World Top R&D Investors: *Industrial Property strategies in the Digital Economy*

European Commission

OECD
BETTER POLICIES FOR BETTER LIVES

EUR 28656 EN

Please, cite this publication as:

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

This is a joint publication of the European Commission's Joint Research Centre (JRC) and the Organisation for Economic Co-operation and Development (OECD)

Acknowledgments:

The authors are grateful to Alessandra Colecchia (OECD), Fernando Hervás Soriano (JRC) and Alexander Tübke (JRC) for steering this initiative and for providing input and feedback throughout the development of the report.

European Commission
Joint Research Centre
Directorate Growth & Innovation

Contact information
Address: Edificio Expo. c/ Inca Garcilaso, 3. E-41092 Seville (Spain)
E-mail: JRC-B3-SECRETARIAT@ec.europa.eu
Tel.: +34 954488318
Fax: +34 954488300
http://www.ec.europa.eu/jrc

Organisation for Economic Co-operation and Development (OECD)
Directorate for Science, Technology and Innovation

Contact information
Address: 2, rue André Pascal 75775 Paris CEDEX 16 (France)
Tel : 33(0)1 45 24 18 00
www.oecd.org/sti

European Commission
JRC107015
EUR 28656 EN

ISBN 978-92-79-69699-2 (PDF)
ISBN 978-92-79-69700-5 (print)

ISSN 1831-9424 (online)
ISSN 1018-5593 (print)

doi:10.2760/837796 (online)
doi:10.2760/861062 (print)

Luxembourg: Publications Office of the European Union

Foreword

The speed, scale and scope of the digital transformation and the widespread use of digital technologies in most aspects of our daily lives are changing the way we work, innovate, produce, interact and live. Knowledge flows almost instantaneously and digitalised information can be infinitely replicated, making the exploitation of knowledge a key factor for competitiveness. At the same time, changes at the local level may have global implications and innovation ecosystems become more and more global.

These dynamics challenge policy making, and call for understanding the drivers of change, detecting trends in a timely fashion, and acting in a coordinated manner. The internet of things, digital manufacturing and 3D printing, industry 4.0 and big data are all components and drivers of the digital transformation, but the ways in which this new technological revolution will transform industries, countries and societies remain difficult to fully anticipate. As we become increasingly aware of the opportunities and the challenges of the digital economy, we also need to better understand how these technologies are forged and to identify the key players in such changes.

The original data and statistics on the innovation output of the world's top corporate R&D investors presented in this report and its focus on digital technologies represent an important step towards this direction. It results from a long-term collaboration between the European Commission's Joint Research Centre and the Organisation for Economic Co-operation and Development, and their joint efforts to provide up-to-date comparable data and state-of-the-art indicators and analysis.

This report is directed at a number of stakeholders, including policy makers, industry representatives, practitioners and the scientific community. By exploiting information on patents, trademarks and designs, this work sheds light on the top R&D investors worldwide in the digital economy, their innovative and creative activities and their branding strategies. It is accompanied by a publicly available database that can be used for further analysis in support of evidence-based policy making.

Vladimir Šucha

Director General, Joint Research Centre
European Commission

Andrew W. Wyckoff

Director
Directorate for Science, Technology and Innovation
Organisation for Economic Co-operation and Development

Contents

Reader's guide

Acronyms

EPC	European Patent Convention
EPO	European Patent Office
EU28	European Union
EUIPO	European Union Intellectual Property Office
EUTM	EU Trademarks
ICT	Information and communication technology
IP(R)	Industrial Property (Rights)
IP5	Five IP offices (EPO, JPO, KIPO, SIPO and USPTO)
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
RCD	Registered Community Design
SIPO	State Intellectual Property Office of the People's Republic of China
TM	Trademark
USPTO	United States Patent and Trademark Office
WIPO	World Intellectual Property Organization

Abbreviations

In selected figures, the ISO codes for countries or economies are reported.

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

Highlights

Top R&D investors lead global ICT development

Top 2000 R&D investors worldwide play a leading role in the development of ICT-related technologies and designs. They own about 75% and 60% of global ICT-related patents and designs, respectively.

The headquarters of world top R&D investors, especially those operating in ICT industries, are concentrated in few economies, including the United States, Japan and China. Conversely, the geographical distribution of their affiliates shows a less concentrated pattern.

On average, top R&D investors have affiliates located in about 21 economies which are active in about 9 different industries. However, on average, about 21% of top R&D investors' affiliates operate in ICT industries

'Computer & electronics' is extremely IP intensive

Companies in the 'Computer & electronics' industry are, by far, the most reliant on IP rights and account for about 1/3 of total IP filings of top R&D investors. Other IP-intensive industries include 'Transport equipment', 'Machinery' and 'Chemicals'.

Top R&D investors' patenting and design behaviours are more similar than trademark ones. The top 250 R&D investors account for 67% of patents and 57% of designs but only 41% of trademarks of all IP rights owned by top R&D investors.

USPTO receives about 30% of patent filings

USPTO, EPO and SIPO receive between 60% and 80% of all patents filed by top R&D investors (up to more than 90% in the case of ICT companies). These companies grant more importance to the US market for the filing of digital IPs. In general, USPTO accounts for 30% or more of the patents filed by the top R&D investors operating in ICT industries.

Top R&D investors in ICT industries appear particularly focused on digital technologies and products. ICT designs are rare in non-ICT industries, while more than 20% of trademarks owned by top R&D investors relate to ICT.

Top R&D investors headquartered in the EU, US and Japan specialise in a relatively broad number of technologies. EU and US companies often specialise in technologies considered fundamental for addressing major societal challenges, such as health or the environment. Korea- and China-headquartered companies specialise almost exclusively in ICT-related technologies.

More than half of top R&D investors use the full IP bundle, i.e. patents, trademarks and designs. Relying on a combination of patents and trademarks is also fairly common, whereas other IP bundling strategies are less frequently used.

Top R&D investors differ in the extent to which they rely on international teams of inventors and designers. ‘Pharmaceuticals’ companies display the largest teams of inventors (13 on average), while the ‘Chemicals’ industry displays the largest average number of countries involved in the generation of new technologies (about 8 per company).

‘Pharmaceuticals’ and ‘Chemicals’ rely the most on international knowledge

1. Introduction

Over the last decades, the development and widespread adoption of digital technologies has changed the way knowledge is generated, used and shared, impacting on all aspects of economies and societies.

While fuelled, especially in its early phases, by the Information and Communication Technologies (ICT) developed by firms mainly operating in ICT-related sectors, the so-called "digital transformation" today encompasses all economic activities, in an increasingly pervasive fashion. On the one hand, digital technologies are now developed and widely used in all sectors of production, even those traditionally considered as unrelated to ICT, such as mining, automotive or health and pharma. On the other hand, ICT companies have progressively begun to diversify their activities and to operate in sectors seemingly unrelated to their core businesses, such as food or textile industries.

The speed, scale and scope of the digital transformation make it hard to fully apprehend the breadth and depth of the changes brought about by this new technological paradigm. Such a difficult exercise is nevertheless fundamental for evidence-based policies aiming at addressing the challenges and leveraging the opportunities that going digital may offer, while making the digital transformation societally enhancing and inclusive.

The present report constitutes an effort in this respect and looks at the innovation-related investment and activities performed by market leaders worldwide to identify their technological trajectories. It shines a new light on the digital transformation and on the strategies pursued by top innovators worldwide to generate knowledge and to appropriate the returns from their knowledge-based investment through industrial property (IP) rights. Special attention is devoted to uncovering the extent to which information and communication technologies and activities are diffusing and have been adopted by actors operating in other technological and economic domains.

Also, investment in R&D may lead to a wide array of innovations including new products, processes or designs, which are protected using different types of IP rights. To better characterise the innovative output of top R&D investors, the present report also analyses the so-called "IP bundle", the joint use of different IP rights. In particular, the analysis relies on patent, design and trademark data to investigate the new technologies and products introduced by these worldwide leading corporations on key markets (China, Europe, Japan, Korea and the United States in the case of patents; Europe, Japan and the United States in the case of trademarks and designs).

This report results from the long-term collaboration between the Joint Research Centre (JRC) of the European Commission (EC) and the Organisation for Economic Co-operation and Development (OECD), and their joint effort to provide up-to-date comparable data and state-of-the-art indicators and analysis. The original data and statistics on the innovation output of the world's top corporate R&D investors presented here aim to help uncovering the innovative, creative and branding strategies of top R&D investors worldwide, and the way they contribute to shape the digital transformation. The publicly available database accompanying the report (available upon request) is meant to allow for further analysis in support of evidence-based industrial and innovation policies.

Identifying the main drivers, features and possible developments of the digital transformation is key for both EU and OECD countries.

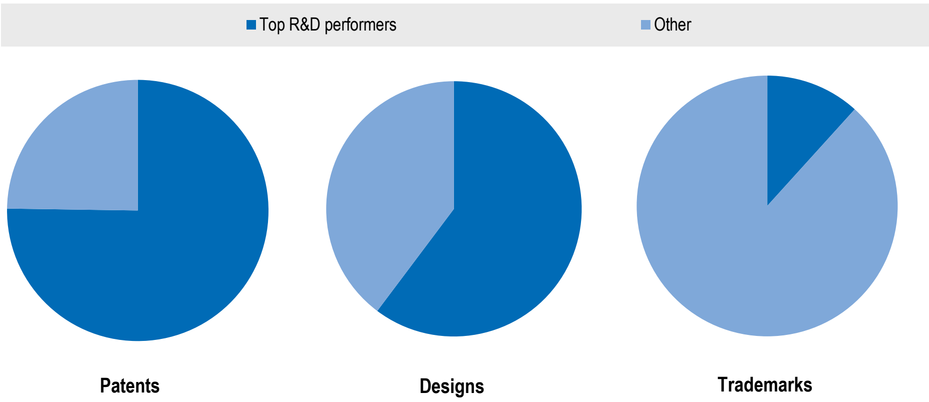
On the one hand, understanding how ICT–related technologies are shaping the very foundations of modern innovative economic systems is at the heart of the "Digital Single Market Strategy for Europe" set out by the European Commission (2015a). Digitalisation is considered a major factor for the EU to maintain its leading role in a number of industries. Therefore, investing in key areas like advanced manufacturing, smart energy, automated driving or e-health is expected to help reaching the right operational scale needed for technologies such as cloud computing, data-driven science and the internet of things to reach their full potential (2016).[1]

On the other hand, the OECD "Going Digital - Making the Transformation Work for Growth and Well-being" project - to which the present report contributes - aims to provide new and sound evidence on the ongoing digital transformation, as well as develop a coherent and comprehensive policy approach to address its challenges and maximize its potential. Evidence and analysis on key cross-cutting issues, including jobs and skills, innovation, productivity, competition and market structure, social challenges and well-being, aim to deliver a comprehensive perspective on the state, effects, expected benefits and issues raised by digitalisation in different sectors and policy areas.

A first look at the IP portfolios of top R&D investors worldwide (see Figure 1.1) reveals a leading role of these companies in the development of digital technologies and ICT-related industrial designs at the global scale. During the period considered (2012-14), these companies owned about 75% of ICT-related patents and 60% of ICT-related designs.

Figure 1.1 - ICT-related IP rights owned by the world top R&D performers, 2012-14

Share of ICT-related Patents, Designs and Trademarks, percentages



Note: Data refer to the number of ICT-related patents (resp. designs and trademarks) owned by the top R&D performers in total patents (resp. designs and trademarks). Patent counts refer to IP5 patent families. The number of designs includes registered designs at the EUIPO and JPO, and USPTO design patents. Trademarks cover all trademarks registered at the EUIPO, the JPO and the USPTO. ICT-related IPRs are identified as described in Annex F.

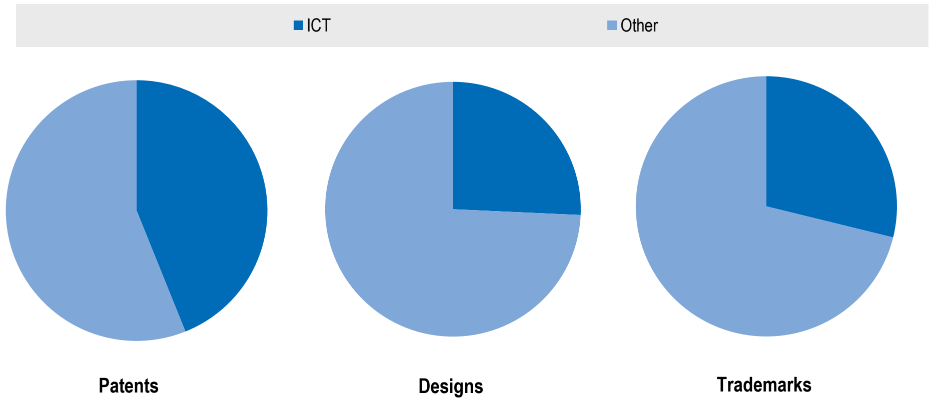
Source: JRC-OECD, COR&DIP© database v.1., 2017.

[1] Press release "Commission sets out path to digitise European industry" Brussels, 19 April 2016. http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=15279

At the same time, digital technologies appear to represent a key area of activity of top R&D performers. Almost half of their patenting activities and more than a quarter of their trademarks and designs relate to ICT (see Figure 1.2).

Figure 1.2 - ICT-related IP rights in the portfolio of the world top R&D performers, 2012-14

Share of ICT in Patents, Designs and Trademarks, percentages



Note: Data relate to the IP bundle's portfolio of the top R&D performers. Patent counts refer to IP5 patent families. The number of designs includes registered designs at the EUIPO and JPO, and USPTO design patents. Trademarks cover all trademarks registered at the EUIPO, the JPO and the USPTO. ICT-related IPRs are identified as described in Annex F.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

The report starts by looking at the geographical and industrial distribution of top corporate R&D investors' headquarters and their affiliates. This is accompanied by an overview of the diversification of the corporate structure to single out features of companies operating in the ICT sector with respect to other industries.

The report then provides a picture of the industrial property bundle owned by top R&D investors, with a special focus on the top 50 IPs assignees. The analysis goes further by comparing across industries their IP intensity, intended as the quantity of different types of output obtained for a given unit of R&D investment; the economic and technological value of the IP rights in their portfolio; and the extent to which they diversify their technology and product-related strategies.

Furthermore, the report brings evidence on the extent to which top corporate R&D investors worldwide diversify their patent, trademark and design activities and on the way they bundle the different IP rights. Technological, brand and product strategies are analysed by highlighting specificities between ICT and non-ICT industries in the development of digital technologies and products across international markets.

Finally, it offers insights into the international IP filing routes and sourcing strategies of the top corporate R&D investors worldwide, followed by some concluding remarks.

2. The geography and activity of top R&D investors

Key findings

- The headquarters of the world's top R&D investors are concentrated in a few economies (65% in just four); however their subsidiaries appear to be geographically more widely spread.
- 82% of the companies among top R&D investors in 2014 appear also in the 2012 list. Differences mainly stem from a lower presence of 'Computer and electronics' companies and a higher number of 'Pharmaceuticals' corporations.
- More than 25% of top R&D investors operate in the ICT sector, and more than 70% of them are headquartered in the United States, Chinese Taipei, China and Japan. The United States are home to about 29% of all top R&D investors' affiliates, and to about 41% of affiliates operating in ICT industries.
- The industrial diversification and the geographical location of top R&D investors' affiliates vary substantially across sectors. On average, top R&D investors have affiliates in 21 economies, covering 9 different industries. About 21% of top R&D investors' affiliates operate in ICT industries.

The analysis presented in this report is based on the sample of the top 2,000 companies that invested the most, that is, the largest amounts of money, in R&D in the year 2014, as published in the 2015 edition of the EU Industrial R&D Scoreboard (European Commission, 2015b).[2]

These companies are either independent companies or parents of (a number of) subsidiaries, defined as firms in which the parent company owns more than 50% of shares. In the case of parent companies, the R&D spending figure considered for the ranking is that which appears in the consolidated group accounts and includes spending by all subsidiaries and headquarters.

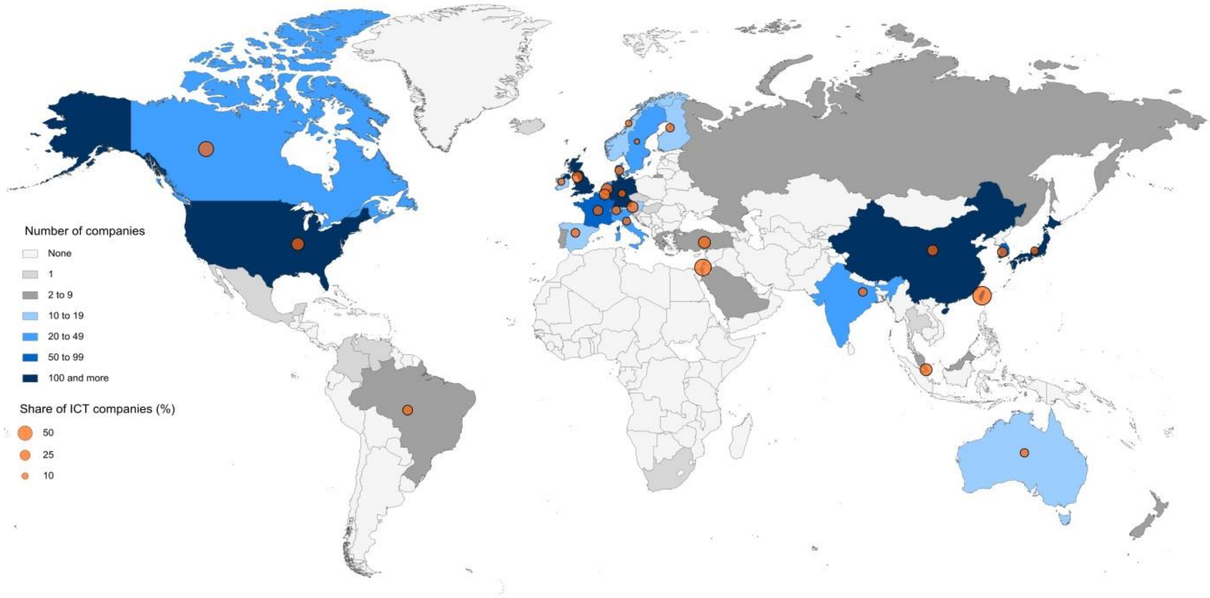
Figure 2.1a shows the geographical distribution of the headquarters of the top 2000 R&D investors worldwide. It also shows the percentage of these corporate headquarters that operate in the ICT sector (orange circles).[3] In 2014, about 60% of top R&D investors (i.e. 1,119 companies) were headquartered in four countries, namely the United States (US), Japan, Germany and the United Kingdom, and about 15% (i.e. 297) in China and Chinese Taipei. A high proportion of these companies (i.e. 571, more than one fourth of the total) operated in the ICT sector, more than half of which were headquartered in the US. Companies headquartered in the US or in three Asian economies – China, Chinese Taipei and Japan – represent more than 70% of the top 2,000 R&D investors operating in ICT industries.

In relative terms, Chinese Taipei, Israel and Canada have a marked specialisation in ICT industries. Indeed, more than half of all top corporate R&D investors headquartered in these countries operates in ICT industries (i.e. 81%, 65% and 52% respectively).

[2] See: http://iri.jrc.ec.europa.eu/scoreboard15.html.
[3] See Annex B for the definition of the 'ICT sector'.

Figure 2.1a - Locations of the world's top R&D investors' headquarters, 2014

Locations of headquarters and percentage of headquarters in the ICT sector



Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015. Map source: ARCTIQUE© - All rights reserved

In total, the top 2000 R&D investors considered in the present study account for more than 600,000 'controlled' subsidiaries. While top corporate R&D investors' headquarters in 2014 were mainly located in the northern hemisphere, the geographical distribution of these affiliates shows a much less concentrated pattern (see Figure 2.1b). Headquarters were distributed over 44 countries, while the subsidiaries appeared to be spread across more than 100 economies around the globe. Nevertheless, more than half (54%) of these corporate affiliates were located in five countries: the United States, the United Kingdom, China, Germany and France.

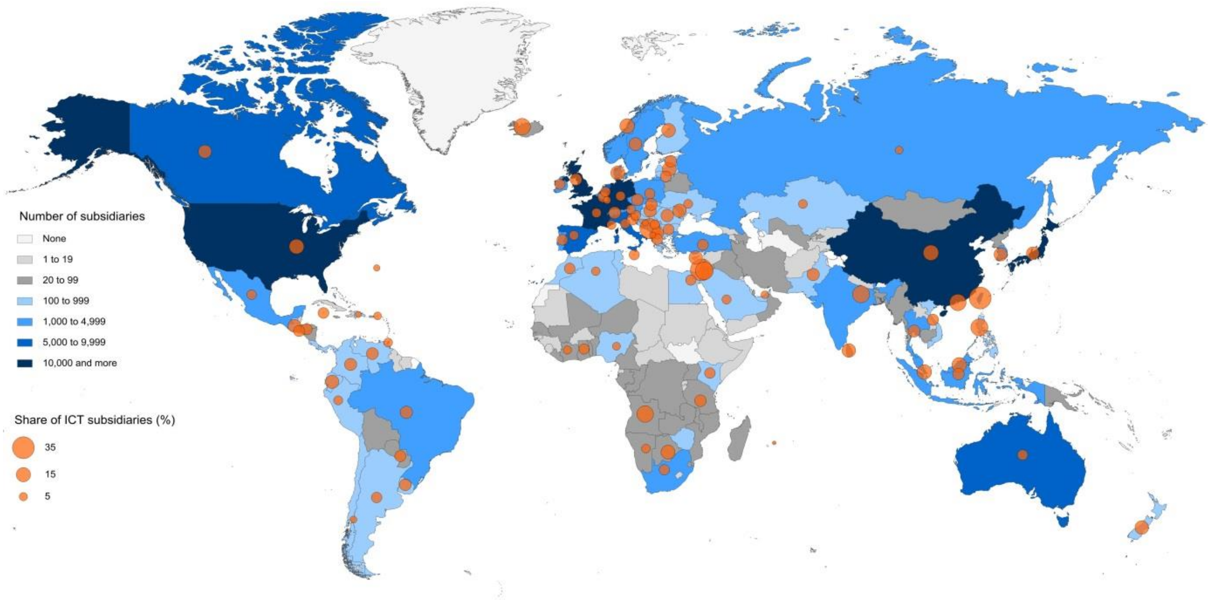
Subsidiaries operating in ICT industries represented, on average, 21% of the affiliates considered in the study. Similarly to the affiliates operating in other industries, ICT affiliates were present in almost all parts of the globe; however, their geographical concentration appears to be much higher. More than 63% of ICT subsidiaries were located in five countries: the United States, the United Kingdom, Japan, Germany and China.

In 2014, Israel and Chinese Taipei recorded above-average shares of ICT companies, in terms of both headquarters (17% and 56%, respectively) and subsidiaries (35% in the two economies).

Data on subsidiaries tend to confirm the greater role of the ICT sector in emerging economies such as India, China, Malaysia and Singapore. In these countries, about 15% to 21% of top R&D performers' subsidiaries mainly operate in the ICT sector. In the US and in northern European economies, this share ranged between 12% and 16%.

Figure 2.1b - Locations of the world's top R&D investors' subsidiaries, 2014

Location of subsidiaries and percentage of subsidiaries operating in the ICT sector

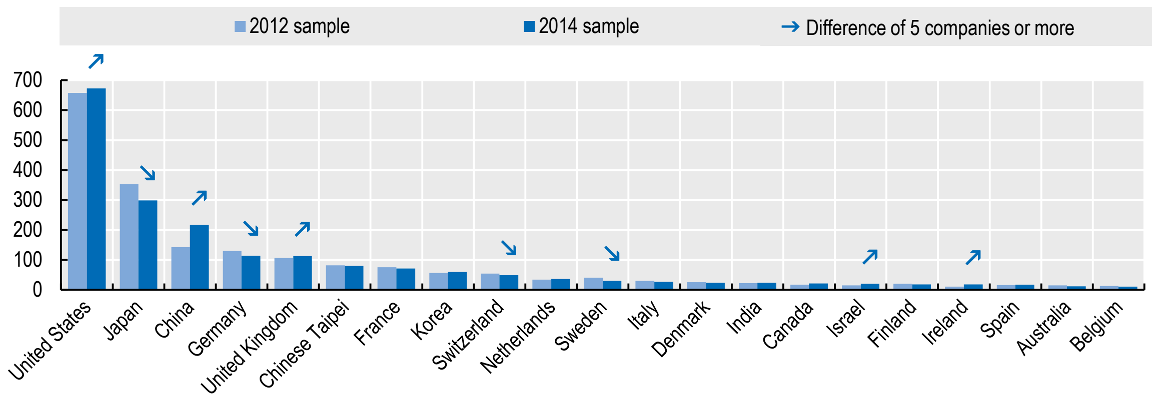


Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015. Map source: ARCTIQUE© - All rights reserved

One can see that 82% of top corporate R&D investors worldwide in the 2014 sample are the same as in the 2012 sample (Dernis et al., 2015. While this means that the vast majority of top innovators worldwide continued to invest significantly in R&D during the period considered, it also points to substantial changes occurring in only two years. Almost one fifth of the biggest corporate R&D performers were replaced by other companies. The distribution by country of the top corporate R&D performers (by headquarter location) and the changes between 2012 and 2014 can be seen in Figure 2.2. The US, China, the UK, Israel and Ireland saw the number of top corporate R&D performers' headquarters grow by at least 5%. By contrast, Japan, Germany, Switzerland and Sweden saw their number of top corporate R&D performers decrease.

