights of companies requires raw data to be linked with enterprise data. For this purpose, the names of the top corporate R&D investors and their subsidiaries were matched to the applicant names provided in published patent and trademark documents.

LINKING TO PATENT APPLICANTS

A new matching procedure developed internally by the JRC was employed to independently link the firm-level data on the top corporate R&D investors with the applicant information contained in the Spring 2021 edition of the EPO PATSTAT Global database. This new algorithm aims to take full advantage of the available information concerning patent applicants to improve its accuracy in the entity recognition exercise. For instance, the algorithm integrates as inputs the name, aliases and all the available geographical information (including freeform addressees, when available) of the top R&D investors and their subsidiaries, and of the patent applicants to be matched.

The entities from the two databases are then matched through a two-step process.

- The first step involves selecting candidates for matching through Elastic search in order to make a subsequent pairwise comparison between entities computationally tractable. The necessity for this initial step stems from the sheer size of the databases to be matched (around one million subsidiaries and tens of millions of applicant names).

- In the second step, the entity pairs returned from the first step are passed through a trained classifier, which establishes which firm-applicant pairs are matches.

The results of the matching are further expanded by taking advantage of the presence, within the PATSTAT database, of cleaned applicant name information, which allows the patent applicant identifiers associated with subsidiary firms via the matching algorithm to be linked to other patent applicant identifiers and, consequently, a larger number of patent applications and families. Patent data used for this report was complemented with records matched at the OECD, following the procedure described below.

LINKING TO TRADEMARK APPLICANTS

The matching of the top R&D investors and their subsidiaries to trademark applicants was carried out on a country-by-country basis using a series of algorithms contained in the Imalinker (Idener Multi Algorithm Linker) system available at the OECD. The matching exercise is implemented over a number of key steps:

- the names of top corporate R&D investors and subsidiaries and of the firms included in the trademark data are harmonised separately using country-specific 'dictionaries'. These aim to deal with legal entity denomination (e.g. 'Limited' and 'Ltd'), common names and expressions as well as phonetic and linguistic rules that might affect how enterprise names are written;

- in a second step, a series of string-matching algorithms – mainly token-based and string-metric-based, such as token frequency matching and Levenshtein (1965) and Jaro-Winkler (Winkler, 1999) distances – are used to compare the harmonised names from the two datasets and provide a matching accuracy score for each pair. The precision of the match, which depends on minimising the number of false positive matches, is ensured through the selection of pairs of company names / trademarks made by owners on the basis of high-score thresholds imposed on the algorithm;

- a post-processing stage is manually handled by reviewing matched pairs, assessing the proportion of non-matched firms (possibly false negatives) and identifying new matches on a case-by-case basis by correcting and augmenting dictionaries and through manual searches.

IP portfolios presented in the report are aggregated at headquarters level: patents or trademarks owned by a given subsidiary are fully attributed to the parent company of the group, regardless of the precise structure of the group. In practical terms, this choice means that the patents, trademarks and publications of a certain subsidiary are attributed to the parent R&D performer in all circumstances, and irrespective of the exact share of the affiliate that the parent company owns.

Overall, 78% of the top R&D-performing companies could be matched to at least one patent applicant in the patent database, either directly or through one or more subsidiary firms. The same overall matching rate was observed for trademark applications (86%).

ANNEX F– DEFINITION OF ICT-RELATED PATENTS AND TRADEMARKS

ICT-RELATED PATENTS:

Patents in ICT related technologies are identified using classes of the International Patent Classification (IPC) in which patents are classified. ICT technologies are subdivided into 13 areas defined with respect to the specific technical features and functions they are supposed to accomplish (e.g. mobile communication), and details provided about the ways in which technologies relate to ICT products.