Figure 2.2 - Distribution of the sample of top corporate R&D performers, 2012 and 2014

Number of companies by location of the headquarters

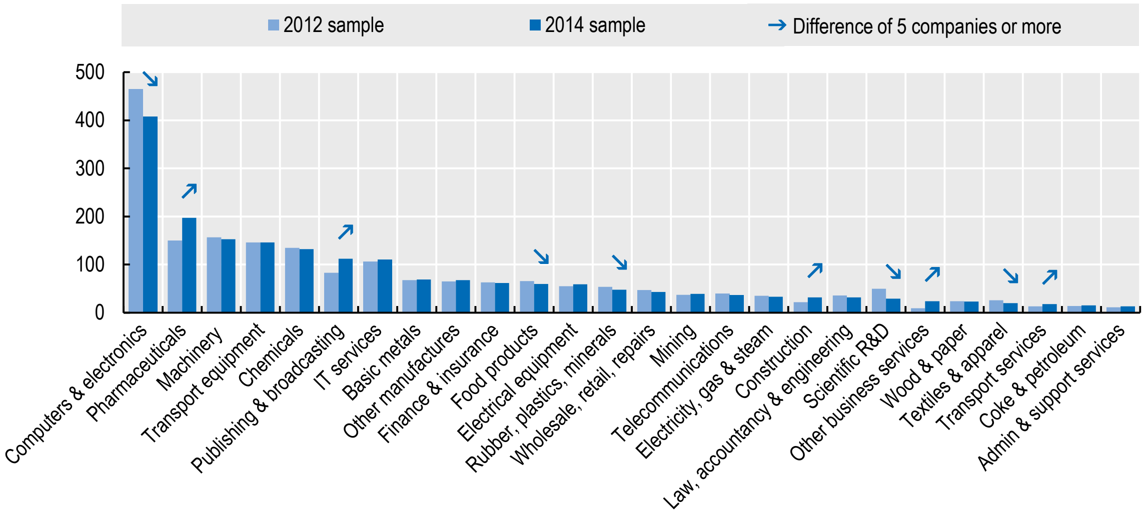


Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015 and 2013.

Differences also emerge in terms of the industries to which the top corporate R&D investors in the 2012 and 2014 samples belong (Figure 2.3). Compared with the 2012 sample, the 2014 sample includes more 'Pharmaceuticals' and 'Publishing & broadcasting' companies, and a lower proportion of companies from the 'Computers & electronics' industry. While these statistics may reflect genuine trends or structural changes, they may also result from shifts in the relative positions of these companies in the bottom part of the ranking,[4] as well as from changes in the industry of affiliation of companies' headquarters.

Figure 2.3 - Distribution of the sample of top corporate R&D performers, by industry, 2012 and 2014

Number of companies by industry



Note: Data relate to industries with at least 10 company headquarters in the 2012 and 2014 samples.

Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015 and 2013. Map source: ARCTIQUE© - All rights reserved

The extent to which the top 2000 R&D investors worldwide diversified their subsidiaries' structure, in terms of both their geographical location and the industrial activities of their affiliates, can be seen in Figure 2.4. The statistics are shown according to the main industry of activity of the headquarters (using a grouping described in Annex A) and are ranked according to the average number of countries in which subsidiaries are located (i.e. following the order emerging in the top panel of Figure 2.4).

As also observed in the JRC and OECD report (Dernis et al., 2015), industries differ in the geographical distribution of their activities and in the extent to which subsidiaries operate in different sectors. 'Transport services' remains the most diversified industry in both areas, whereas 'Scientific R&D' continues to exhibit low values for both indicators.

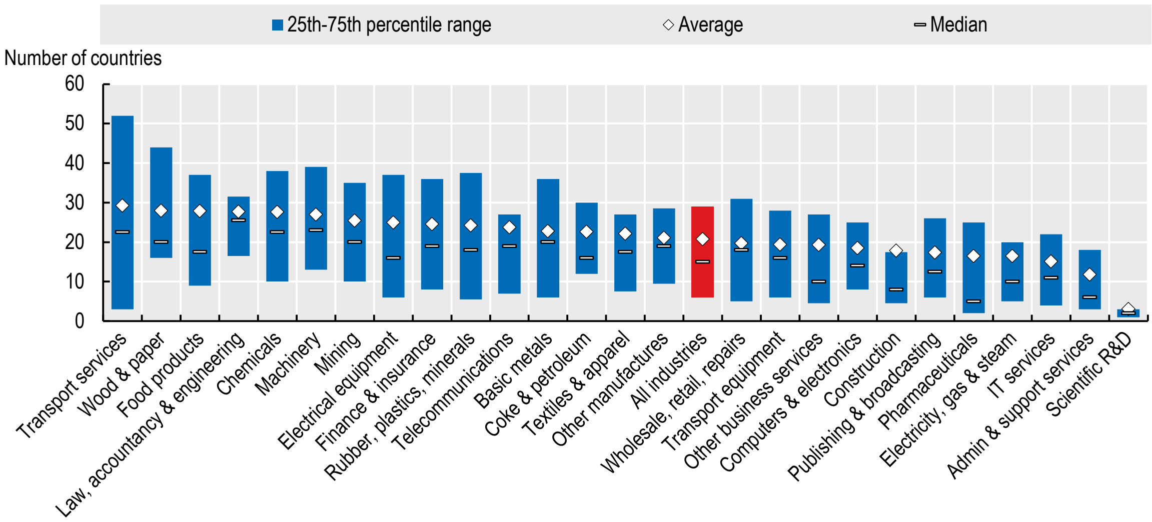
Furthermore, different patterns are observed even between industries pertaining to the same business area. For instance, investors in the three main industries in the ICT space, namely 'Computers & electronics', 'IT services' and 'Telecommunications', seem to

[4] For instance, a company that was in the 2,001st position worldwide (and therefore not included in the sample) might now be ranked 1999th because it had increased its R&D investment more than other companies previously in the top 2,000 ranking. Given the highly skewed distribution of R&D investments across companies, these shifts in the bottom part of the ranking could have some impact on the relative weight of a given industry or country.

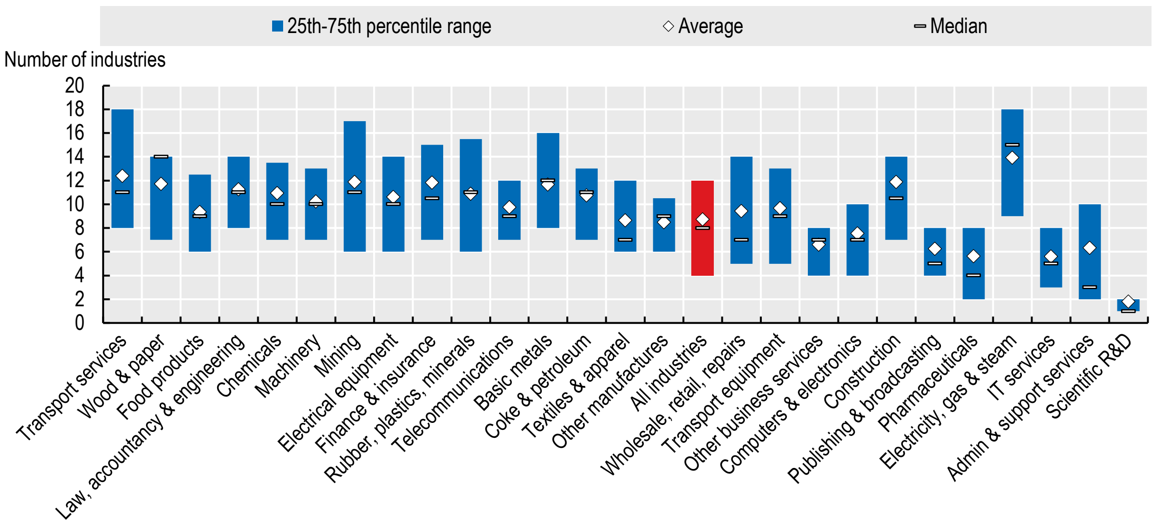
behave very differently. In 2014, the top 2,000 corporate R&D investors operating in ‘Computers & electronics’ and ‘IT services’ had diversification levels below the average, in both areas, whereas ‘Telecommunications’ firms appear to be more diversified, both geographically and in terms of activities. Other sectors, for example ‘Construction’ and ‘Electricity, gas & steam’, appear to have affiliates operating in a wide array of industries, while concentrating their activities in a relatively small set of countries.

Figure 2.4 - Diversification of subsidiaries of the world's top R&D investors, by industry, ISIC rev. 4, 2014

Geographical location of subsidiaries, number of countries in the corporate structure



Industry classifications of subsidiaries, number of industries in the corporate structure



Note: Data relate to industries with at least 10 company headquarters in the 2014 sample.

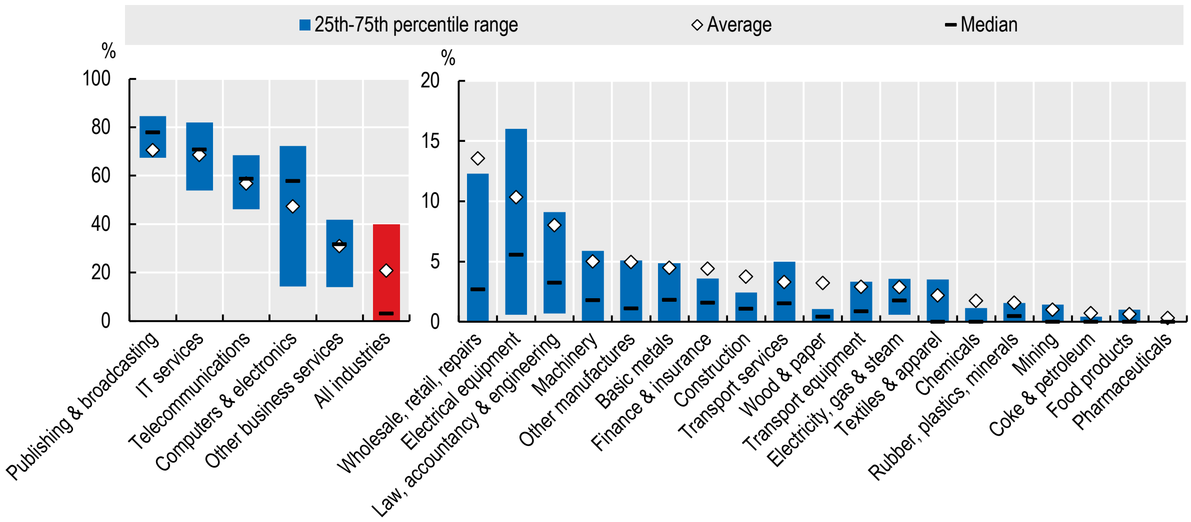
Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015.

Figure 2.5 provides more insights into the ICT orientation of the subsidiary companies of top corporate R&D investors worldwide. The statistics are shown according to the industry average of the percentage of affiliates operating in ICT. ICT industries appear to be very much ICT-focused, including in terms of the sectors in which affiliates operated. In fact, top R&D investors belonging to ICT industries – that is ‘Publishing & broadcasting’, 'IT services', 'Telecommunications', 'Computers & electronics, 'Other business services' – exhibited the largest shares of subsidiary companies active in the ICT sector. As Figure 2.5 details, the average and median values of ICT subsidiaries in these industries are above the sample average, displayed as all industries (21%). Noteworthy is the fact that the 197 'Pharmaceutical' companies in the sample do not seem to rely on affiliates operating in ICT. Likewise, three of the most populated sectors, i.e. 'Machinery' (153 companies), 'Chemicals' (132 companies) and 'Transport equipment' (146 companies), also had very low percentage values of affiliates operating in ICT, respectively 5%, 3% and 2%.

ICT industries also show the greatest dispersion across companies, as illustrated by the 25th-75th percentile range. Figure 2.5 highlights this remarkable difference between ICT-operating headquarters and non-ICT ones by using two different scales to report the two groups. Companies from 'Computers & electronics' display, by far, the highest dispersion in terms of proportion of ICT affiliates.

Figure 2.5 - ICT subsidiaries of the world's top R&D investors, by industry, ISIC rev. 4, 2014

Percentage of ICT subsidiaries



Note: Data relate to industries with at least 10 companies in the top 2,000 corporate R&D sample for 2014, having at least 10 subsidiaries.

Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015.

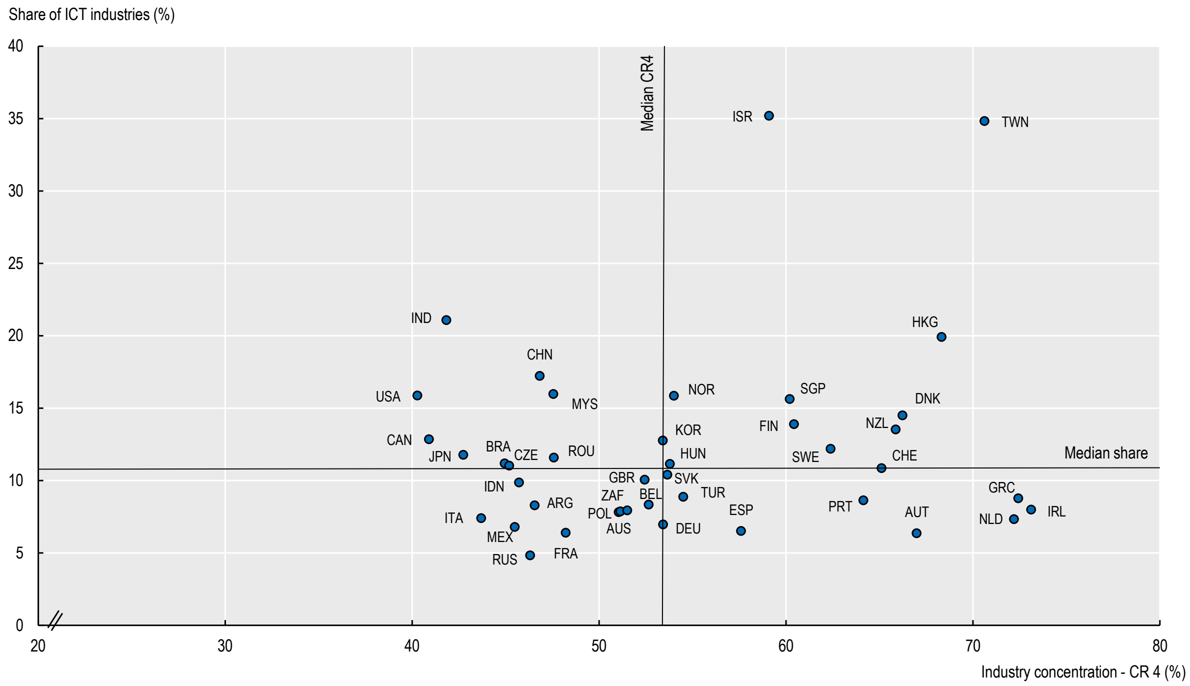
Figure 2.6 shows the relationship that exists between the concentration of industrial activities of top corporate R&D investors in a given economy and the share of ICT affiliates in that economy.

Industrial concentration (measured by the concentration ratio, CR4 indicator) is calculated on the basis of the number of affiliates active in each industry. For each country, the number of affiliates in the top four industries (in terms of number of subsidiaries) is divided by total number of affiliates. Country-related statistics are displayed on the *x*-axis. The ICT share, shown on the *y*-axis, corresponds to the share of ICT-related affiliates located in a certain country, over the total number of affiliates located in the same country. The median ICT share – the horizontal line – corresponds to a value of 11%, whereas the median CR4, the vertical line, corresponds to a value of 53%.

The top left quadrant contains countries that combine a relatively high presence of ICT affiliates with a relatively low concentration of industrial activities. Among the countries exhibiting this patterns are the US, Canada and Japan, as well as large, fast-growing economies such as China, India and Malaysia. The top right quadrant shows countries with many ICT affiliates of top corporate R&D investors located in their territory, as well as a specialisation in a relatively narrow set of industries. Among these are Nordic countries such as Denmark, Finland, Norway and Sweden, as well as economies that are highly specialised in ICT industries, such as Israel and Chinese Taipei. Obviously, relatively smaller economies are more likely to display relatively pronounced specialisation patterns.

Figure 2.6 - Industry concentration of subsidiaries, by country, 2014

Concentration of subsidiaries in four main industries and in the ICT sector



Note: Data relate to countries in which at least 500 subsidiaries are located.

Source: JRC-OECD, calculations based on EU R&D Scoreboard data, 2015

In the bottom quadrants of Figure 2.6 are those economies with a relatively low presence of ICT affiliates of the top 2,000 corporate R&D investors worldwide. The bottom left quadrant contains countries with a relatively low industrial concentration as measured by the affiliates of the companies in question, whereas the bottom right part of the figure shows those economies that are relatively more specialised. This evidence is consistent with the geographical distribution of affiliates shown in Figure 2.1b.

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3. The industrial property bundles of top R&D investors

Key findings

- Top R&D investors in ICT industries represent more than a quarter of companies and account for about 30% of total patents filed. More than half of the top 50 patenting corporations operate in ICT industries and 31 are headquartered in Asia.
- Trademarks are more widely used across different industries, and very few ICT companies are among the top 50 trademark registering companies.
- A ranking based on design-related data more closely resembles a patent-related ranking than trademark-based one. Of the top five corporations leading the design ranking, two are headquartered in the United States and three in Japan.
- ICT-related patents have a narrower scope than non-ICT ones. Notably, ‘Electricity, gas & steam’, ‘Machinery’, ‘Transport services’ and ‘Electrical equipment’ industries show a wider technological scope for ICT patents filed at the EPO.
- Top R&D investors in ICT industries present relatively more concentrated IP portfolios in terms of both technologies (patents) and products (trademarks and designs).

3.1 Appropriating the returns from investment in R&D: top 50 IPs assignees

Companies generally invest in R&D for two main reasons: to innovate and to increase their absorptive capacity, by means of increasing their knowledge repository and upskilling their human capital. An assessment of the extent to which companies appropriate the returns from their investment in R&D in the form of innovative output can be made using data about the IP assets they own.

For this report, such an assessment exercise was carried out using data about the patent applications and the trademark and industrial design registrations filed by the top corporate R&D investors and their affiliates during the period 2012-14. IP portfolios were identified using matching procedures linking data on the name of patent, trademark and design assignees to the names of the top corporate R&D investors and their subsidiaries. Links were established on a country-by-country basis, to maximise accuracy, as described in Annex C. The resulting IP portfolios, as defined in Box 3.1, were aggregated at the headquarter level, in the case of companies belonging to a group: patents, trademarks and designs owned by a given subsidiary are thus fully attributed to the parent company of the group. Tables 3.1, 3.2 and 3.3 list the top patenting, top trademarking and top industrial design registering companies in the sample of the top 2,000 companies that invested the most in R&D in 2014.

Table 3.1 presents the top 50 patenting companies in terms of IP5 families (see Box 3.1). Companies are ranked according to the share of their patent portfolio in the overall patent portfolio of the top R&D investors worldwide.

Box 3.1. The IP bundles of the 2014 top R&D investors: patents, designs and trademarks

Patents

To better reflect the inventive activities of top corporate R&D investors worldwide, the statistics presented here are based on families of patent applications filed at the five largest IP offices (IP5):* the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the State Intellectual Property Office of the People's Republic of China (SIPO) and the United States Patent and Trademark Office (USPTO).

Depending on a number of factors and on the market strategies that companies pursue, innovators may want to protect the very same invention in different countries. This being the case, they need to file a set of related patent applications in each national or regional office where protection is sought: the first patent filing made to protect a given invention worldwide (the so-called 'priority' filing) is often followed by (a series of) subsequent and related filings, thus giving birth to a so-called patent 'family' (see Martínez, 2011).

To avoid counting several times those patents that have been filed at different IP offices with the aim of protecting the very same invention, patent portfolios need to be consolidated on the basis of the families that patents belong to. The definition of IP5 patent families presented in this report relies on families of patent applications with members filed in at least one of the IP5, provided that another family member has been filed in any other office worldwide (see Dernis et al., 2015 for further discussion of IP5 families). The International Patent Classification (IPC) is used to allocate patents to technological fields (see http://www.wipo.int/classifications/ipc and Annex D).

Designs

Registered design data used in the report refer to design applications filed at the European Union Intellectual Property Office (EUIPO) and the JPO and to design patents filed at the USPTO. The EUIPO administers Registered Community Designs (RCD), that is, designs that are valid throughout the European Union and coexist with nationally registered designs. USPTO designs data refer to design patent applications, as industrial designs in the US are protected though patent rights. The Locarno Classification, an international classification used for the registration of industrial designs, is used here to identify the product areas to which designs relate (see http://www.wipo.int/classifications/locarno/).

Trademarks portfolio

Data on trademark applications relate to trademarks registered at the 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 http://www.wipo.int/classifications/nice/en).

Period of analysis

IP rights (IPR) can be applied for by the parent company and/or by any of its subsidiaries and be used at different moments in time, in the neighbourhood of the period in which R&D investment is observed. In addition, as R&D investment flows are characterised by high persistency over time, and in big corporations a number of innovative projects may party or fully overlap over time, in terms of their development stages, one needs to consider the IP accruing over a number of years, rather than in one specific year, to better capture the link between R&D investment and innovative output. The IP data presented in the report thus refer to the IP rights filed in 2012-14 and owned by the top 2,000 R&D investors as well as their 'controlled' subsidiaries, based on the corporate structure reported at the end 2014. This conservative choice, and the consequent focus on a relatively short period of time, is driven by lack of information about the pre-2014 corporate structure of top R&D performers and the impossibility of looking at the 2013-2015 period for patents rights. There are a number of reasons for this, including the fact that patent applications become known (i.e. are published), 18 months after filing and that, under the Paris Convention of 1883, companies have one year to extend the territorial coverage of an invention and to start building its 'family'. For these and other reasons, it is impossible to obtain information about very recent IP5 families, which limits researchers' ability to accurately map the industrial properties of top corporate R&D performers over time, and to assess the extent to which company dynamics such as mergers, acquisitions and divestment might shape the stock and flow of industrial properties.

For this report, it is assumed that the corporate structures of top R&D performers over the two years preceding 2014 (i.e. 2012-13) were sufficiently similar to that observed in 2014, and that statistics based on the three-year period 2012-14 provides a substantially accurate picture of the companies' IP-related activities. This could not be assumed if longer time frames were to be considered.

Unless otherwise specified, IP data are reported according to the earliest filing date and applicant. Furthermore, statistics rely on fractional counts, to ensure that innovative output is not overestimated in the case of, for example, shared ownership of the IP assets at stake or IP rights relating to several technological or product categories.

* *The IP5 is a forum of the five largest intellectual property offices in the world that was set up to improve the efficiency of the examination process for patents worldwide. The IP5 offices together handle about 90 per cent of the world's patent applications. See http://www.fiveipoffices.org.*

Table 3.1 - Top 50 patenting companies, 2012-14

Top 50 patenting companies in terms of IP5 patent families
and shares of their patent portfolios in the total top R&D performers' patent portfolio

		Industry	IP5 families Share	Rank
Samsung	KOR	Computers & electronics	6.2	*(1)*
Canon	JPN	Machinery	2.9	*(2)*
Toshiba	JPN	Computers & electronics	2.4	*(3)*
Fujitsu	JPN	Computers & electronics	1.6	*(4)*
Hitachi	JPN	Electrical equipment	1.5	*(5)*
Hon Hai Precision Industry	TWN	Computers & electronics	1.5	*(6)*
Robert Bosch	DEU	Transport equipment	1.3	*(7)*
Sony	JPN	Computers & electronics	1.2	*(8)*
Toyota	JPN	Transport equipment	1.2	*(9)*
General Electric	USA	Machinery	1.2	*(10)*
Fujifilm	JPN	Computers & electronics	1.2	*(11)*
Seiko Epson	JPN	Computers & electronics	1.1	*(12)*
Ricoh	JPN	Machinery	1.1	*(13)*
United Technologies	USA	Transport equipment	1.0	*(14)*
LG Elect	KOR	Computers & electronics	1.0	*(15)*
Hyundai	KOR	Transport equipment	1.0	*(16)*
Denso	JPN	Transport equipment	1.0	*(17)*
Dow Chemical	USA	Chemicals	0.9	*(18)*
Qualcomm	USA	Computers & electronics	0.9	*(19)*
IBM	USA	IT services	0.9	*(20)*
Mitsubishi Electric	JPN	Electrical equipment	0.9	*(21)*
Siemens	DEU	Machinery	0.9	*(22)*
General Motors	USA	Transport equipment	0.9	*(23)*
Panasonic	JPN	Electrical equipment	0.9	*(24)*
Hewlett-Packard	USA	Computers & electronics	0.8	*(25)*
Samsung Electro-Mechanics	KOR	Computers & electronics	0.8	*(26)*
Kyocera	JPN	Computers & electronics	0.7	*(27)*
Huawei	CHN	Finance & insurance	0.7	*(28)*
Intel	USA	Computers & electronics	0.7	*(29)*
Honda	JPN	Transport equipment	0.7	*(30)*
Boe Technology Group	CHN	Computers & electronics	0.7	*(31)*
Sk Hynix	KOR	Computers & electronics	0.6	*(32)*
Ericsson	SWE	Computers & electronics	0.6	*(33)*
Taiwan Semiconductor	TWN	Computers & electronics	0.6	*(34)*
Brother Industries	JPN	Electrical equipment	0.6	*(35)*
Volkswagen	DEU	Transport equipment	0.6	*(36)*
Philips	NLD	Electrical equipment	0.6	*(37)*
Infineon Technologies	DEU	Computers & electronics	0.6	*(38)*
Airbus	NLD	Transport equipment	0.5	*(39)*
Ford	USA	Transport equipment	0.5	*(40)*
Samsung Sdi	KOR	Computers & electronics	0.5	*(41)*
Honeywell	USA	Transport equipment	0.5	*(42)*
Sumitomo Electric	JPN	Basic metals	0.5	*(43)*
Microsoft	USA	Publishing & broadcasting	0.5	*(44)*
Olympus	JPN	Computers & electronics	0.4	*(45)*
NEC	JPN	Computers & electronics	0.4	*(46)*
Konica Minolta	JPN	Computers & electronics	0.4	*(47)*
Tencent	CHN	IT services	0.4	*(48)*
Nokia	FIN	Computers & electronics	0.4	*(49)*
ZTE	CHN	Computers & electronics	0.4	*(50)*

Source: JRC-OECD, COR&DIP© database v.1., 2017.

In line with what we have already seen in the 2015 JRC and OECD report (Dernis et al., 2015), Asia-based companies emerge as the biggest patent assignees in the sample. More precisely, of the top 50 IP5 assignees, 30 are headquartered in Asia, mainly in Japan (19 corporations) and Korea (6 corporations). Samsung Electronics, headquartered in Korea, exhibits the biggest IP5 patent portfolio, with Samsung patents representing more than 6% of all patents belonging to the top 2,000 R&D investors worldwide. Among the top 50 patent assignees in the top corporate R&D investors' sample, 11 are headquartered in the US and only 8 in Europe.

In terms of sectors, the importance of ICT industries stands out clearly: more than half of the top 50 patenting companies operate in these industries (coloured in light blue in Table 3.1), mainly in 'Computers & electronics'. Overall, companies in the ICT sector account for about 30% of all the patents owned by the top 2,000 R&D investors.

Table 3.2 and Table 3.3 list the top trademark- and design- registering[5] companies at the EUIPO, the JPO and the USPTO. The top R&D performers included in the lists are those ranked among the top 50 applicants in at least two of the three intellectual property offices considered. In total, 29 companies in the case of trademarks and 38 companies in the case of registered designs (or design patents) fulfil this criterion. For each office, the share of trademarks (Table 3.2) or designs (Table 3.3) registered by a company with respect to the total trademarks or designs registered by the whole sample is reported together with the corresponding rankings. The three IP offices for which data are provided are considered to be equally important.

Table 3.2 - Top trademark-registering companies, 2012-14

Top trademark registering companies, EUIPO, JPO and USPTO
and shares and rankings of their portfolios in terms of the total top R&D performers' portfolios

			EUIPO		JPO		USPTO	
		Industry	*Share*	*Rank*	*Share*	*Rank*	*Share*	*Rank*
In the top 50 in the 3 offices								
Johnson & Johnson	USA	Pharmaceuticals	1.0	*(12)*	0.7	*(38)*	1.7	*(2)*
LG	KOR	Computers & electronics	2.0	(3)	0.5	(50)	0.8	(15)
Procter & Gamble	USA	Chemicals	1.3	*(5)*	0.5	*(49)*	1.5	*(4)*
Samsung	KOR	Computers & electronics	1.7	(4)	0.6	(45)	1.1	(8)
Sony	JPN	Computers & electronics	0.7	(20)	0.9	(24)	0.6	(19)
In the top 50 in at least 2 offices								
Amazon.com	USA	Wholesale, retail, repairs	0.4	*(42)*	0.17	*(142)*	0.3	*(47)*
Bayer	DEU	Pharmaceuticals	0.7	*(19)*	0.18	*(129)*	0.4	*(36)*
Bristol-Myers Squibb	USA	Pharmaceuticals	0.4	*(34)*	0.30	*(83)*	1.0	*(11)*
Christian Dior	FRA	Textiles & apparel	0.7	*(17)*	0.07	*(244)*	0.8	*(14)*
Colgate-Palmolive	USA	Chemicals	0.4	*(47)*	0.03	*(342)*	0.5	*(29)*
Diageo	GBR	Food products	0.9	*(14)*	0.11	*(186)*	0.7	*(17)*
Eli Lilly	USA	Pharmaceuticals	0.6	*(22)*	0.39	*(69)*	0.6	*(18)*
General Electric	USA	Machinery	0.4	*(49)*	0.13	*(171)*	0.4	*(31)*
Glaxosmithkline	GBR	Pharmaceuticals	0.6	*(24)*	0.28	*(89)*	1.4	*(5)*
Henkel	DEU	Chemicals	0.7	*(16)*	0.04	*(317)*	0.4	*(32)*
International Game Technology	USA	Other manufactures	1.0	*(10)*	-	-	0.9	*(12)*
Jarden	USA	Electrical equipment	0.4	*(33)*	0.19	*(121)*	0.9	*(13)*
L'Oreal	FRA	Chemicals	2.4	*(2)*	0.34	*(74)*	1.4	*(6)*
Medtronic	IRL	Computers & electronics	0.6	*(25)*	0.08	*(218)*	0.5	*(24)*
Merck US	USA	Pharmaceuticals	0.6	*(23)*	0.35	*(73)*	0.8	*(16)*
Nestle	CHE	Food products	0.4	*(38)*	0.05	*(297)*	1.0	*(10)*
Nissan	JPN	Transport equipment	0.4	*(40)*	0.73	*(33)*	0.3	*(66)*
Novartis	CHE	Pharmaceuticals	2.4	*(1)*	0.39	*(66)*	1.6	*(3)*
Pepsico	USA	Food products	0.4	*(37)*	0.10	*(197)*	1.0	*(9)*
Reckitt Benckiser	GBR	Chemicals	1.1	*(8)*	0.05	*(276)*	0.4	*(37)*
Sanofi	FRA	Pharmaceuticals	0.5	*(32)*	0.21	*(110)*	0.4	*(34)*
Shiseido	JPN	Chemicals	0.2	*(136)*	2.78	*(1)*	0.4	*(39)*
Siemens	DEU	Machinery	0.8	*(15)*	0.01	*(473)*	0.5	*(22)*
Toshiba	JPN	Computers & electronics	0.2	(89)	1.39	(11)	0.4	(41)

Source: JRC-OECD, COR&DIP© database v.1., 2017.

[5] For simplicity, the discussion refers to the registration of designs *tout court*, without differentiating between registering a design at the EPO or JPO, or filing for a design patent at the USPTO.

Table 3.3 - Top design-registering companies, 2012-14

Top companies with registered designs, EUIPO, JPO and USPTO
and shares and rankings of their portfolios in terms of the total top R&D performers' portfolios

		Industry	EUIPO Share	EUIPO Rank	JPO Share	JPO Rank	USPTO Share	USPTO Rank
In the top 50 in the 3 offices								
3M	USA	Rubber, plastics, minerals	1.8	(8)	0.7	(36)	1.3	(10)
Apple	USA	Computers & electronics	0.7	(25)	0.7	(35)	2.1	(4)
Bridgestone	JPN	Rubber, plastics, minerals	1.5	(10)	1.5	(11)	0.9	(18)
Hitachi	JPN	Electrical equipment	1.1	(18)	3.9	(2)	0.8	(19)
Honda	JPN	Transport equipment	1.1	(14)	2.4	(6)	1.2	(11)
LG	KOR	Computers & electronics	2.2	(4)	1.0	(19)	4.3	(2)
Microsoft	USA	Publishing & broadcasting	0.7	(27)	0.7	(34)	4.0	(3)
Mitsubishi Electric	JPN	Electrical equipment	0.7	(28)	3.6	(3)	0.5	(34)
Panasonic	JPN	Electrical equipment	1.8	(7)	5.5	(1)	1.6	(6)
Philips	NLD	Electrical equipment	2.6	(2)	0.6	(46)	1.4	(9)
Samsung	KOR	Computers & electronics	7.4	(1)	2.2	(8)	13.7	(1)
Sony	JPN	Computers & electronics	1.1	(15)	1.3	(15)	1.0	(14)
Toshiba	JPN	Computers & electronics	0.7	(31)	2.7	(5)	0.5	(35)
Toyota	JPN	Transport equipment	0.5	(37)	1.9	(10)	1.1	(12)
In the top 50 in at least 2 offices								
Blackberry	CAN	Computers & electronics	2.1	(6)	-	-	0.8	(20)
BMW	DEU	Transport equipment	0.6	(33)	0.2	(128)	0.9	(17)
Christian Dior	FRA	Textiles & apparel	1.1	(16)	0.2	(111)	0.4	(50)
Colgate-Palmolive	USA	Chemicals	0.8	(22)	0.0	(318)	0.4	(48)
Daimler	DEU	Transport equipment	0.9	(19)	0.0	(328)	0.8	(21)
Electrolux	SWE	Electrical equipment	0.7	(26)	-	-	0.4	(49)
Fujifilm	JPN	Computers & electronics	0.3	(64)	0.9	(23)	0.5	(36)
General Electric	USA	Machinery	0.5	(45)	0.1	(212)	0.6	(30)
Google	USA	IT services	0.6	(35)	0.2	(133)	1.1	(13)
Hewlett-Packard	USA	Computers & electronics	0.4	(49)	-	-	0.6	(26)
Japan Aviation Electronics Industry	JPN	Computers & electronics	0.1	(304)	0.6	(41)	0.5	(38)
Johnson & Johnson	USA	Pharmaceuticals	1.1	(13)	0.4	(70)	0.6	(29)
JS	JPN	Basic metals	0.5	(38)	2.4	(7)	0.3	(81)
Karl Storz	DEU	Other manufactures	0.7	(23)	0.0	(426)	0.4	(43)
Michelin	FRA	Rubber, plastics, minerals	1.2	(12)	0.3	(86)	0.5	(39)
Nissan	JPN	Transport equipment	0.3	(77)	1.4	(13)	0.6	(27)
Omron	JPN	Computers & electronics	0.5	(40)	0.8	(29)	0.3	(60)
Pepsico	USA	Food products	0.4	(50)	0.1	(164)	0.5	(37)
Procter & Gamble	USA	Chemicals	0.1	(207)	0.7	(37)	1.6	(5)
Robert Bosch	DEU	Transport equipment	2.1	(5)	0.1	(148)	1.4	(8)
Shimano	JPN	Transport equipment	0.5	(42)	0.5	(50)	0.1	(195)
Stanley Black & Decker	USA	Machinery	1.4	(11)	0.0	(317)	0.7	(24)
Tata S	IND	Transport equipment	0.8	(20)	-	-	0.6	(28)
Volkswagen	DEU	Transport equipment	2.3	(3)	0.4	(67)	1.0	(16)

Source: JRC-OECD, COR&DIP© database v.1., 2017.

The significant variations in companies' rankings across IP offices suggest the existence of market diversification strategies, in terms of both industries and countries. Only five companies - Johnson & Johnson, LG, Procter & Gamble, Samsung and Sony - are consistently ranked among the top applicants across the three offices for the period considered. Furthermore, evidence confirms the extent to which product complexity may shape companies' IP behaviours: R&D investors operating in 'Pharmaceuticals' and 'Chemicals' consistently appear among the top trademark- registering companies, whereas, as noted, companies operating in the ICT sector play a much more important role in terms of patenting. This happens because thousands of patents are generally needed for one product such as a mobile phone or a tablet to work. That one product is then generally made recognisable to the broad public through one or very few trademarks. Conversely, the relationship between patents and trademarks in the case of drugs is more balanced: one trademark generally identifies a drug relying on one or a few patents.

In addition to the existence of product and industry market diversification strategies, the data suggest that products and services get adjusted to different extents to the tastes with regards to the ‘look and feel’ of the different countries in which products are sold. This can be seen from Table 3.3, which suggests that registered designs differ depending on characteristics such as the location of the headquarters, the sector of activity of the company and the IP office where protection is sought.

The number of companies ranked at the top for all three of the offices considered is higher in the case of registered designs than in the case of trademarks (see Tables 3.2 and 3.3: 14 and 5 companies, respectively). Among these companies, the Korean LG and Samsung and the Japanese Sony emerge as the most active in terms of trademark and design filings during 2012-14. All of them operate in ICT industries.

More generally, and in contrast to the case of trademarks, top R&D investors in ICT industries rely to a significant extent on registered designs (12 out of the 38 companies listed in Table 3.3). Rankings based on design data are more similar to patent-based rankings (Table 3.1) than to the rankings based on trademarks (Table 3.2). Furthermore, a significant number of companies headquartered in Japan and the US can be seen in both the list of top patenting and the list of top design-registering R&D investors. In addition to ICT companies, the sectors that seemingly rely in a more marked way on patent and design rights to appropriate the returns from their investment in R&D are ‘Transport equipment’ and ‘Electrical equipment’.

Finally, when all types of industrial properties are accounted for, very few top R&D performers make it into the top IP-based rankings shown above, namely General Electric (US), Samsung (Korea), and Sony and Toshiba (Japan).

3.2 IP “intensity”

As the statistics above show, different companies rely on IP to different extents, depending on characteristics such as the industry they belong to, the locations of the headquarters and so on. To further explore the innovation-related behaviours of top R&D investing companies worldwide, in what follows attention is devoted to measures of ‘intensity’. These measures focus on the amount of R&D expenditures, per IP5 patent family, as well as the amounts of net sales per trademark application or per registered design.[6] The figures are presented according to the median values of industries and provide the interquartile ranges (the 25th and the 75th percentile) of the intensity values. In this way, both the general trend and the dispersion characterising the phenomenon can be assessed.

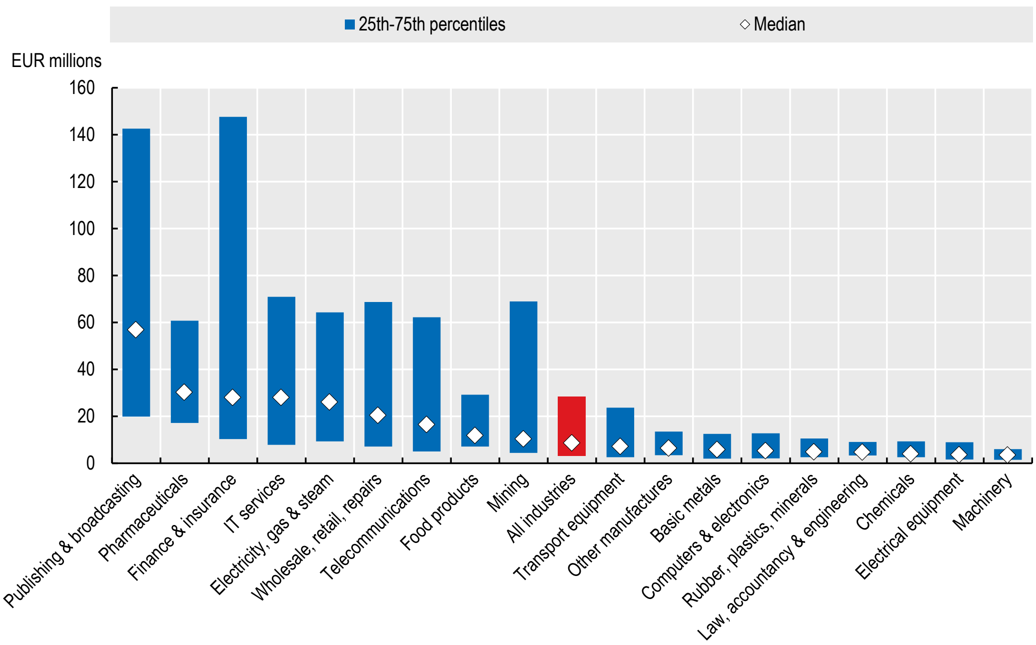
Substantial heterogeneity emerges within and across industries with respect to the amount of R&D investment per patent (Figure 3.1), sales per trademark application (Figure 3.2) and sales per registered design (Figure 3.3). Since it is impossible to use trademark or design families in this context, the statistics rely on figures based on all

[6] At the individual company level, R&D, net sales and IP rights are computed as averages for the period 2012-14.

trademarks or designs registered at the three offices considered, namely the EUIPO, the JPO and the USPTO.[7]

Figure 3.1 - R&D investment per patent of top R&D performers by industry, ISIC rev. 4, 2012-14

Million EUR per IP5 patent family, median values by industry



Note: Data relates to industries with at least 25 company headquarters in the top 2,000 corporate R&D sample having filed patents in 2012-14.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

The red bar in Figure 3.1, representing values computed across all companies considered (denoted by ‘All industries’), splits industries between those with higher and those with lower R&D investment per patent than the median value observed for the whole sample. Among the industries with values above the sample median, ‘Publishing & broadcasting’, ‘Finance & insurance’ and ‘Mining’ show high dispersion in the value of R&D investment per patent family. ‘Publishing & broadcasting’ and ‘Pharmaceuticals’ exhibit the highest median R&D investment per patent filed: EUR 57 million and EUR 30 million, respectively. At the other end of the spectrum, ‘Electrical equipment’ and ‘Machinery’ display median investments per patent of EUR 3.7 million and EUR 3.5 million, respectively. Dispersion is lowest in industries such as ‘Machinery’ and, to a lesser extent, ‘Computers & electronics’, two of the best represented industries in the sample of top R&D investors.

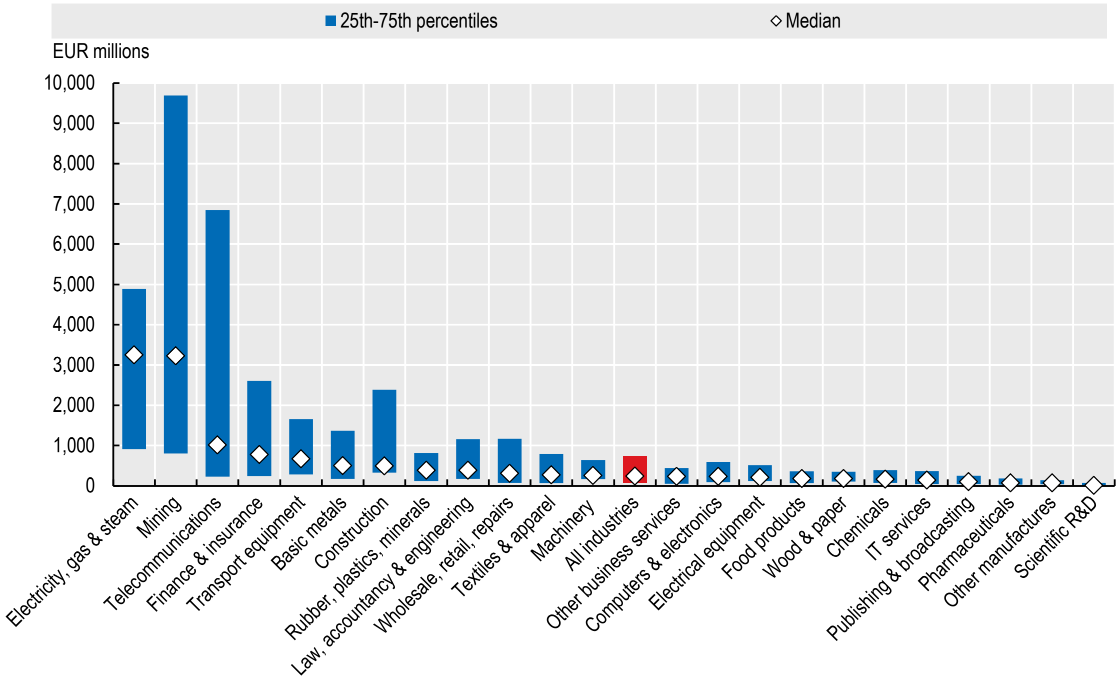
The stylised facts observed to some extent reflect features such as the complexity of the products that different industries produce, as well as the costs of identifying and developing new technological solutions. For instance, in the case of the pharmaceutical

[7] In the case of patents, the priority number allows all the patents filed in different offices and related to the same invention to be identified. In the case of trademark applications, documents are rarely linked across offices by priority numbers (only 12% of trademark applications at the EUIPO between 2012 and 2014 have a priority number, and only 3% of USPTO trademarks do so). In the case of designs, only 22% of EUIPO registrations claim a priority number, and 28% do so in the case of USPTO design patents.

industry, the higher median values observed may relate to the often very high investments needed to discover or develop a new molecule or drugs.

Figure 3.2 - Net sales per trademark of top R&D performers by industry, ISIC rev. 4, 2012-14

Million EUR per trademark applications (EUIPO, JPO, USPTO), median values by industry



Note: Data refer to the total number of trademark applications filed at the EUIPO, the JPO and the USPTO in 2012-14. Data relate to industries with at least 20 company headquarters in the top 2,000 corporate R&D sample.

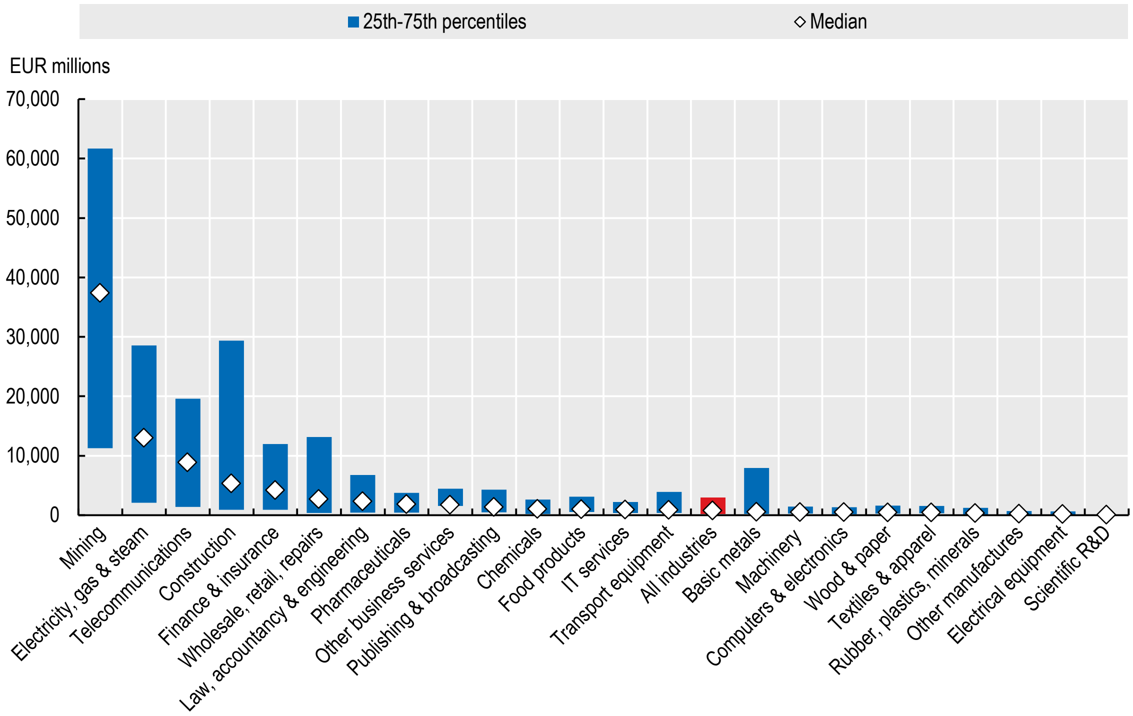
Source: JRC-OECD, COR&DIP© database v.1., 2017.

Top corporate R&D investors behave very differently when bringing new goods and services onto the market and branding them so that consumers can recognise and purchase them. This is exemplified by the figures for sales per trademark registered, which show significant variations both within and across industries and markets. The within-industry figures vary greatly at the extremes of the distribution, as illustrated by the 25-75th percentile range. In 'Mining', 'Telecommunications' and 'Finance & insurance', companies in the third quartile have a net sales to trademark ratio that is more than 10 times higher than that of companies in the first quartile. With a median sale to trademark ratio of EUR 3,249 million, 'Electricity, gas & steam' is well above the other sectors, whereas for 'Scientific R&D' the median value is the lowest in the sample. In addition, firms in ICT industries emerge as a heterogeneous group, with 'Telecommunications' displaying trademark intensity above the 'All industries' ratio, whereas the opposite holds true for 'Computers & electronics'. For these two industries, and unlike 'Publishing & broadcasting' and 'IT services', a similar pattern emerges when IP intensities based on patents and registered designs are considered.

The competitiveness and success of firms increasingly depend on their ability to innovate, create and diversify their products from those of their competitors and to identify and exploit new market opportunities. Design differentiates products in a unique manner that makes them visually appealing to consumers and is at the heart of the creative industries.

Figure 3.3 - Net sales per design of top R&D performers by industry, ISIC rev. 4, 2012-14

Million EUR per registered designs (EUIPO, JPO, USPTO), median values by industry



Note: Data refer to the total number of registered designs filed at the EUIPO and the JPO and design patents filed at the USPTO in 2012-14. 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.1., 2017.