Technology area	Sub area	IPC
1. High speed network	Digital communication technique	H03K, H03L, H03M, H04B1/69-1/719, H04J, H04L (excluding H04L9, H04L12/14) *H04L9, *H04L12/14
	Exchange, selecting	H04M3-13,19,99, H04Q
	Others	H04B1/00-1/68, H04B1/72-1/76, H04B3-17 (excluding H04B1/59, H04B5, H04B7), H04H *H04B1/59, *H04B5, *H04B7
2. Mobile communication	-	H04B7, H04W (excluding H04W4/24, H04W12) *H04W4/24, *H04W12
3. Security	Cyphering, authentication	G06F12/14, G06F21, G06K19, G09C, G11C8/20, H04K, H04L9, H04M1/66-665, H04M1/667-675, H04M1/68-70, H04M1/727, H04N7/167-7/171, H04W12
	Electronic payment	G06Q20, G07F7/08-12, G07G1/12-1/14, H04L12/14, H04W4/24 *G06Q30/02
4. Sensor and devices network	Sensor network	G08B1/08, G08B3/10, G08B5/22-38, G08B7/06, G08B13/18-13/196, G08B13/22-26, G08B25, G08B26, G08B27, G08C, G08G1/01-065 *G06F17/40, *H04W84/18
	Electronic tag	H04B1/59, H04B5 *G01S13/74-84, *G01V3, *G01V15
	Others	*H04W84/10
5. HIgh speed computing	-	G06F5, G06F7, G06F9, G06F11, G06F13, G06F15/00, G06F15/16-15/177, G06F15/18, G06F 15/76-15/82
6. Large-capacity and high speed storage	-	G06F3/06–3/08, G06F12 (exclude G06F12/14), G06K1-7, G06K13, G11B, G11C (exclude G11C8/20), H04N5/78-5/907 *G06F12/14, *G11C8/20
7. Large-capacity information analysis	Database	G06F17/30, G06F17/40
	Data analysis, simulator, management	G06F17/00, G06F17/10-17/18, G06F17/50, G06F19, G06Q10, G06Q30, G06Q40, G06Q50, G06Q90, G06Q99, G08G (exclude G08G1/01-065, G08G1/0962-0969) *G08G1/01-065, *G08G1/0962-0969
8. Cognition and meaning understanding	-	G06F17/20-17/28, G06K9, G06T7, G10L13/027, G10L15, G10L17, G10L25/63,66 *G06F15/18

Technology area	Sub area	IPC
9. Human interface	-	H04M1 (exclude H04M1/66-665, H04M1/667-675, H04M1/68-70, H04M1/727), G06F3/01-3/0489, G06F3/14-3/153, G06F3/16, G06K11, G06T11/80, G08G1/0962-0969, G09B5, G09B7, G09B9 *H04M1/66-665, *H04M1/667-675, *H04M1/68-70, *H04M1/727, *G06F17/50, *G06K9, *G06T11, *G06T13, *G06T15, *G06T17-19
10. Imaging and sound technology	Imaging technique	H04N (excluding H04N5/78-5/907, H04N7/167-7/171), G06T1-9 (excluding G06T7), G06T11 (excluding G06T11/80), G06T13, G06T15, G06T17-19, G09G *H04N5/78-5/907, *H04N7/167-7/171, *G06T7, *G06T11/80
	Sound technique	H04R, H04S, G10L (excluding G10L13/027, G10L15, G10L17, G10L25/63,66) *G10L13/027,* G10L15, *G10L17, *G10L25/63,66
11. Information communication device	Electronic circuit	H03B, H03C, H03D, H03F, H03G, H03H, H03J Cable and conductor H01B11
	Cable and conductor	
	Semi conductor	H01L29-33, H01L21, 25, 27, 43-51
	Optic device	G02B6, G02F, H01S5
	Others	B81B7/02, B82Y10, H01P, H01Q
12. Electronic measurement	-	G01S, G01V3, G01V8, G01V15
13. Others	Computer input-output	G06F3/00, G06F3/05, G06F3/09, G06F3/12, G06F3/13, G06F3/18
	Other related technique	G06E, G06F1, G06F15/02, G06F15/04, G06F15/08-15/14, G06G7, G06J, G06K15, G06K17, G06N, H04M15, H04M17 +

Note: An asterisk precedes those IPC codes that are relevant, although of secondary importance, for the technology area considered, and that may conversely be key in other ICT areas.
Source : Inaba and Squicciarini (2017).

DIGITAL TRADEMARKS:

Digital trademarks are identified using combinations of classes of the international classification of goods and services, the Nice Classification, and a list ICT related keywords (or combination of keywords) searched in the description of trademarks.

Nice classes	Description
9	Scientific, nautical, surveying, photographic, cinematographic, optical, weighing, measuring, signalling, checking (supervision), life-saving and teaching apparatus and instruments; apparatus and instruments for conducting, switching, transforming, accumulating, regulating or controlling electricity; apparatus for recording, transmission or reproduction of sound or images; magnetic data carriers, recording discs; compact discs, DVDs and other digital recording media; mechanisms for coin-operated apparatus; cash registers, calculating machines, data processing equipment, computers; computer software; fire-extinguishing apparatus.
28	Games, toys and playthings; video game apparatus; gymnastic and sporting articles; decorations for Christmas trees.
35	Advertising; business management; business administration; office functions.
38	Telecommunications.
41	Education; providing of training; entertainment; sporting and cultural activities.
42	Scientific and technological services and research and design relating thereto; industrial analysis and research services; design and development of computer hardware and software.

Source: WIPO, Nice classification, http://www.wipo.int/classifications/nice/en/

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