Large variation in the net sales per registered design can be observed in many industries, both above and below ‘All industries’ median values. Examples of industries belonging to the former category include ‘Mining’, ‘Electricity, gas & steam’ and, to a lesser extent, ‘Telecommunications’. Median values in the industries on the left-hand side range from EUR 853 million per registered design in ‘Transport equipment’ to more than EUR 37,000 million in ‘Mining’. Among industries on the right hand side of the distribution, ‘Basic metals’ displays by far the greatest dispersion.

Overall, few industries show consistent behaviours in terms of patents, trademarks and registered designs. Industries such as ‘Computers & electronics’ and ‘Electrical equipment’ exhibit above-sample-median propensities to rely on the three IP rights considered. On the other side of the spectrum, ‘Telecommunications’, ‘Mining’, ‘Finance & insurance’, ‘Electricity, gas & steam’ and ‘Wholesale, retail, repairs’ consistently have relatively low levels of IPs filings. Finally, top R&D investors in a number of industries show divergent patterns across the different IPs types. This is the case, for instance, for top R&D investors operating in the ‘Pharmaceuticals’ and ‘IT services’ industries, having some of the highest R&D investments per patent, but with much lower ratios of sales to trademarks and designs. Conversely, ‘Machinery’ appears at the very bottom of the distributions of R&D investment per patent and sales per design, while it ranks higher than the ‘All industries’ median in the case of sales per trademarks.

3.3 The value of IP

The descriptive evidence provided thus far suggests the existence of significant differences between firms in the same industry and across industries in terms of the extent to which IP rights are used to appropriate the returns from investment in R&D. This section sheds further light on the quality of patents and the scope of trademarks and registered designs across industries, as more does not necessarily mean better. Quality is here intended to mean the technological and prospective economic value of patented inventions.

As it is almost impossible to obtain systematic information about market transactions involving patents or about the actual use of technologies, a number of indicators relying on information contained in patent documents have been developed (see Squicciarini et al., 2013). Some of these indicators, namely patent family size and patent scope, are used here to provide some information about the value of patented inventions (see Box 3.2). Patent family size is an indicator that closely relates to the economic value of an invention, whereas patent scope relates to its technological complexity. Trademark and design scope indicators were constructed in a similar way to that in which patent scope indicators were calculated, by means of counting the Nice and Locarno classes, respectively, for which they were registered. Indicators of the scope of trademarks and designs provide information on the breadth and differentiation of companies' products.

The statistics shown in previous parts of this report suggest that firms in ICT-related industries behave somewhat differently from firms in other industries. To assess whether ICT-related patents also intrinsically differ from patents in other fields, Figures 3.4a and 3.4b present statistics based on ICT and non-ICT patent families, for the period 2012-2014 (see Annex F for the definition of ICT-related patents). Due to data limitations, the analysis is restricted to EPO and USPTO patent family members.

Box 3.2. The quality of patents

The proposed indicators rely on a set of information contained in patent documents. To account for possible variations over time and for technology-specific features, indicators are normalised using information from the same cohort, that is, patents filed in the same technological field or fields in the same year. Due to differences in the rules and regulations of patent offices (e.g. patent classification systems, citation procedures, etc.), indicators based on EPO patents shall not be directly compared with those derived from, for example USPTO patents.

Family size

The economic value of a patent has been found to be associated with the number of jurisdictions in which the patent has been sought, that is, with their patent family size. Large international patent families have been found to be particularly valuable. According to the Paris Convention (1883), applicants have up to 12 months from the first filing of a patent application to file applications in other jurisdictions regarding the same invention and claim the priority date of the first application.

The normalised patent family size index shown here refers to the number of patent offices at which a given invention has been protected.

Patent scope

The technological breadth of patents in a firm's portfolio has been shown to be strongly associated with the value of inventions: broad patents are more valuable when many possible substitutes in the same product class are available (Lerner, 1994). The scope of a patent is here defined as the number of distinct subclasses of the International Patent Classification (IPC) the invention is allocated to.

Source: Squicciarini et al. (2013)

Figure 3.4a - Relative value of ICT- and non-ICT-related patents by industry, ISIC rev. 4, 2012-14

Average family size, EPO and USPTO patents

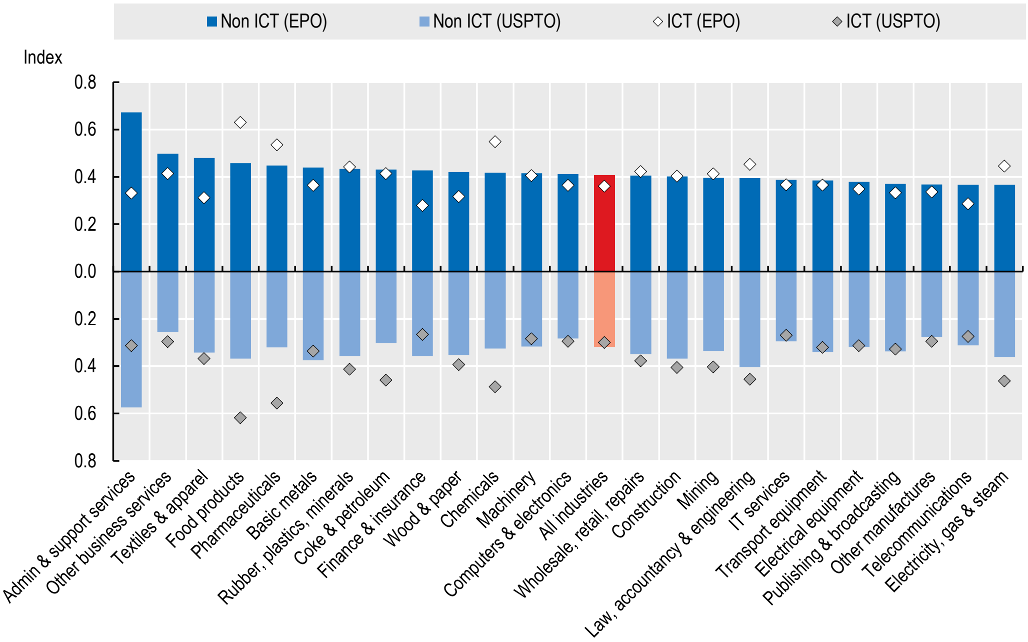
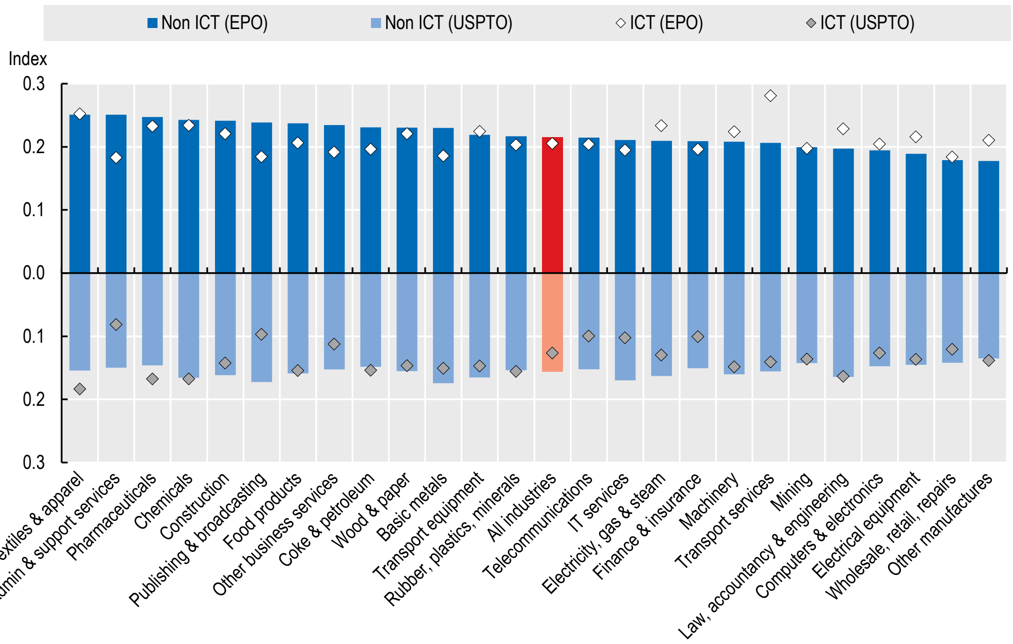


Figure 3.4b - Relative value of ICT- and non-ICT-related patents by industry, ISIC rev. 4, 2012-14

Average patent scope index, EPO and USPTO patents



Note: The data refer to patent applications filed at the EPO (top part of the charts) and to the USPTO (bottom part) that belong to IP5 patent families. The family size indices are normalised according to the maximum value observed for patents in the same cohorts (filing date and WIPO technological fields). Data relate to industries with more than 200 patents filed at the EPO and the USPTO.

Source: JRC-OECD, COR&DIP© database v.1., 2017, and OECD, STI Micro-data Lab: Intellectual Property Database, http://oe.cd/ipstats, April 2017.

The average family size of USPTO patents (shown in the bottom part of Figure 3.4a) is, in general, smaller than that of EPO patents, for both ICT and non-ICT patents. This is consistent with what was observed by Dernis et al. (2015) and could be the sign of the greater attractiveness of the US market, meaning possibly less of a need to extend coverage to other countries, or of a more inward-looking approach on the part of companies creating US-targeted inventions.

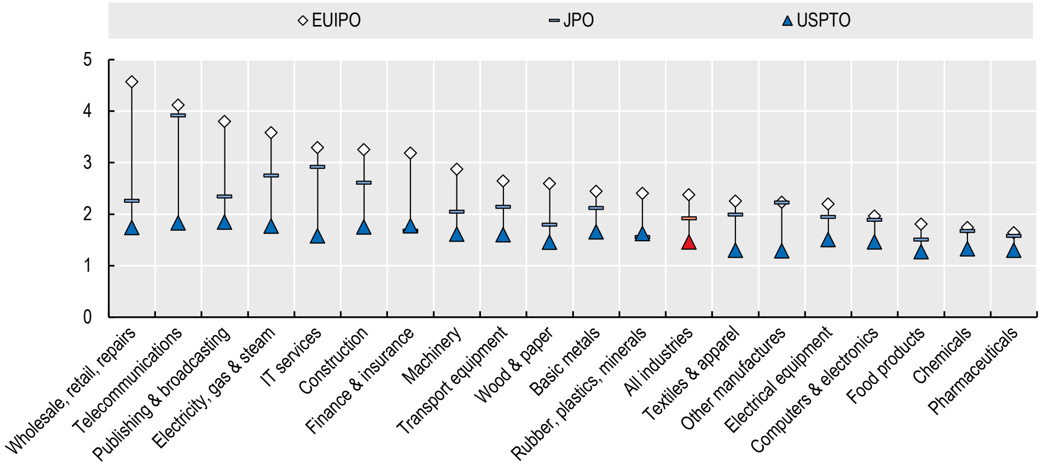
In some industries, such as ‘Food products’, ‘Pharmaceuticals’, ‘Law accountancy & engineering’ and ‘Electricity, gas & steam’, the family size of ICT patents is larger than that of non-ICT patents; and this holds true for both offices considered (Figure 3.4a). The opposite seems to apply to ‘Admin & support services’ and ‘Finance & insurance’. In general, in ICT industries – ‘Computers & electronics’, ‘IT services’, ‘Telecommunications’, ‘Publishing & broadcasting’ – ICT-related patent families are of a size equal to or smaller than those of non-ICT-related technologies. ICT and non-ICT patent families owned by top R&D investors operating in ‘Machinery’, ‘Electrical equipment’ and ‘Transport equipment’ are of similar value.

In terms of patent scope, ICT-related patents overall have a slightly narrower scope than patents in other fields, as can be seen from the average scope indices for ‘All industries’ (Figure 3.4b). Marked variability is observed across industries, especially when considering ICT-related patents filed at the EPO. Industries such as ‘Transport equipment’, ‘Electricity, gas & steam’, ‘Machinery’, ‘Transport services’ and ‘Electrical equipment’, generally have a wider technological scope in the case of ICT patents filed at the EPO.

Figure 3.5 reports, for each industry, the average number of product classes per trademark application observed at the EUIPO, the JPO and the USPTO. The statistics confirm the heterogeneous behaviour of companies both at the industry and the market levels. In general, inter-industry variability and trademark scope appear to be lowest at the USPTO (i.e. between one to two classes per application). The higher averages observed in the case of the EUIPO may nevertheless relate to the fact that this office offers the possibility applying for up to three trademark classes with a unique binding fee.

Figure 3.5 - Average number of classes per trademark, by industry, ISIC rev. 4, 2012-14

NICE classes per trademark, EUIPO, JPO and USPTO



Note: The data refer to NICE classes for which trademarks are registered. Data relate to industries with more than 100 trademarks filed at the EUIPO, the JPO and the USPTO.

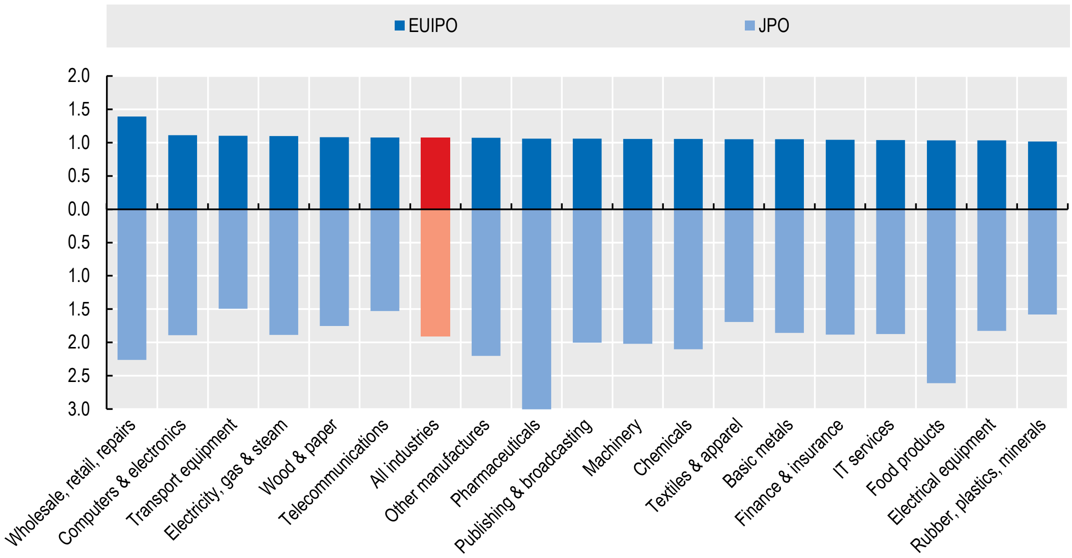
Source: JRC-OECD, COR&DIP© database v.1., 2017.

A closer look at the differences emerging across industries reveals that, among the three main ICT industries, companies in 'Telecommunications' and 'IT services' own trademarks covering a broader range of classes than those owned by companies in 'Computers & electronics'. At the other end of the spectrum, firms in 'Pharmaceuticals' and 'Chemicals' industries tend to register trademarks more narrowly, for fewer than two trademarks featuring less than 2 classes per application.

A similar design scope measure is proposed in Figure 3.6, which shows the average number of Locarno classes per design registration at the EUIPO and the JPO for the period 2012-14. Industries are ranked according to the average number of design classes specified in the EUIPO registration. While the design scope at EUIPO is quite homogeneous across industries, marked differences by industry are observed at the JPO (shown in the bottom part of Figure 3.6). In the latter office, 'Pharmaceuticals', 'Food products', 'Wholesale, retail, repairs' and 'Other manufactures' stand out as having designs registered for more than 2 classes on average, whereas the 'Transport equipment' or 'Telecommunications' industries have designs registered for only around 1.5 classes.

Figure 3.6 - Average number of classes per design, by industry, ISIC rev.4, 2012-14

Locarno classes per design, EUIPO and JPO



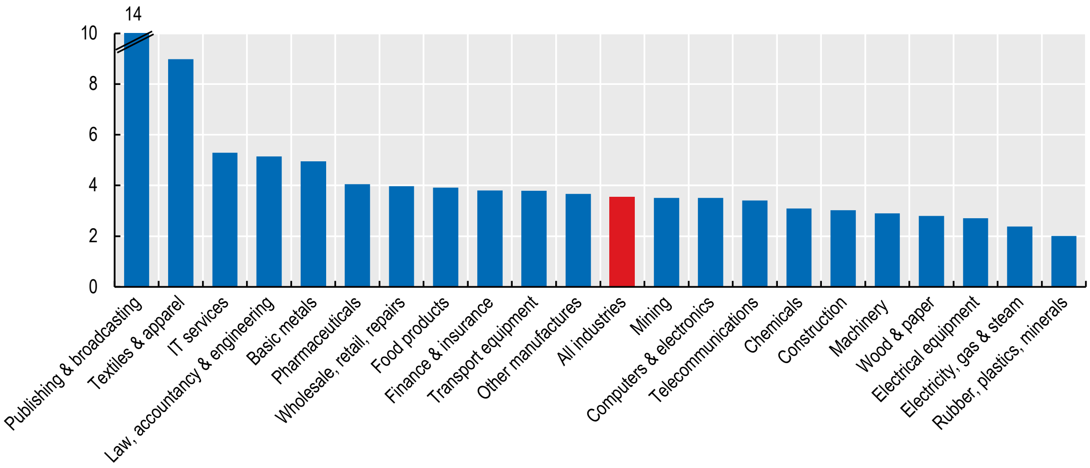
Note: Data relate to industries with at least 20 companies in the top 2000 corporate R&D sample and with at least 100 design applications at EUIPO and JPO. USPTO design patents contain only one Locarno class.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

A measure of the value of designs can also be obtained by looking at the number of individual designs contained in each registered design. Figure 3.7 shows that industries differ substantially in the extent to which different designs are registered together. Top 'Publishing & broadcasting' R&D investors include seven times as many designs in each registration as top 'Rubber, plastics and minerals' R&D investors.

Figure 3.7 - Average number of designs per design registration, by industry, ISIC rev. 4, 2012-14

EUIPO registered designs



Note: Data relate to industries with more than 100 designs filed at the EUIPO.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Furthermore, top R&D investors in the 'Textiles & apparel' stand out in terms of number of designs per registration; in this industry, a greater number of views is used to represent a single product.

3.4 IP "concentration"

In addition to looking at corporate IP portfolios in terms of both size and quality, interesting insights can be gained by analysing the technological and product diversification strategies of top corporate R&D investors worldwide.

To this end, statistics based on the Concentration ratio 4, CR4 index, are used. The CR4 index is constructed by synthesising the proportion of IP rights that companies in a given industry *I* file in the top four technology classes referred to in their patent applications. The CR4 for each industry *I* is calculated as follows: $CR_{4,I} = \sum_{n=1}^{4} s_n$. Where s_n denotes the share of the n^{th} IP classes over the total IP rights and 4 is the number of classes considered (ranked in descending order) to compute the index. Patent indicators rely on statistics based on technological classes grouped using the 35 technological fields identified in WIPO (2013). Trademark concentration ratios use the 45 classes of the Nice classification, while design indicators are based on the 32 Locarno classes (see Box 3.3).

Box 3.3 Classifying IP rights

Patents, designs and trademarks are classified by the IP offices during the examination procedure (in the case of patents) or the registration process (for designs and trademarks), according to international standards.

International Patent Classification (IPC) codes are attributed by patent examiners to identify the technology domains to which inventions belong. (see http://www.wipo.int/classifications/ipc). The IPC divides technology into eight sections with approximately 70,000 subdivisions. In this report, IPC codes are aggregated into 35 technological fields, according to the concordance proposed by WIPO (2013).

The **Locarno Classification** is an international classification used for the registration of industrial designs: it comprises 32 classes and 219 subclasses, with explanatory notes, combined with a list of goods that constitute industrial designs (see http://www.wipo.int/classifications/locarno/en/).

Trademarks are filed according to the International Classification of Goods and Services, also known as the **Nice Classification (NCL)**, which consists of 34 classes covering a wide range of goods and 11 classes relating to services (see: http://www.wipo.int/classifications/nice/en/).

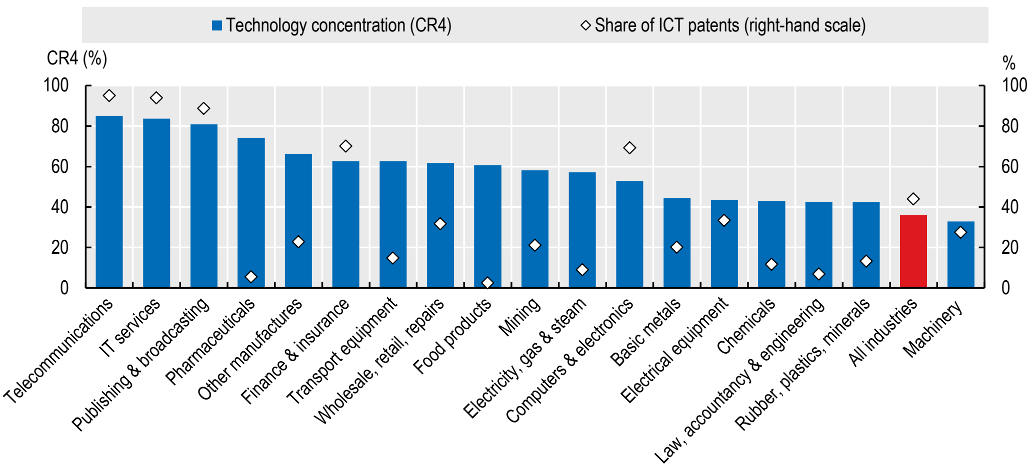
Figure 3.8 shows the extent to which top R&D investors worldwide diversify their technological activities. Data refer to concentration indices for those industries with at least 25 company headquarters in the sample.

'Telecommunications', 'IT services' and 'Publishing & broadcasting' industries present the highest CR4 values in terms of technological concentration, filing more than 80% of their patents in four technology areas. 'Pharmaceuticals', 'Other manufactures', 'Finance & insurance', 'Transport equipment', 'Wholesales, retail, repairs' and 'Food products', follow in terms of the concentration of their inventive activities in selected areas, with CR4 values above 60%.

'Telecommunications', 'IT services', and 'Publishing & broadcasting' industries also have the highest share of ICT patents, suggesting that these industries are not only very specialised but also very much focused on ICT-related technologies. A high degree of ICT specialisation is also observed in 'Computers & electronics' and 'Finance & insurance'.

Figure 3.8 - Technological concentration and share of ICT patents, by industry, ISIC rev. 4, 2012-14

Technological concentration (CR4) and share of ICT patents in companies' portfolio



Note: Data relates to industries with at least 25 company headquarters in the top 2,000 corporate R&D sample having filed patents in 2012-14. The technological concentration figures reflect the composition of companies' patent portfolios in relation to the 35 technological fields defined by WIPO (2013).

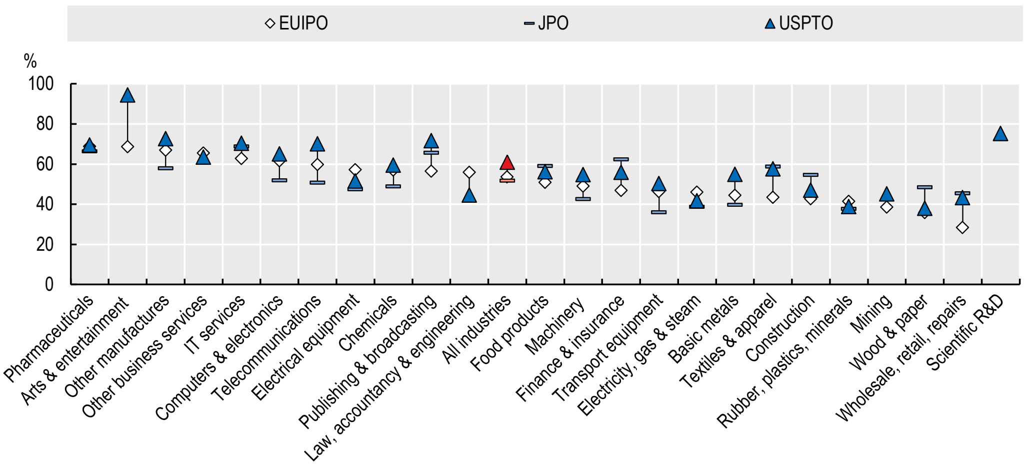
Source: JRC-OECD, COR&DIP© database v.1., 2017.

Among the latter industries, 'Pharmaceuticals' and 'Food products' have the lowest shares of ICT patents, about 5% and 2% of companies' patent portfolios, respectively. Other industries, such as 'Transport equipment' and 'Chemicals', also develop relatively few ICT-related innovations, as indicated by the shares of ICT patents in these companies' portfolios. Of the industries considered, 'Machinery' shows particularly low CR4 values (below 40%), thus emerging as the least concentrated industry among those accounting for a high number of top R&D investing companies. Nonetheless, firms in this industry tend to rely quite significantly on ICT-related technology development. The same holds true for 'Electrical equipment', where about 40% of innovations can be related to four technological fields.

Much less variation is observed in terms of trademark concentration indices (Figure 3.9a), as compared with the distribution of design registrations (Figure 3.10a). Figure 3.9a shows that 'Pharmaceuticals', 'Arts & entertainment', 'Other manufactures', 'Other business services' and 'IT services' do not diversify their brands very much. In these industries, the top trademark classes account for more than 60% in at least two of the three selected offices.

Figure 3.9a - Product diversification, by industry, ISIC rev. 4, 2012-14

Top four trademark classes in companies' portfolios (CR4), by IP office



Note: Data relates to industries with at least 20 company headquarters in the top 2,000 corporate R&D sample having filed for at least 100 trademarks in 2012-14. Product diversification (CR4) is calculated as the share of the top four Nice classes in trademarks owned by companies in a given industry. Industries are ranked according to the CR4 values observed for EUIPO trademarks.

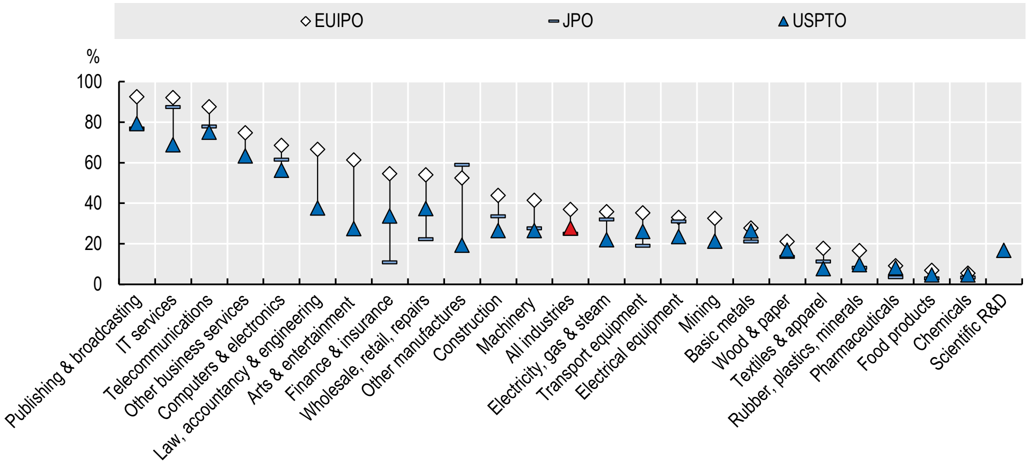
Source: JRC-OECD, COR&DIP© database v.1., 2017.

As it might be expected, companies in ICT industries have much higher shares of ICT-related trademarks (above 55%, irrespective of the IP office considered).[8] This group of industries also stands out in terms of ICT designs. Moreover, in the majority of industries, companies often register more than 20% of their trademarks in ICT-related classes. Finally, Figure 3.9b shows very low ICT trademark shares for 'Pharmaceuticals', 'Food products' and 'Chemicals' companies (i.e. less than 10% in all offices).

[8] See Annex F for a definition of ICT related trademark and design.

Figure 3.9b - Shares of ICT trademarks in companies' portfolios, by industry, ISIC rev. 4, 2012-14

IP offices, percentages



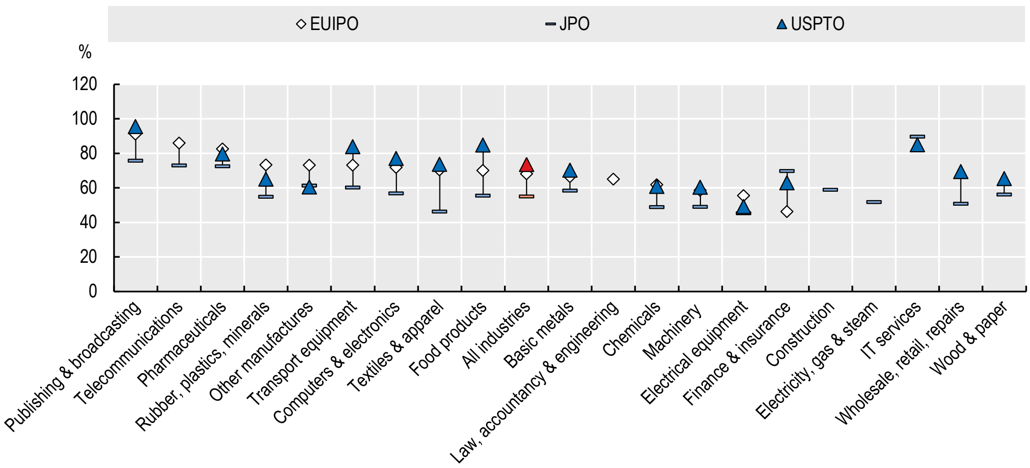
Note: Data relates to industries with at least 20 companies' headquarters in the top 2,000 corporate R&D sample having filed for at least 100 trademarks in 2012-14. Industries are ranked according to the share of ICT trademarks in all EUIPO trademarks.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

All in all, on average more than 25% of the trademarking activities of top R&D investors relate to four trademark classes (Figure 3.9a), whereas in the case of registered designs the equivalent figure is much higher: 45% of top R&D investors' designs are registered for four classes, regardless of the office and industry in question.

Figure 3.10a - Design diversification, by industry, ISIC rev. 4, 2012-14

Top four design classes in companies' portfolios (CR4), by IP office



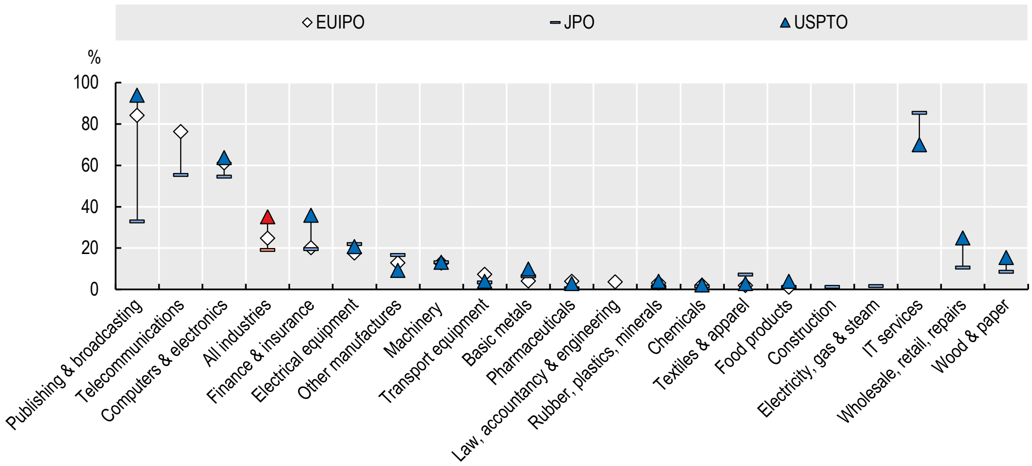
Note: Data relates to industries with at least 20 company headquarters in the top 2000 corporate R&D sample having filed for at least 100 designs in 2012-14. Design diversification (CR4) is calculated as the share of the top four Locarno classes (at two-digits) in designs owned by companies in a given industry. Industries are ranked according to the CR4 values observed for EUIPO designs.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

In terms of registered designs, the most concentrated industries are 'Publishing & broadcasting', 'Telecommunications', 'Pharmaceuticals' and 'IT services', with CR4 values above 70% (Figure 3.10a). Among these, only 'Pharmaceuticals' and 'IT services' are also among the industries with the highest values for trademark-based concentration. In contrast, ‘Publishing & broadcasting’ and ‘Telecommunications’, the two most concentrated industries in terms of design classes, have relatively diversified trademark portfolios.

Figure 3.10b - Shares of ICT designs in companies' portfolio, by industry, ISIC rev. 4, 2012-14

IP offices, percentages



Note: Data relate to industries with at least 20 company headquarters in the top 2,000 corporate R&D sample having filed at least 100 designs in 2012-14. . Industries are ranked according to the share of ICT designs in all EUIPO designs.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Although to a much lesser extent than ICT industries, ‘Finance & insurance’ and ‘Electrical equipment’ have significant shares of ICT designs in their portfolios: above 20% in at least two of the offices considered. The least ICT-oriented industries in terms of design registrations include ‘Transport equipment’, ‘Basic metals’, ‘Pharmaceuticals’, ‘Chemicals’ and ‘Food products’ (ICT-related designs represent less than 10% of the companies' portfolios). In the ‘Machinery’ industry, the share of ICT designs is approximately 13%, about half the equivalent figure for the industry’s patent portfolios. In this industry, the ICT content of the technologies developed is much higher than can be observed from product designs.

4. Innovation and diversification strategies of top R&D investors

Key findings

- Top R&D investors based in EU, US and Japan exhibit a broader technological knowledge base than their Korean and Chinese counterparts, which are highly specialised in ICT technologies.
- European and US companies have technological advantages in a number of fields that are fundamental for addressing major societal challenges such as health or the environment.
- More than half of top R&D investors use the full IP bundle (patent, trademark and design). However, IP strategies change depending on the target market considered and the industry in which companies operate.
- The combination of patents and trademarks is a common R&D output appropriation strategy, and is especially used by top R&D investors in 'Scientific R&D' and 'Pharmaceuticals' industries.
- Companies in the 'Computer & electronics' industry register, by far, the greatest number of IP rights and account for about one third of total IP filings of top R&D investors. Other IP-intensive industries include 'Transport equipment', 'Machinery' and 'Chemicals'.

4.1 Technological profiles and specialisation strategies of top R&D investors

The indicators considered in this chapter provide further evidence about the extent to which top corporate R&D investors worldwide diversify their patent, trademark and design activities and how they use IP rights bundles, that is, the joint use of patents, trademarks and designs. In addition, this chapter offers some insights into the innovative activities – that is, patented technologies, trademark-protected brands and designs – of top corporate R&D investors worldwide in the ICT space, to shed some light on the digital transformation of leading firms and industries worldwide.

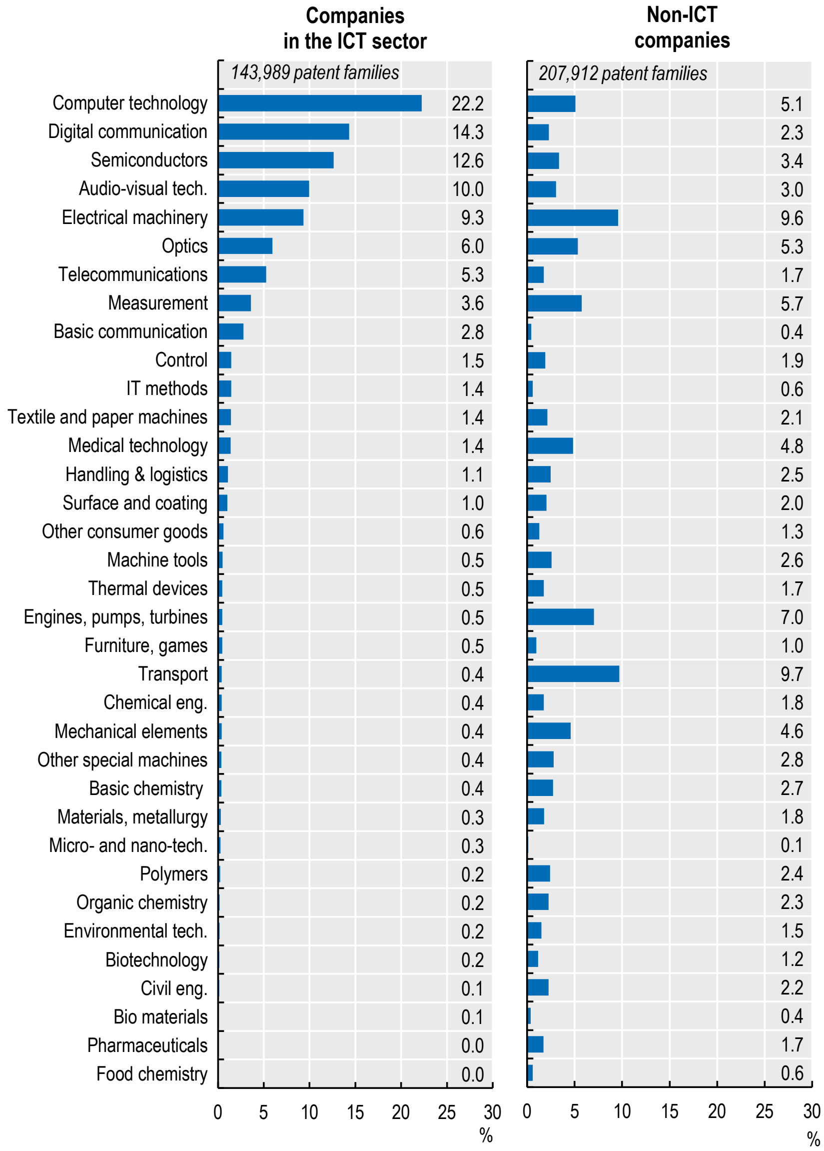
Making use of information contained in patent documents, it is possible to identify the main technological fields in which top corporate R&D investors focus their innovative activities. The different technology areas that patented inventions pertain to are classified on the basis of the International Patent Classification (IPC). To assist in the interpretation and characterisation of the technology-related activities of companies, in this report IPC classes are grouped into 35 technological fields (WIPO, 2013, see Annex D). A novel ICT technology taxonomy based on IPC patent classes (Inaba and Squicciarini, 2017) is used, as are OECD methodologies (OECD, 2015) identifying ICT-related trademarks and designs (see Annex F).

Figure 4.1 details the extent to which top R&D investors in ICT and non-ICT industries filed patents in different technological fields during the period 2012-14. Technological fields are ranked, in decreasing order, following the positions emerging in the left-hand panel, that is, the one based on the patent families owned by ICT companies. As expected, top R&D investors in the ICT sector mainly focused on developing ICT technologies, especially in *Computer technology*, *Digital communications*, *Semiconductors* and *Audio-visual technologies*. Almost a quarter of ICT companies' patent families relate to

Computer technology (22%). Each of the three other technology areas mentioned above accounts for at least ten percent of the patent portfolios of top corporate R&D investors active in ICT industries. These patterns confirm the importance of ICT technologies, an emerging trend reported by Dernis et al. (2015). Although to a lesser extent, top R&D investors operating in the ICT sector also show significant levels of inventive activities in the fields of *Electrical machinery* (9.3%) and *Optics* (6.0%).

Figure 4.1 - Technological diversification of ICT and non-ICT companies, 2012-14

Shares of patents owned by industries in technological fields, percentages



Source: JRC-OECD, COR&DIP© database v.1., 2017.

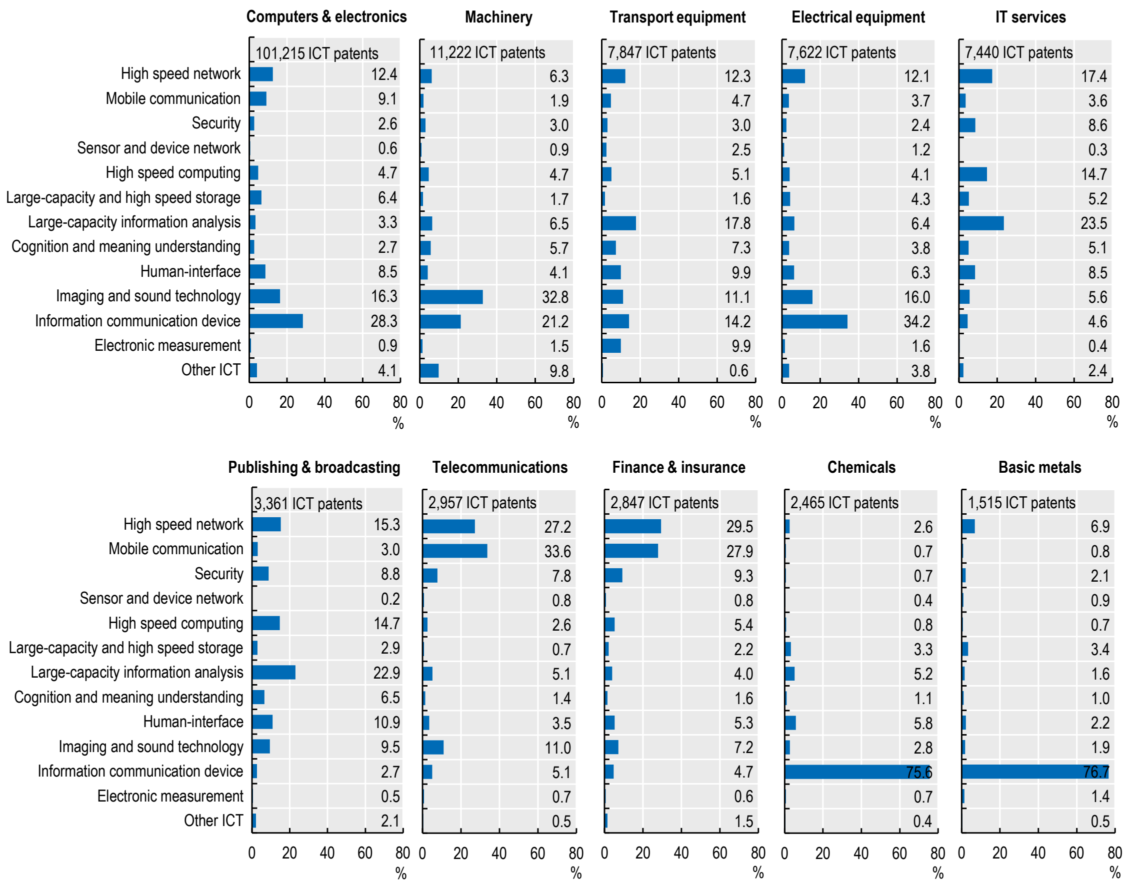
Non-ICT industries, which account for a heterogeneous group of firms, mainly focus their inventive activities in technological fields such as *Transport*, *Electrical machinery*, *Engines, pumps and turbines* and, to a lesser extent, *Measurement*, *Optics* and *Computer technology*. All these technology areas account for between 5% and 10% of the patent families of world-leading R&D investors operating in non-ICT industries. A wide range of industry-, firm- and technology-specific characteristics, including diversification strategies may contribute to explaining the differences observed.

Figure 4.2 further breaks down the ICT-related technological activities of top R&D investors in the 10 industries most active in ICT over the period 2012-14.

In terms of absolute numbers of patent families, ‘Computers & electronics’ emerges as the most active industry, and exhibits almost 10 times as many ICT patents as ‘Machinery’, the second most important industry in this respect. Among ICT-related technologies, *Information and communication device*, *Imaging and sound technology* and *High-speed network* rank more frequently at the top. In a number of industries, including ‘Computers & electronics’, ‘Electrical equipment’, ‘Publishing & broadcasting’, ‘Chemicals’ and ‘Basic metals’, the highest share of patents is filed in relation to *Information and communication devices*. These include ICT sub-classes[9] such as electronic circuits, cable and conductors, semiconductors and optic devices. In the case of ‘Chemicals’ and ‘Basic metals’, the share of ICT patents related to *Information and communication device* even exceeds 75% of the total ICT patenting in the industry.

Figure 4.2 - ICT technology profile of the top 10 industries patenting in ICT, ISIC rev. 4, 2012-14

Shares of ICT patents owned by industries in ICT areas, percentages



Source: JRC-OECD, COR&DIP© database v.1., 2017.

[9] See Annex F for the definition of ICT related patents and the related sub-areas.

'Computers & electronics', 'Machinery' and 'Electrical equipment' show similar ICT-related profiles in terms of distribution of patents across ICT sub-areas. In these industries, *Information and communication device*, *Imaging and sound technology*, *High speed network* account for the majority of innovation efforts in ICT related technologies. In contrast firms operating in 'Transport', 'IT services' and 'Publishing and broadcasting' focus to a greater extent on the development of *Large-capacity information analysis*, whereas *Mobile communication* and *High speed network* rank the highest in the 'Telecommunications' and 'Finance & insurance' industries. In addition, within ICT technology development, heterogeneity arises across industries in terms of the specific technologies that firms seem to master.

To shed further light on the technological specialisation of top R&D investors, revealed technological advantage (RTA) indicators have been compiled at the country level (or geographical area level, in the case of Europe). Companies are assigned to the country or area where their headquarters are located. The RTA index is defined as the share of patents in a particular technological field generated at the country/area level over the share of patents in the same technological field filed at a global level:

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

where ps_{it} represents the number of patents of a country or area i in technological field t. The numerator represents the share of patents filed in technological field t over the total number of patents filed in the country or area i, whereas the denominator represents the share accounted for by patents in technology t over all patents. The index is equal to 0 when the country or area where the headquarters is based holds no patent in a given technology; has a value between 0 and 1 when a country or area exhibits a share that is lower than that observed at the global level (no specialisation); is equal to 1 when the area's share in a technology equals the share at the global level; and has a value above 1 when the share is higher, indicating that the country or area is relatively specialised in the technology in question.

Interesting insights emerge when comparing the specialisation patterns of different countries or areas. These are displayed in Table 4.1, which reports the RTAs for Europe, the US, Japan, Korea, China and the rest of the world for the period 2012-14. RTA values greater than 1 (indicating specialisation) are marked in blue. To provide additional insights into technology specialisation patterns over time across the different countries and areas considered, upward and downward arrows underline positive and negative variations, respectively, that are greater than 5% of the initial value. Changes over time are calculated by comparing the RTA indices in the 2010-12 and in the 2012-14 periods.

Top corporate R&D investors headquartered in Europe, the US and, to a lesser extent, Japan specialise in a relatively high number of technologies. This suggests the possible existence of technological advantages in fields requiring a broader range of competences and corporate strategies pursuing broader technological diversification. In contrast, top R&D investors headquartered in Korea and China are much more specialised, with activities focused on ICT-related technologies. A similar pattern emerges also in the case of top corporate R&D investors located in the rest of the world.

Table 4.1 - RTAs by geographical location of the headquarters, 2012-14

Revealed technology advantages and changes compared with the 2010-12 level

Field of Technology	Europe	United States	Japan	Korea	China	Rest of the World
Electrical machinery	1.0	0.6	1.1 ↗	1.3	0.4 ↘	1.1
Audio-visual tech.	0.4 ↗	0.6 ↗	1.1 ↘	1.7 ↗	1.4 ↗	2.0
Telecommunications	0.7	0.8 ↗	1.1	1.2 ↘	1.9 ↘	1.5 ↗
Digital communication	0.9 ↘	1.3 ↗	0.6	1.2	3.9 ↘	0.9 ↘
Basic communication	0.7	1.2 ↗	0.9 ↘	1.1 ↗	0.5 ↘	1.8
Computer technology	0.5	1.1 ↘	0.8	1.6 ↗	1.9 ↗	1.8
IT methods	0.8 ↘	1.7	0.7	0.9 ↘	2.0 ↗	0.8 ↘
Semiconductors	0.5 ↗	0.6 ↘	1.0	1.9	1.2 ↗	1.8 ↗
Optics	0.3 ↗	0.4 ↘	1.7	1.0 ↘	1.4 ↗	1.2 ↗
Measurement	1.5	1.2	0.9	0.6 ↗	0.4 ↗	0.7 ↘
Bio materials	1.6	1.4 ↘	0.8	0.6 ↗	0.1 ↗	0.2 ↗
Control	1.2 ↘	1.1 ↘	1.0 ↗	0.5 ↗	0.5 ↘	1.2 ↘
Medical technology	1.6	1.3 ↘	0.9	0.5 ↗	0.1 ↗	0.2 ↗
Organic chemistry	1.9	1.3 ↘	0.6	0.4 ↗	0.3 ↘	0.4 ↗
Biotechnology	1.8	1.5 ↘	0.6	0.7 ↗	0.1 ↘	0.2 ↘
Pharmaceuticals	2.0	1.5 ↘	0.5	0.3 ↗	0.2 ↗	0.8 ↗
Polymers	1.1 ↘	0.9	1.2 ↗	0.5 ↘	0.2 ↘	0.8 ↗
Food chemistry	1.9 ↘	1.7 ↘	0.6 ↗	0.2 ↘	0.1 ↗	0.2 ↗
Basic chemistry	1.2 ↘	1.4 ↗	1.0	0.4 ↘	0.4 ↗	0.4 ↗
Materials, metallurgy	1.2	0.9 ↗	1.3	0.6 ↗	0.5 ↗	0.4 ↗
Surface and coating	0.9 ↗	1.1	1.2 ↗	0.7	0.4 ↗	0.7 ↘
Micro- and nano-tech.	1.6 ↗	1.0	0.7	0.8 ↘	0.7 ↗	1.6 ↘
Chemical eng.	1.6	1.3 ↘	0.8 ↗	0.5 ↘	0.4 ↗	0.5 ↗
Environmental tech.	1.5	1.1 ↘	1.0 ↗	0.5 ↗	0.2 ↘	0.2 ↗
Handling & logistics	1.2	0.7 ↘	1.4 ↗	0.2 ↘	0.3 ↘	0.6 ↘
Machine tools	1.4 ↘	1.1	1.1 ↗	0.3 ↗	0.2 ↘	0.7
Engines, pumps, turbines	1.4 ↘	1.7	0.8	0.4	0.1 ↗	0.3 ↗
Textile and paper machines	0.6	0.5 ↘	2.1 ↗	0.1 ↘	0.1 ↘	0.1 ↘
Other special machines	1.6 ↗	1.0 ↘	1.1	0.2 ↘	0.2 ↗	0.5 ↗
Thermal devices	1.5	0.7 ↘	1.1 ↗	0.9 ↗	0.2 ↘	0.5 ↘
Mechanical elements	1.6	1.1 ↘	0.9 ↗	0.5	0.3 ↗	0.4 ↘
Transport	1.4 ↘	1.0	1.0	0.8 ↗	0.1 ↗	0.3 ↗
Furniture, games	1.6 ↘	0.9 ↗	1.0	0.8 ↗	0.3 ↘	0.5 ↘
Other consumer goods	1.7 ↘	0.9 ↗	0.7	1.4	0.4 ↗	0.4
Civil eng.	1.4 ↘	2.2 ↗	0.5	0.2 ↗	0.4 ↘	0.3 ↘

Note: The arrow denotes a more than 5% changes in the RTA compared with the 2010-12 level.
Source: JRC-OECD, COR&DIP© database v.1., 2017.

In terms of ICT-related specialisation, companies headquartered in Japan and the US show fully complementary patterns, with no overlapping profiles. For instance, the US is relatively specialised in ICT-related fields such as *IT methods*, *Digital and Basic communications*, and *Computer technology*, while Japan is relatively specialised in *Audio-visual technology*, *Telecommunications* and *Semiconductors*. [10] Top R&D investors headquartered in Europe, conversely, appear to be relatively unspecialised in ICT technologies, with the exception of *Electrical machinery*, which has an RTA slightly above one.

[10] In the WIPO classifications, all these fields belong to *Electrical engineering*.

As already observed by Dernis et al. (2015), top corporate R&D investors headquartered in Europe and the US appear to specialise in a common set of technology areas: *Measurement*, *Bio materials*, *Control*, *Medical technology*, *Organic chemistry*, *Biotechnology*, *Pharmaceuticals*, *Food chemistry*, *Basic chemistry*, *Micro- and nano-technologies*, *Chemical engineering*, *Environmental technologies*, *Machine tools*, *Engines, pumps and turbines*, *Mechanical elements*, *Transport and Civil engineering*. Top corporate R&D investors headquartered in Europe and the US tend to specialise in a number of technologies that are fundamental for addressing major challenges such as those related to health, ageing and the environment. In the case of Europe, specialisation is quite high in fields such as *Medical technology*, *Pharmaceuticals*, *Food chemistry*, *Organic chemistry*, *Chemical engineering*, *Biotechnology* and *Environmental technologies*. In these particular fields, companies headquartered in the US have been losing ground, as indicated by decreasing RTAs.

By comparing the RTAs obtained for the top corporate R&D investors included in the present report with those reported by Dernis et al. (2015), one can appreciate the extent to which relative technological advantages have changed over time. The most pervasive changes can be seen in the case of top R&D investors headquartered in Korea, China and the rest of the world, where most technological fields exhibit variations above 5% in absolute terms. The US, Europe and Japan show variations concentrated in a relatively smaller number of technological fields. The EU shows increased specialisation in *Micro- and nano-technologies* and *Other special machines*; the US in *Digital communication*, *Basic communication*, *Basic chemistry* and *Civil engineering*; while Japan has strengthened its initial specialisation in a large number of technological fields ranging from *Electrical machinery* to *Thermal devices*.

In the case of the US, a decrease in specialisation in *Computer technology* emerges, which is counterbalanced by an increase in specialisation by Korea and China. The US also shows a decrease in specialisation in instruments-related (e.g. *Control* or *Mechanical elements*) technological fields and other fields in the broad area of Chemistry, including *Organic chemistry*, *Biotechnology*, *Pharmaceuticals* and *Food chemistry*. R&D investors headquartered in Europe saw their RTA in *Digital communications* decrease, compared with the 2010-12 period. Similar patterns for Europe can also be observed in the case of chemistry-related technological fields, such as *Polymers*, *Food chemistry* and *Basic chemistry*, and in Mechanical engineering, including *Machine tools*, *Engines, pumps and turbines* and *Transport*. However, Europe maintains a relative advantage in these fields, as illustrated by RTAs greater than 1.

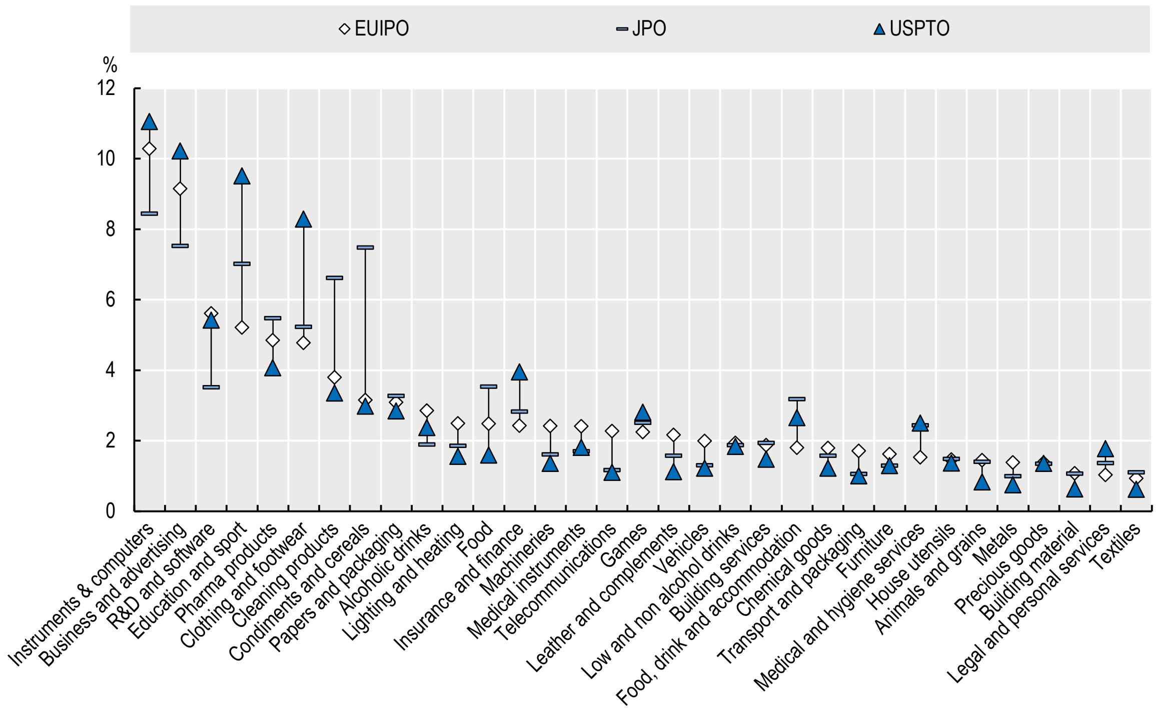
Interestingly, Korea-based top R&D investors show the broadest specialisation in ICT-related technological fields. However, they seem to have lost some advantage in complementary areas such as *Micro and nano-technologies* (Dernis et al., 2015). Top R&D investors headquartered in China have broadened their ICT specialisation, as illustrated by greater RTAs in fields such as *Audio-visual technology*, *IT methods*, *Semiconductors* and *Computer technology*.

4.2 The brand differentiation strategies of top R&D investors: trademarks

Analysing information on the product classes for which top R&D investors register their trademarks allows getting some insights into the market strategies that these companies pursue when bringing one or more novel goods or services onto the market. The international Nice Classification differentiates between goods-related (Classes 1-34) and services-related (Classes 35-45) trademarks (see Box 3.3 in Chapter 3).

The distribution of applications by Nice class, shown in Figure 4.3, allows an assessment of the extent to which top corporate R&D investors use trademarks to differentiate their goods and/or services in order to try and steer customers' choices.[11] In addition, it provides some information about the possible country-specific product differentiation strategies that top corporate R&D investors pursue.

Figure 4.3 - Distribution of trademark applications by Nice class, 2012-14



Note: Classes are ranked according to EUIPO figures. Classes' titles correspond to short labels based on the International Classification of Goods and Services for the Purposes of the Registration of Marks (Nice Classification). Only classes representing more than 1% of Trademarks in the IP offices are included. For an exact description of the classes, see www.wipo.int/classifications/nivilo/nice/index.htm

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Two product classes, namely *Instruments and computers* (*class 9*) and *Business and advertising (class 35)* are consistently designated in at least 7% of top corporate R&D investors' trademark applications at the three IP offices considered. At the USPTO and the EUIPO, at least 20% of filings are associated with these two classes. In addition to *Business and advertising*, *Education and sport (class 41)* appears among the most used classes: at least 5% of applications - up to 9% at the USPTO - are filed in this latter class.

[11] A fractional counting method was employed to compute the share of product classes designated in applications for trademarks. For example, each class was counted as 0.25 in an application that designated four classes.

Furthermore, *R&D and software* (*class 42*) also emerges as an important trademark class for top corporate R&D investors, to a greater extent at the EUIPO and the USPTO than at the JPO.

At the JPO, goods-related classes including *Pharma products*, *Clothing and footwear*, *Cleaning products* and *Condiments and cereals*, have trademark applications shares above 5%. At the USPTO, 8% of trademark applications also mention *Clothing and footwear*, while the share at the EUIPO is relatively low. Finally, *Pharma products* also constitute a non-negligible share of top corporate R&D investors' trademark applications at the three offices.

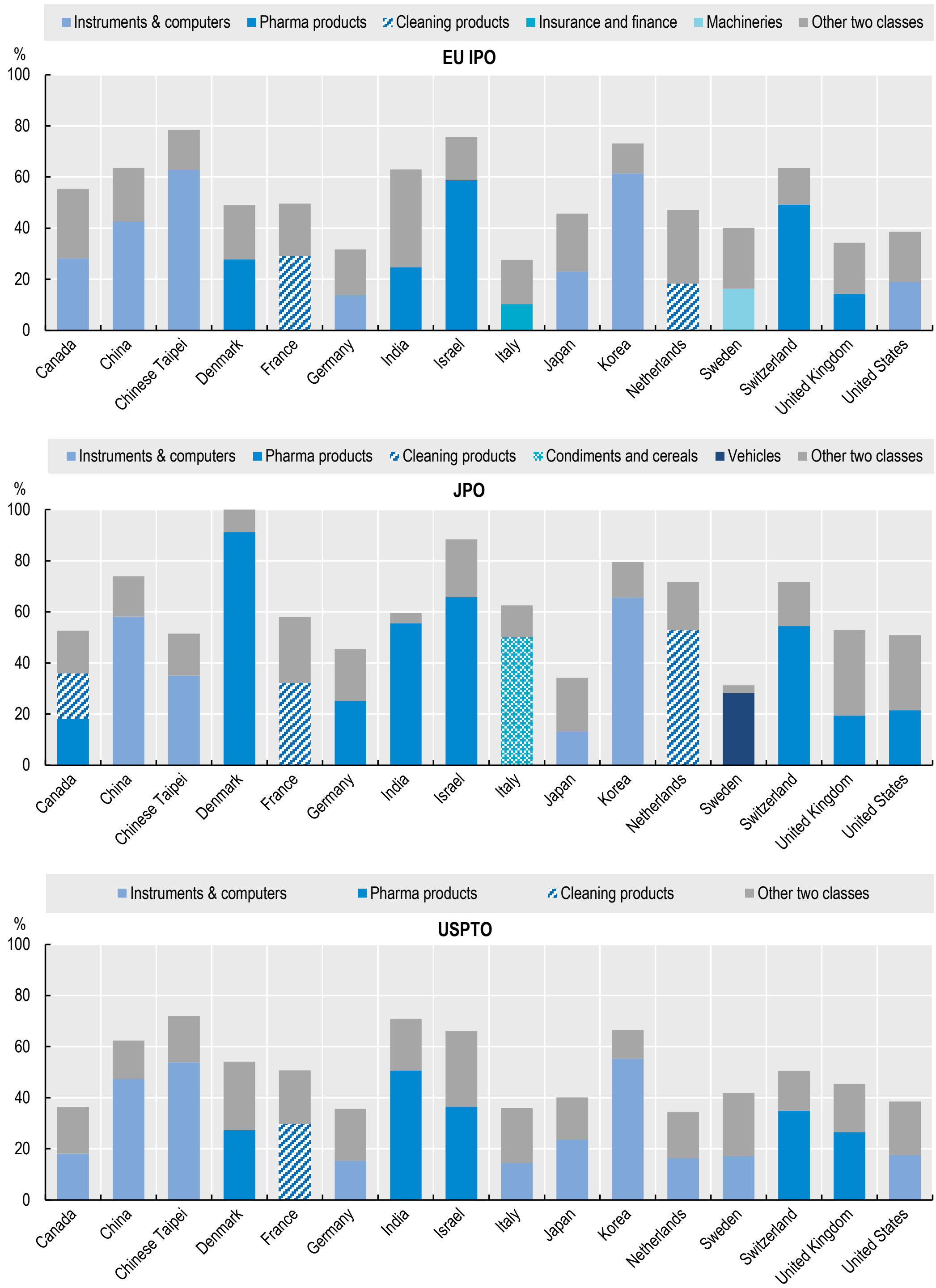
Figure 4.4 details, by headquarters' location, the top three Nice trademark classes and their respective cumulative shares at the EUIPO (top panel), the JPO (central panel) and the USPTO (bottom panel). As might be expected, a few classes show up frequently. In particular, *Instruments and computers, Pharma products and Cleaning products*, appear among the top classes in all three offices considered. Other trademark classes feature strongly at the EUIPO – *Insurance and finance* and *Machineries* – and at the JPO – *Condiments and cereals* and *Vehicles*. Overall, applications at the JPO appear to be particularly concentrated on the top three trademark classes, while differences are less marked between the EUIPO and the USPTO. A higher concentration on the top field or the two top fields is often found at the EUIPO or the JPO. Companies from Chinese Taipei, Israel and Korea (at the EUIPO), and China, Denmark, Israel and Korea (at the JPO) appear to designate one product class for about 60% or more of their applications. Conversely, this percentage never exceeds 60% at the USPTO.

Top R&D investors headquartered in China, Chinese Taipei and Japan always have *Instruments and computers* among the top two classes in their trademark applications, regardless of the office considered. This strong focus on ICT seems to reflect what was previously observed in terms of technology development. Canada, Germany and the US also often refer to *Instruments and computers* in their trademark applications. *Pharma products* are the most frequently designated class for companies based in Denmark, India, Israel, Switzerland and the UK. Conversely, corporate R&D investors based in France and the Netherlands file the greatest share of trademark applications in *Cleaning products*. This class is the most designated class for corporations headquartered in France, regardless of the office where protection is sought, while it represents more than 50% of trademarks registered at the JPO by Netherlands-based companies.

At the USPTO, *Instruments and computers* is the most designated class for top corporate R&D investors headquartered in at least 10 countries. Top R&D investors seeking trademark protection in the US market show a relatively narrower focus, in terms of top targeted trademark classes, than those seeking protection in Europe and Japan. At the USPTO, *Pharma products* is the most frequently designated class for companies headquartered in Denmark, India, Israel, Switzerland and the UK. Pharma *products* is also the most designated class at the JPO (for eight countries), followed by *Instruments and computers* and *Cleaning products*.

Figures 4.4 - Top international classes in trademark applications, by headquarters' location, 2012-2014

Shares of top three NICE classes in trademarks and top NICE class, by office



Note: Data relate to countries with at least 20 companies in the top 2000 corporate R&D sample. Only the top one NICE class in each country is coloured.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

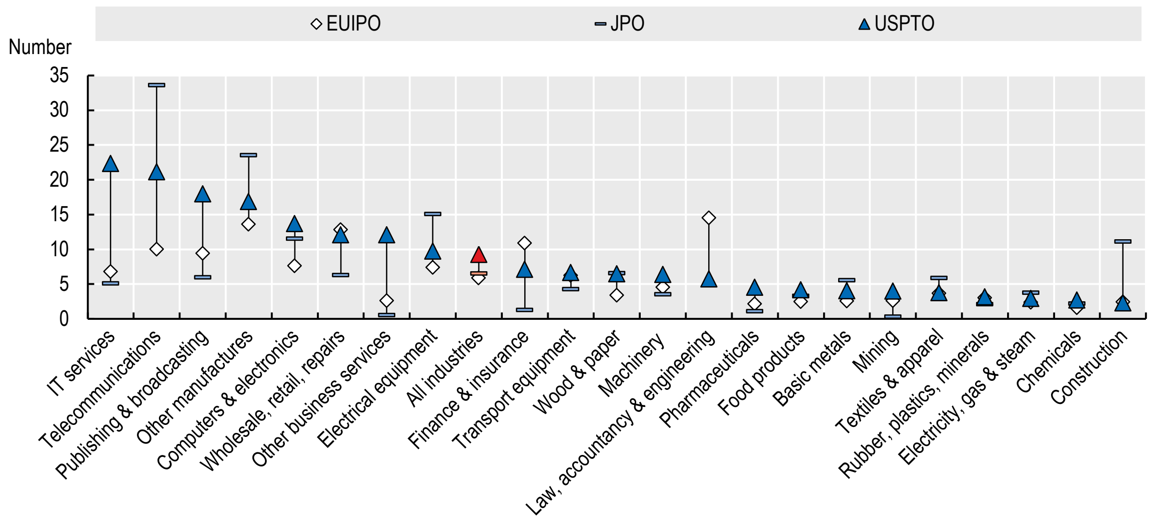
In general, for 10 out of the 16 countries shown, the same product field ranks first in terms of trademark applications filed in all the three offices. In contrast, for countries such as Canada, Germany and Italy, trademark patterns remain relatively similar at the EUIPO and at the USPTO, while they differ to a greater extent in the case of trademarks filed at the JPO. For instance, companies headquartered in Germany designate *Pharma products* most frequently at the JPO and *Instruments and computers* most frequently at the two other offices. In addition, companies headquartered in Italy undertake relatively more intense trademarking activities in *Condiments and cereals* at the JPO and in *Insurance and finance* at the EUIPO. At the other end of the spectrum, companies headquartered in Sweden show different patterns across all three offices considered. In this latter case, the most designated class are *Machineries* at the EUIPO, *Vehicles* at the JPO and *Instruments and computers* at the USPTO.

Figure 4.5 reports the average number of ICT-related trademarks in the top R&D investors' trademark portfolio. ICT-related, or digital, trademarks refer to trademark applications in *Instruments and computers (class 9)*, *Games (class 28)*, *Business and advertising* (*class 35*), *Telecommunications* (*class 38*), *Education and sport* (*class 41*) and/or *R&D and software* (*class 42*). These classes contain ICT-related keywords in the descriptions of the goods and services included therein.[12] In Figure 4.5, the numbers of digital trademarks are shown by industry and ranked according to USPTO values.

Figure 4.5 shows noticeable industrial differences in ICT-related trademarking across the three offices. Top R&D investors tend to exhibit relatively high levels at the USPTO in comparison with the levels observed at the JPO and the EUIPO. Relatively active industries in terms of ICT-related trademarks include 'Telecommunications' and 'Other manufactures' at the JPO and the EUIPO, and 'IT services' and 'Telecommunications' at the USPTO. On average, more than 20 trademarks per company refer to ICT products in these industries at the JPO and USPTO, while the figure does not exceed 15 at the EUIPO. As suggested also by the statistics observed by Dernis et al. (2015), these divergences in ICT-related trademarking may reflect differences in corporate and brand strategies, in the size and sophistication of both home and target markets, and in those markets' industrial and specialisation patterns.

Figure 4.5 - Number of ICT-related trademarks per company, by industry, ISIC rev. 4, 2012-14

Average number of ICT trademarks in companies' trademark portfolios, by office



Note: Data relate to countries with at least 20 companies in the top 2,000 corporate R&D sample having filed more than 10 ICT-related trademarks in the offices considered.

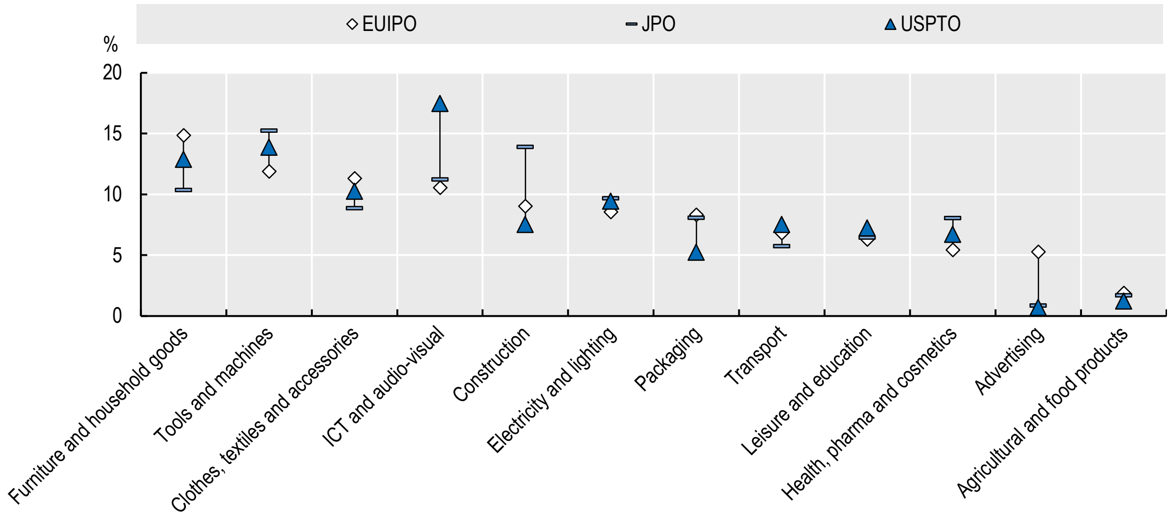
Source: JRC-OECD, COR&DIP© database v.1., 2017.

[12] The complete list of keywords is available on demand.

4.3 The product differentiation strategies of top R&D investors: designs

In the case of registered designs, statistics are based on an experimental aggregation of Locarno classes into 12 product design categories. This aggregation aims to facilitate comparisons with patented technologies and product-related trademarks (see Annex E). The distribution of applications by type of design product shown in Figure 4.6, demonstrates the extent to which top corporate R&D investors use designs to differentiate their products on the basis of ornamental or aesthetic aspects, such as configuration or shape, surface ornamentation, patterns or any combination of these.[13]

Figure 4.6 - Distribution of design applications by design product, 2012-14



Note: Design products are ranked according to EUIPO figures. The design products correspond to an aggregation of the Locarno classes (see Annex E).

Source: JRC-OECD, COR&DIP© database v.1., 2017.

In all the offices considered, the top four product categories that were the object of registered design activities represent about 50% of registered designs between 2012 and 2014. Importantly, *ICT and audio-visual*, *Tools and machines* and *Furniture and household goods* consistently feature among the top four design product, although rankings differ across offices. *ICT and audio-visual* designs rank highest at the USPTO (17% of design patents) and represent the third most important area of registered design activities at the JPO. In this latter office, *Tools and machines* are referred to in about 15% of total registrations. In contrast, at the EUIPO, *Furniture and household goods* stands as the most frequent category designated, and accounts for about 15% of total registrations.

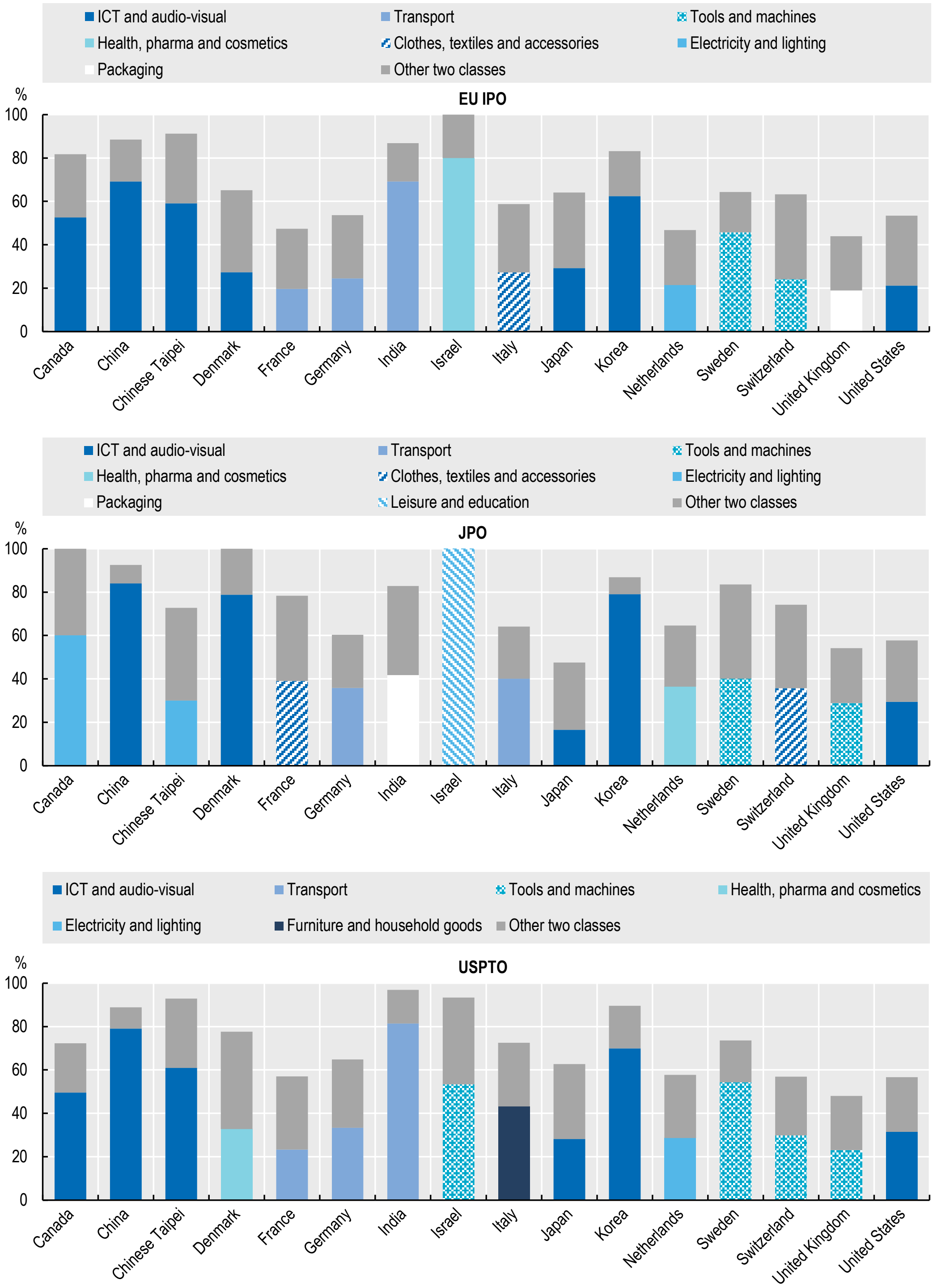
Figure 4.7 reports the cumulative share of the top three design classes designated at the EUIPO, the JPO and the USPTO, respectively, by location of the headquarters. In general, activities are seemingly more concentrated at the JPO and at the USPTO than at the EUIPO. The share of *ICT and audio-visual designs* for China and Korea exceeds 60% in all the offices considered. This is in line with what was observed in the case of trademarks and patents, and further highlights the strong specialisation of these countries in ICT-

[13] A fractional counting method was used to compute the share of product classes designated in the design applications. For example, in an application designating four classes each class was counted as 0.25.

related product and technologies. *ICT and audio-visual* often appears as the most frequent design class used, although different patterns emerge across offices; this type of product design always ranks first in the case of companies headquartered in China, Japan, Korea and the US.

Figures 4.7 - Top design products in design registrations, by headquarter location, 2012-2014

Shares of top three products in designs and top design product, by office



Note: Data relate to countries with at least 20 companies in the top 2,000 corporate R&D sample. The design products correspond to an aggregation of Locarno classes (see Annex E). Only the top one design product in each country is coloured.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Other types of design classes emerge as important at the three offices. For instance, *Transport*-related designs are the most frequently registered by companies headquartered in Germany, regardless of the office considered. This is also the most frequent type of design product designated by top R&D investors based in India, accounting for 60% and 80% of registrations at the EUIPO and the USPTO, respectively. *Transport* is the object of more than 20% of design registrations made at the EUIPO and the USPTO by companies headquartered in France and comes first at the JPO in the case of top R&D investors headquartered in Italy. *Tools and machines* also ranks high in the designs portfolios of top R&D investors, for instance in the case of Israel, Sweden, Switzerland and the UK at the USPTO.

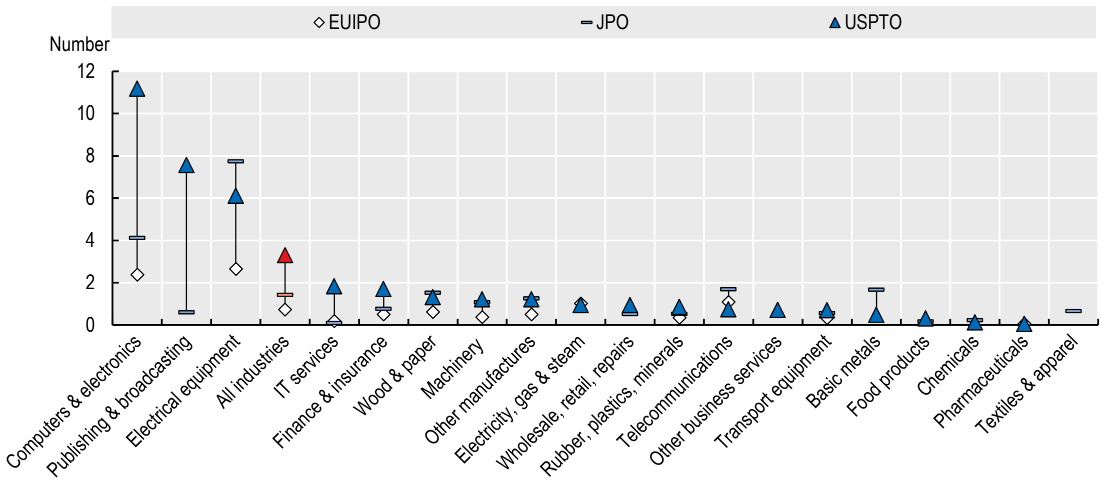
Differentiated strategies emerge when looking at the focus of design registrations across offices by country of headquarters. Only top R&D investors headquartered in China, Germany, Japan, Korea, Sweden and the US consistently focus on the same product classes when registering designs. Other countries focus their design registrations on classes that vary depending on the target market, with differences that are generally less marked across Europe and the US, and more so in the case of Japan.

Italy and Israel are the only economies with distinct design patterns across the three offices. Companies with Italy-based headquarters mainly target *Clothes, textiles and accessories* at the EUIPO, *Transport* at the JPO and *Furniture and household goods* at the USPTO. Companies headquartered in Israel focus almost exclusively on *Leisure and education*-related designs at the JPO, mainly on *Health, pharma and cosmetics* at the EUIPO, and mainly on *Tools and machines* at the USPTO.

Figure 4.8 shows the average number of ICT-related designs in the top R&D investors' design portfolios by industry. ICT-related designs refer to registrations in *Recording, communication or information retrieval equipment*, *Photographic, cinematographic and optical apparatus* and *Printing and office machinery*; values are ordered according to the industries' rankings at the USPTO.

Figure 4.8 - Number of ICT-related designs per company, by industry, ISIC rev. 4, 2012-14

Average number of ICT designs in companies' designs portfolios, by office



Note: Data relate to countries with at least 20 companies in the top 2,000 corporate R&D sample having filed more than 10 ICT-related designs in the offices considered.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Marked differences in registering ICT-related designs by the top R&D investors can be observed across offices and industries. Similarly to what was observed in the case of trademarks, top R&D investors have relatively low levels of ICT design registrations at the EUIPO, compared with their equivalent activity at the JPO and the USPTO. At the USPTO, ‘Computers & electronics’, ‘Publishing & broadcasting’ and ‘Electrical equipment’ have the greatest numbers of digital design registrations.

4.4 The IP bundle: the combined used of patents, trademarks and designs

Patents, trademarks and designs represent important tools to enable firms to compete in global markets and differentiate themselves from their competitors. Analysing if and to what extent companies jointly rely on different types of IP assets (i.e. the extent to which they rely on IP bundles) further illuminates top R&D corporate investors’ innovation and market strategies.

Figure 4.9 illustrates the extent to which companies resort to the ‘full IP bundle’, using patents, trademarks and designs, or combine these assets in different ways. Data are displayed by industry and show the share of companies using the different possible combinations of such assets.

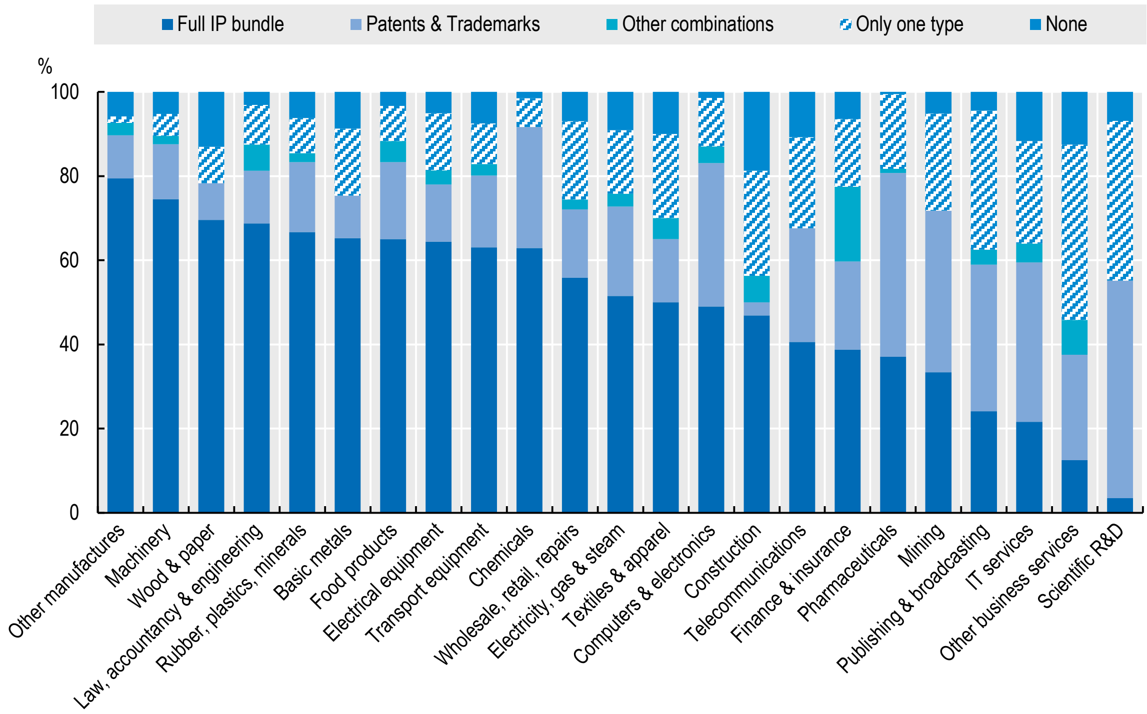
About half of the companies, or more, make use of the full IP bundle in 13 out of the 23 industries shown. In industries such as ‘Other manufactures’, ‘Machinery’ and ‘Wood & paper’, the full IP bundle is used by 70% or more companies. At the other end of the spectrum, the full bundle is used by less than one fourth of the companies in ‘Publishing & broadcasting’, ‘IT services’, ‘Other business services’ and ‘Scientific R&D’. In particular, in the last of these industries the share of companies combining the three IP rights is below 5%; this is due mainly to the very limited use of designs.

The use of patents in combination with trademarks is more frequent in 'Scientific R&D' (52% of companies), ‘Pharmaceuticals’ (44%), ‘Mining’, ‘IT services’, ‘Publishing & broadcasting’ and ‘Computers & electronics’. More than one third of companies operating in these industries use the patent-trademark bundle. In the other industries, the share of companies combining patents with trademarks only is lower; in ‘Wood & paper’ and ‘Construction’ it is particularly low, below 10%.

Combinations including only patents and designs or only trademarks and designs remain less frequently used and are not reported in the chart, being combined in the ‘Other combinations’ category. In addition, designs alone are seldom used across all industries. Conversely, a patents-alone strategy appears to be more common, especially in ‘Construction’, ‘Pharmaceuticals’, ‘Basic metals’, ‘Mining’ and ‘Scientific R&D’, where the share of companies using only patents ranges between 10% and 20% for the 2012-14 period. The use of trademark-only strategies is the most single-right strategy: over 40% of companies follow this strategy in the ‘Other business services’ industry, followed by ‘Publishing & broadcasting’ (30%) and ‘IT services’, ‘Scientific R&D’ and ‘Textiles & apparel’ (all above 20%). Surprisingly, a non-negligible share of companies in ‘Construction’, ‘Wood & paper’, ‘Other business services’, ‘IT services’, 'Telecommunications' and 'Textiles & apparel' do not seem to have registered any IP rights during the period considered (between 20% and 10%).

Figure 4.9 - Top R&D investors with patents, trademarks and designs, by industry, ISIC rev. 4, 2012-14

Shares of companies with patents and/or trademarks and/or designs



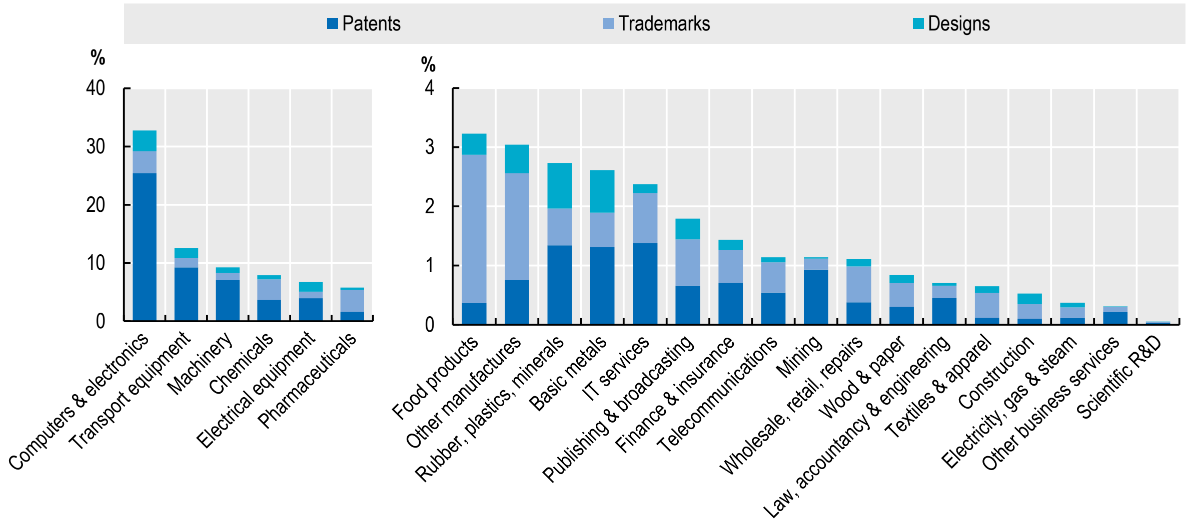
Note: Data relate to industries with at least 20 company headquarters in the top 2,000 corporate R&D sample. Patent data refer to IP5 patent families filed in 2012-14; data for trademarks and designs refer to applications to the EUIPO, the JPO and the USPTO made in 2012-14.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Figure 4.10 shows how the total IP bundle of the world's top R&D investors is distributed across industries. Companies in 'Computers & electronics' are, by far, those that rely to the greatest extent on IP rights and account for about one third of all IP rights filed by the companies in the sample. Other industries in which companies own a high number of IP rights include 'Transport equipment', 'Machinery', 'Chemicals', 'Electrical equipment' and 'Pharmaceuticals', with IP bundle shares ranging between 12% and about 6%. As Figure 4.10 suggests, a natural cut-off point of about 5% splits the sample into two distinct groups of industries. The combined share of IPs owned by the second group of industries (from 'Food products' to 'Scientific R&D') amounts to about 24% of the total portfolio much lower than that of 'Computers & electronics' alone. Patents remain the most frequently used IP right for the majority of industries. However, companies operating in 'Pharmaceuticals', 'Foods products' and 'Other manufactures' appear to register more trademarks than patents. In absolute terms, 'Pharmaceuticals', 'Computers & electronics' and 'Chemicals' are the industries registering the higher numbers of trademarks.

Figure 4.10 - The IP bundle of the world's top R&D investors, by IP type and industry, ISIC rev. 4, 2012-14

Share of the IP bundle in the total IP portfolio of the world's top R&D investors



Note: Data relates to industries with at least 20 company headquarters in the top 2,000 corporate R&D sample having filed for patents in 2012-14. Patent data refer to IP5 patent families; data for trademarks and designs refer to applications to the EUIPO, the JPO and the USPTO.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Patents, and the technologies that companies protect through them, are often accompanied by designs and trademarks, which are aimed at differentiating goods on the market and signalling their existence to prospective consumers. As the same technology may lead to various commercial applications, it is interesting to look at the association between technology classes and product fields, and to investigate the extent to which different technologies relate to different product classes.

Figures 4.11a and 4.11b show the composition of trademark portfolios (in terms of Nice classes) and design portfolios (in terms of Locarno classes) portfolios for the top corporate R&D investors owning patent families in the 2012-14 period. Statistics are shown separately for ICT and non-ICT companies and according to the technological field in which patents are filed. Patent data refer to IP5 patent families, whereas trademark and design registrations data are from the EUIPO, the JPO and the USPTO considered together. For the sake of readability, only the top three product classes are reported. In line with the statistics presented so far, the propensity to use trademarks and designs along with patents appears to vary depending on the sector and on the technological domain in which patenting companies are active.

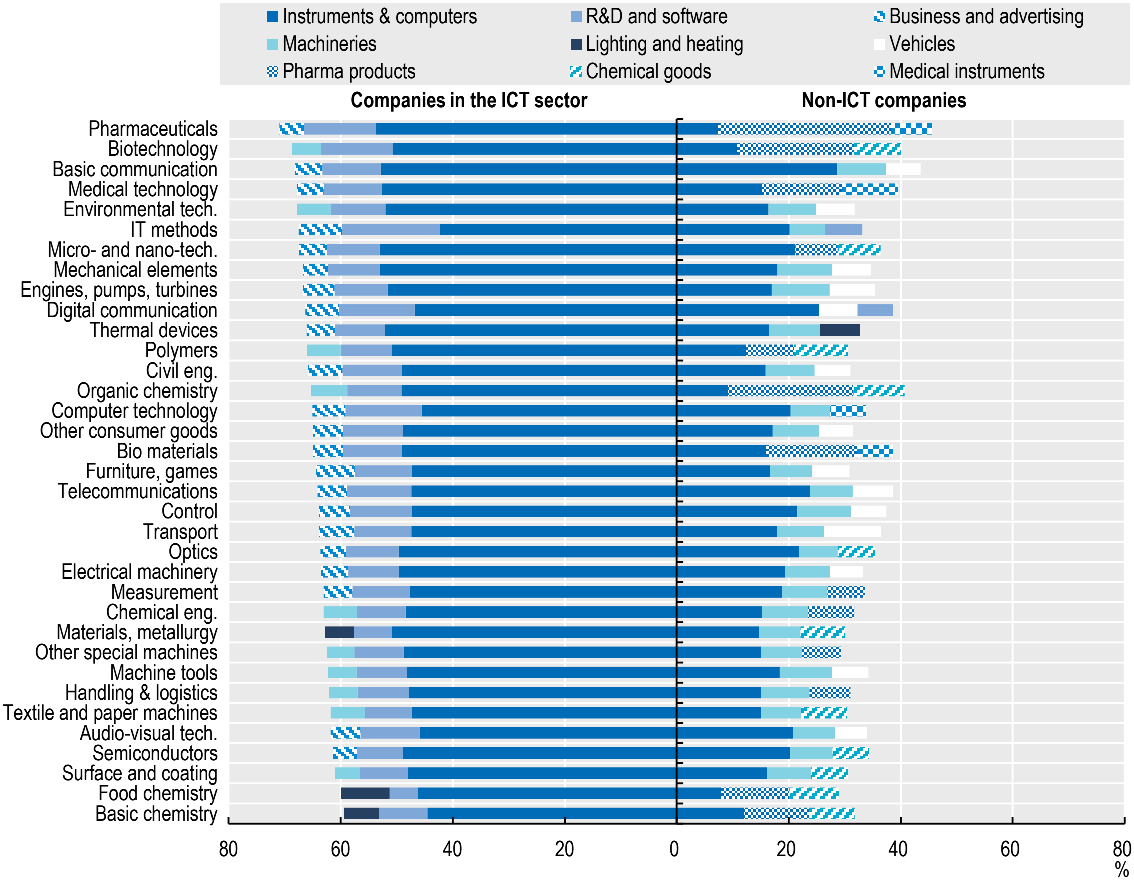
A number of patterns emerge in the way in which top R&D investors combine product classes per technological field. First of all, for each technology considered, the distributions of ICT companies' trademarks and designs present a similar pattern in terms of classes used; conversely, the same technology appears to be associated with different products and services in non-ICT companies. Moreover, the trademark and design portfolios of ICT companies are much more concentrated than those of non-ICT corporations, regardless of the technology patented.

In line with what was observed in Section 4.2 (Figure 4.3), *Instruments and computers* is the most frequently designated class in trademark applications and ranks among the top three across all technologies covered by patents. Moreover, *Instruments and Computers* is always the first trademark class in terms of share of trademark registrations in the ICT sector, and ranks first in a number of technologies protected in non-ICT industries.

Focusing on the ICT sector, the services class *R&D and software* emerges as the second most frequently designated class across all technologies. Consistently with the top Nice classes (Figure 4.3), the *Business and advertising* service class also constitutes another important product line in the portfolios of ICT companies: this holds true for at least 22 out of the 35 technological fields. The frequent combination of product (e.g. *Instruments and computers*) and services classes (e.g. *R&D and software*) reflects the importance for top corporate R&D investors of combining technology-based products with a range of services in their market innovation strategies.

Figure 4.11a - Composition of patenting companies' trademark and design portfolios, by technology, 2012-14

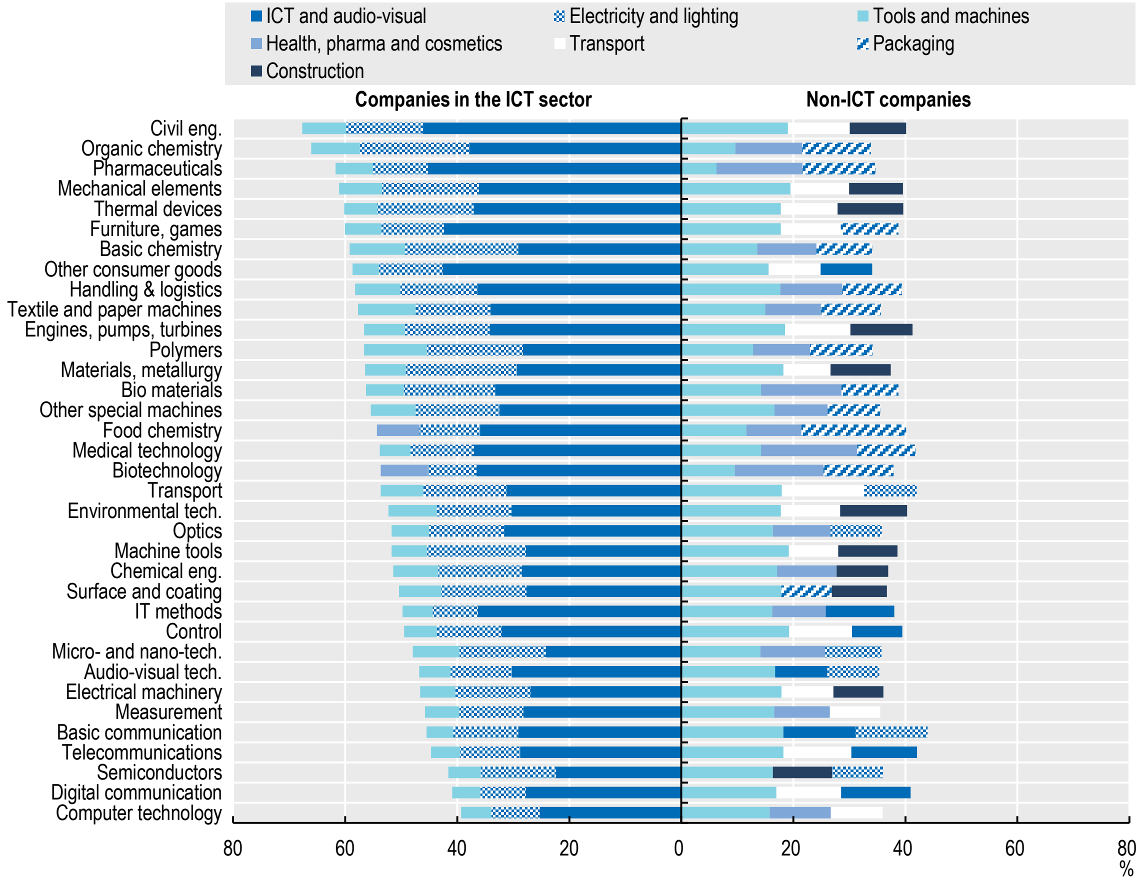
Top three trademark classes associated with patented technologies in companies' portfolios



Note: Patent data refer to IP5 patent families; data for trademarks and designs refer to applications to the EUIPO, the JPO and the USPTO. Series are ranked according to the share of top three trademark classes associated with patenting technologies in the IP portfolios of companies in the ICT sector.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Figure 4.11b - Top three design products associated with patented technologies in companies' portfolios



Note: Patent data refer to IP5 patent families; data for trademarks and designs refer to applications to the EUIPO, the JPO and the USPTO. Series are ranked according to the share of top three design products associated to patenting technologies in the IP portfolios of companies in the ICT sector.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

In non-ICT industries, *Machineries* appears as a sort of transversal product class, as it is associated with a broad range of technologies (25 out of 35). For the corporations in the top 2,000 R&D investors' list for 2014, this class plays an important role, especially in non-ICT industries This is in line with the evidence presented by Dernis et al. (2015), which pointed to the important role of this class in the trademarks activities of the corporations investing the most in R&D in 2012.

In non-ICT industries patents related to *Pharmaceuticals*, *Biotechnology*, *Medical technology*, *Micro- and nano-technologies*, *Chemistry* (organic, basic or food chemistry), *Chemical engineering*, *Polymers* and *Bio materials* are frequently associated with trademark applications in *Pharma products*. The share of trademarks related to this class is particularly high for *Pharmaceuticals* and *Biotechnology*: more than one fifth of patented technologies related to *Pharma products*.

Top corporate R&D investors also frequently designate *Chemical goods* and *Vehicles* goods classes. For instance, companies with patents in *Transport* technologies seem to associate about 10% of their trademark applications with the *Vehicles* goods class (this is still lower than the share of *Instruments and computers*). Companies with patents in

Pharmaceuticals, *Medical technologies*, *Computer technology and Bio materials* also often apply for trademarks in the *Medical instruments* goods class.

Figure 4.11b confirms a dual picture also with regard to the designs registrations of top corporate R&D investors in ICT and non-ICT industries. Furthermore, consistent with the statistics on top design classes (see Figure 4.6), top corporate R&D investors register designs primarily for *ICT and audio-visual* designs in the ICT sector, whereas *Tools and machines* are the main type of design products for non-ICT industries. These patterns hold true across all the patented technologies.

Again, companies in the ICT industry show much more uniform behaviour in terms of types of designs across patented technologies. *Electricity and lighting* and *Tools and machines* are ranked second across all patented technologies, with the exception of *Food chemistry* and *Biotechnology* patented technologies. Overall, between 10% and 20% of design registrations in *Electricity and lighting* are associated with each of the 35 technological fields.

Apart from for *Pharmaceutical* technologies, in non-ICT industries the share of *Tools and machines*-related designs is always equal to or greater than 10%. Companies with patents in *Pharmaceuticals*, *Biotechnology*, *Medical technology*, *Bio materials*, *Chemistry* (organic, basic or food chemistry) always combine *Health, pharma and cosmetics* and *Packaging* design products. *Packaging*, *Transport* and *Construction* are the top three design products for a number of patented technologies (13, 15 and 11, respectively). These three design products, together with *Tools and machines* and *Health, pharma and cosmetics*, are the most transversal in non-ICT industries. All in all, the evidence emerging from the combined analysis of technological fields and design products indicate a more differentiated profile across ICT and non-ICT industries than the picture that results from a combined analysis of technological fields and trademark classes.

5. IPs filing routes in international markets

Key findings

- ❖ Among the industries with the largest IP portfolios, pharmaceutical companies display the average largest teams of inventors per patent (13 inventors).
- ❖ The extent to which top R&D investors rely on international repositories of knowledge varies substantially across industries. Companies in the 'Chemicals' industry spread their sourcing activities across a large set of countries, while 'Pharmaceuticals' companies source knowledge in few economies (about 5).
- ❖ In the case of ICT-related technologies, the share of patents generated by international teams of inventors varies between more than 60% ('Admin and support services') to around 10% ('Machinery').
- ❖ About 40% of designs filed at USPTO rely on international teams of creators. Also, designs appear to be the result of the co-creation of 3 designers; teams of designers are, on average, smaller than those of inventors.
- ❖ USPTO, EPO and SIPO receive between about 60% and 80% of all patents filed by top R&D investors (up to more than 90% in the case of ICT companies). USPTO generally receives about 30% or more patent filings of top R&D investors.
- ❖ When it comes to preferred filing routes, differences between ICT and non-ICT industries are less marked in the case of trademarks than in that of patents or designs.

5.1 International knowledge and designs sourcing strategies of top R&D investors

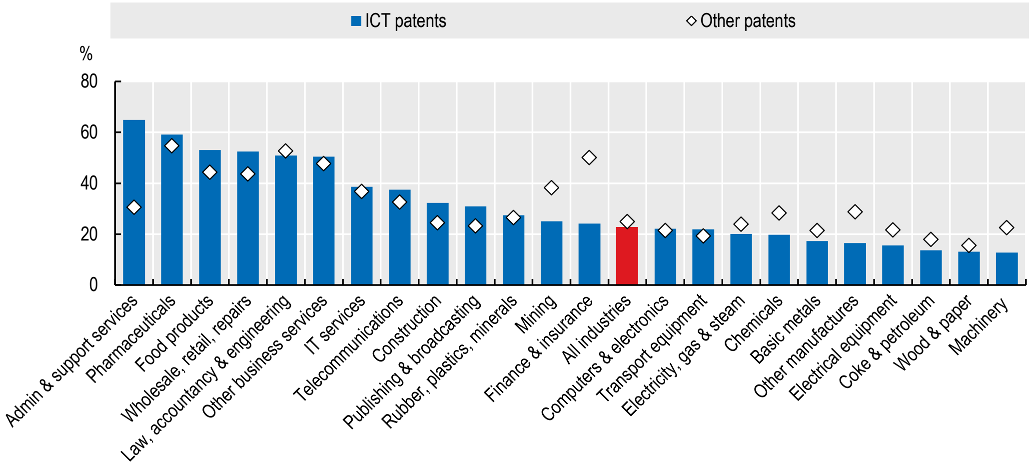
Information about the location of IP assignees and the country of residence of patent inventors contained in IP documents makes it possible to locate where inventive and creative activities happen and where new knowledge and design ideas are sourced from. The geography of inventive activities is at the centre of this section, which provides interesting insights into the international IP filing and sourcing strategies of the top corporate R&D investors worldwide. To this end, it exploits information mainly about the countries of residence of inventors, contained in patent data, and those of designers included in designs registrations.

Figure 5.1 shows the shares of ICT and non-ICT patents with at least one inventor located outside the headquarter country. Data are reported by industry and show only industries with at least 50 ICT-related patent families.

Overall, top corporate R&D investors in different industries appear to rely to different extent on international knowledge sourcing. With more than 50% of their inventions involving an inventor located abroad, companies operating in the 'Pharmaceuticals' and 'Law, accountancy & engineering' industries appear to be the most internationalised, in terms of both ICT and non-ICT patents. In addition, 'Food products', 'Wholesale, retail, repairs' and 'Other business services' rely significantly on international knowledge sourcing: their shares of patents resulting from human capital including at least one inventor located abroad are consistently above 40%, with more than 50% of ICT patents being developed internationally.

Figure 5.1 - Patents based on international teams of inventors, by industry, ISIC rev. 4, 2012-14

Share of ICT and non-ICT patents with at least one inventor located outside the company's headquarters



Note: The data are based on the inventors' countries of residence listed in each company's patent portfolio (using the information available from the priority application). Data relate to industries with at least 50 ICT-related patent families.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

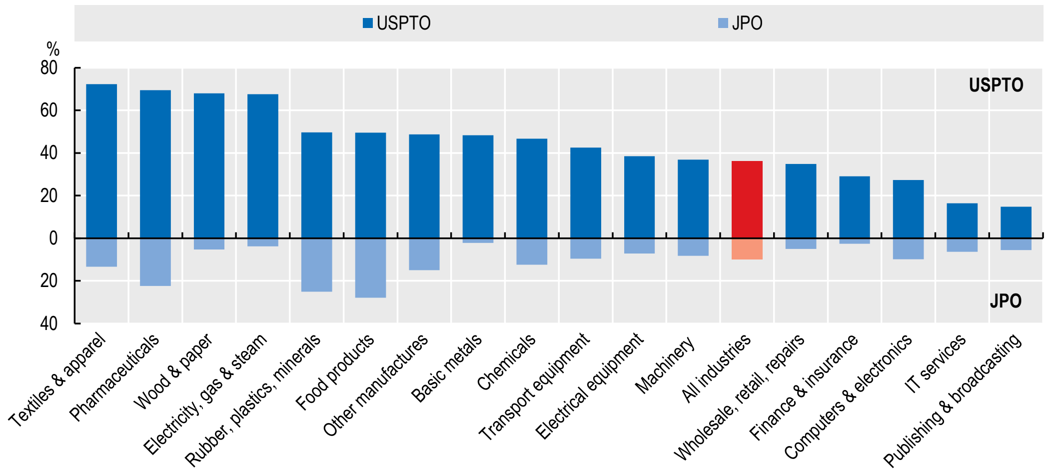
Among the six industries with the largest IP portfolios (see Figure 4.10) only in 'Pharmaceuticals' does the knowledge production of inventions appear to be largely internationalised. The other five top patenting industries – 'Computers & electronics', 'Transport equipment', 'Machinery', 'Chemicals' and 'Electrical equipment' – have much lower shares of patents, both ICT and non-ICT, resulting from international teams of inventors with the 'Chemicals' industry being the only one with shares above 25%.

Generally, differences in the extent to which companies rely on inventors located abroad for their ICT- or non-ICT-related technological developments remain somewhat limited. However, a few industries such as 'Admin & support services', 'Mining', 'Finance & Insurance' and, to a lesser extent, 'Chemicals', 'Other manufactures' and 'Machinery' display non-negligible differences in the extent to which they rely on international teams of inventors when developing ICT and non-ICT inventions. 'Admin & support services' emerges as the most internationalised industry in relation to the development of ICT-related technologies (65%) but seems to rely mainly on country-specific teams when developing non-ICT inventions (30%). By contrast, 'Mining' and 'Finance & insurance' own much lower shares of ICT patents that stem from international teams of inventors (about 25% in both cases) than of non-ICT-related patents that do so (38% and 50%, respectively).

Following a similar approach to that used to identify internationally developed patents, Figure 5.2 looks at the registered designs created by on one or more designers located outside the country where the company headquarters are based. Only statistics for industries with more than 20 companies in the sample are reported. Due to data availability constraints, the statistics shown reflect the activities of top corporate R&D investors at the JPO and the USPTO only.

Figure 5.2 - Registered designs based on international teams of designers, by industry, ISIC rev. 4, 2012-14

Shares of designs with at least one designer located outside the company's location



Note: The data are based on the designers' countries of residence listed in each company's design portfolio at the JPO and the USPTO. The information is not available for EUIPO designs. Data relate to industries with at least 20 companies in the top 2,000 corporate R&D investors sample having at least 100 designs at the JPO and the USPTO.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Top corporate R&D investors seem to rely to a much greater extent on designers located abroad when filing design patents at the USPTO than they do when registering designs at the JPO. The shares of designs with at least one designer located outside the HQs location are consistently below 30% at the JPO, while the majority of industries have an equivalent or greater share of such designs at the USPTO. At the USPTO, companies in 'Textiles & apparel', 'Pharmaceuticals', 'Wood & paper', 'Electricity, gas & steam', 'Rubber, plastics, minerals' and 'Food products' industries rely quite heavily on international teams of designers: more than half of their registered designs include designers located abroad. Tapping into the repository of design-related skills available abroad is common in the first four industries, where more than two thirds of registered designs have designers residing abroad.

Interestingly, with shares not exceeding 30%, companies operating in ICT industries, namely 'Computers & electronics', 'IT services' and 'Publishing & broadcasting', are those with the lowest shares of international teams of designers. This reduced propensity to use foreign-based designers suggests that top corporate R&D investors from these sectors maintain a relatively strong home-based dimension in their designs activities, especially in the US market.

At the JPO (bottom part of Figure 5.2), more than 20% of the designs of top corporate R&D investors active in 'Food products', 'Rubber, plastics, minerals' and 'Pharmaceuticals' industries have at least one designer residing in a country different to headquarter location. 'Other manufactures', 'Textiles & apparel' and 'Chemicals' follow in this respect, with more than one tenth of 'Chemicals' designs involving one or more designers located abroad.

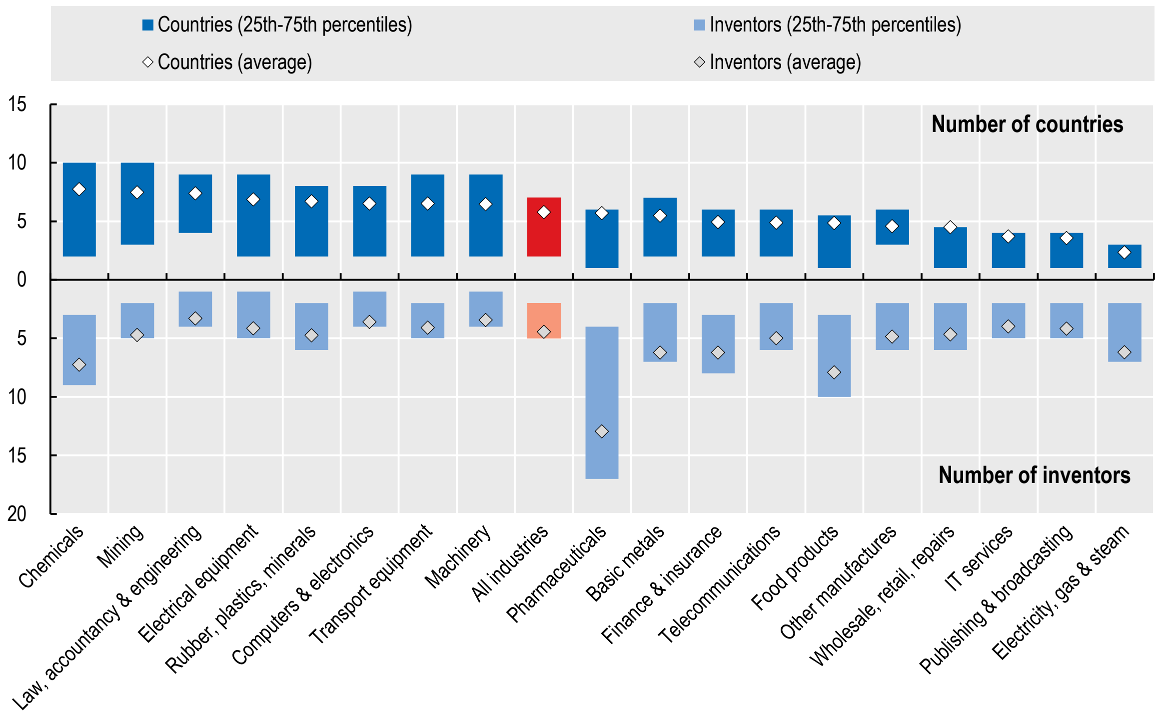
Comparing statistics across the two offices shows that 'Textiles & apparel', 'Pharmaceuticals', 'Rubber, plastics, minerals' and 'Food products' stand among the industries that rely to the greatest extent on foreign designers. By contrast, top corporate R&D investors in 'Wholesale, retail, repairs' and 'Finance & insurance' consistently rely only to a very limited degree on foreign design talents.

Figure 5.3 sheds some light on the extent to which top corporate R&D investors diversify their technological development activities, both geographically (top part) and in terms of number of inventors involved in each patented invention (bottom part). The number of inventors' countries of residence is displayed in dark blue, whereas the size of the team of inventors is shown in light blue.

A marked heterogeneity emerges among industries: overall, more than half of the industries considered tend to tap into the repository of human capital of at least five countries when developing their inventions. Among them, 'Chemicals', 'Mining' and 'Law, accountancy & engineering' rely on a relatively broad geographical repository of knowledge, in terms of number of distinct countries involved. In particular, top R&D investors in the 'Chemicals' industry tend to spread their sourcing activities across a large number of countries and also to use large teams of inventors (seven countries and a team of seven on average per each patented invention).

Figure 5.3 - Diversification of inventors' locations by industry, ISIC, rev. 4, 2012-14

Number of inventors' countries of residence in companies' portfolios and number of inventors per patent



Note: The data are based on the inventors' countries of residence listed in each company's patent portfolio (using the information available from the priority application). Data relate to industries with at least 25 companies in the top 2,000 corporate R&D investors sample.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

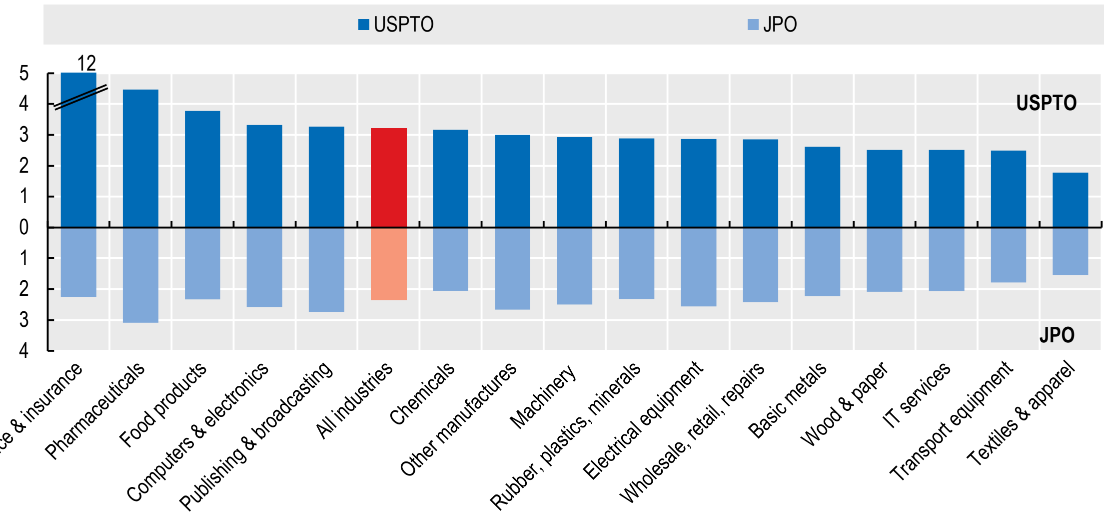
'Pharmaceuticals' is the industry displaying the largest differences in terms of number of countries in which inventors are located and number of inventors involved in each patent: on average, 'Pharmaceuticals' companies rely on inventors located in a relatively low number of countries (about five), but have inventor team sizes of about 13 inventors per patent.

Other industries such as ‘Food products’, ‘Finance & insurance’ and ‘Electricity, gas & steam’ rely more on relatively large teams of inventors (on average, six inventors or more) than on a wide geographical repository of knowledge, as indicated by the numbers of countries where inventors reside. ‘Computers & electronics’, ‘Machinery’ and ‘Transport equipment’ show a different pattern: in these industries, broader geographical sourcing is coupled with relatively small teams of inventors. A similar pattern holds true for all the industries having teams of inventors drawn from a number of countries above the sample average.

With respect to designs, Figure 5.4 indicates that leading R&D investors use teams of designers of different sizes, both across industries and depending on the market targeted. Top corporate R&D investors have, on average, larger design teams for their registrations at the USPTO than for those at the JPO. Team sizes do not exceed three designers for the designs filed at the Japanese office, while for the designs filed at the USPTO about half of the industries use teams of three or more designers.

For designs filed at the USPTO, creative teams may include up to about 12 designers in the ‘Finance & insurance’ industry, about three times the average number of designers in ‘Pharmaceuticals’ (four), the second-ranked industry in terms of designers per registered design. Companies operating in ‘Food products’, ‘Computers & electronics’ and ‘Publishing & broadcasting’ also rank above sample average for the USPTO.

Figure 5.4 - Average number of designers per design, by industry, ISIC rev. 4, 2012-14



Note: The data are based on the designers’ countries of residence listed in each company’s design portfolio. Data relate to industries with at least 20 companies in the top 2,000 corporate R&D investors sample having more than 100 designs.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

A few industries such as ‘Finance & insurance’ and ‘Food products’, present somewhat diverging patterns with regard to USPTO and JPO. However, most industries use, on average, teams of designers of similar size across the two offices considered: between two and three designers per filing.

Team size is in general smaller in the case of designs (Figure 5.4) than in the case of patents (Figure 5.3, bottom part). This holds true for all industries except for 'Finance & insurance' where companies have design teams of a larger size than their teams of inventors, on average more than 11 designers versus 6 inventors. Furthermore, companies in industries such as 'Food products' and 'Pharmaceuticals' exhibit relatively large teams, in the case of both patents and designs. Conversely, in 'Machinery' companies tend to rely on relatively small teams of designers and inventors (three or fewer per IP right).

5.2 Which markets? International IP filing routes of top corporate R&D investors

Top corporate R&D investors generally seek protection for their intellectual assets from one or more IP offices around the world. Looking at the extent to which IP rights are protected at different IP offices may provide interesting information about the world-leading R&D firms' innovation strategies, and about the relative importance of domestic and non-domestic markets.

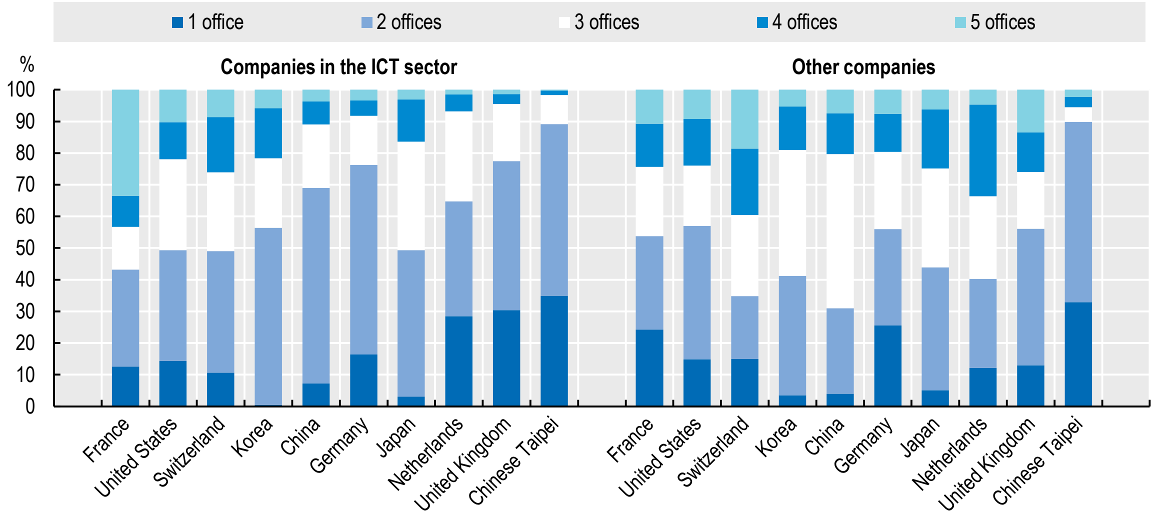
The top panel of Figure 5.5 shows the number of IP5 offices in which every patent family is protected, that is, the proportion of patents protected only at one IP5 office, the proportion protected at two IP5 offices, and so on. Figures are displayed by country of headquarters. The bottom panel of Figure 5.5 provides information about the IP5 offices targeted. It displays the share of patents filed at the EPO, the JPO, the KIPO, and so on. To examine possible country and industry specificities of R&D investors' IP filing routes, information about top R&D investors in ICT industries is provided on the left part of the panels, whereas figures for the other industries are provided on the right.

As can be seen from the top panel of Figure 5.5, top R&D investors generally tend to protect their inventions at at least two of the IP5 offices, with two IP5 offices also representing the norm in the case of ICT companies. In industries other than ICT, the picture is less clear-cut and the number of IP5 offices targeted seems to be very much dependent on the location of the headquarters. About 90% of the patents filed by companies headquartered in Chinese Taipei target at most two of the IP5 offices, indicating a highly focused protection strategy. By contrast, this holds true only in about 30% of cases for non-ICT top R&D investors headquartered in China or Switzerland.

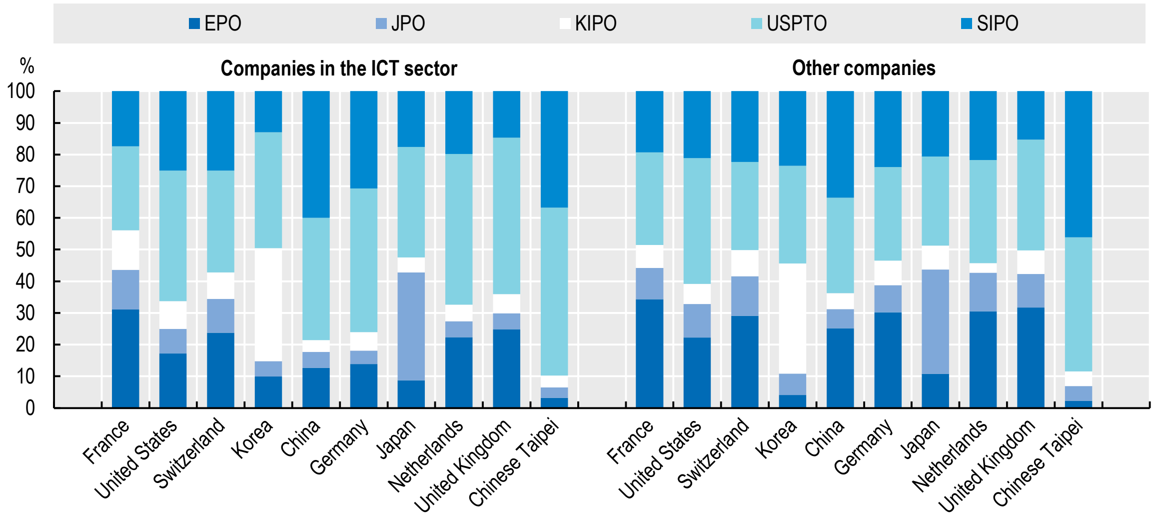
In all industries, the top R&D investors headquartered in China, Korea and Japan rarely limit the protection of their inventions to only one office: more than 90% of their patent families are filed in multiple IP5 offices. The most comprehensive protection strategies in ICT are pursued by top R&D performers headquartered in France (seeking protection for more than 30% of patents in all IP5 offices), while in non-ICT industries Switzerland-based companies often seek protection in all IP5 offices (about 20% of patents).

Figure 5.5 - Patent filing routes by headquarter location, 2012-14

Composition of patent families by IP5 offices, top 10 economies



Distribution of IP5 patent families by IP offices, top 10 economies



Note: The figures are based on the number of patents by IP offices included in each company's IP5 patent family portfolio. Data relate to the top 10 economies of patenting companies. Series are ordered in proportion to the total number of patent families filed at the IP5 offices by companies in the ICT sector.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

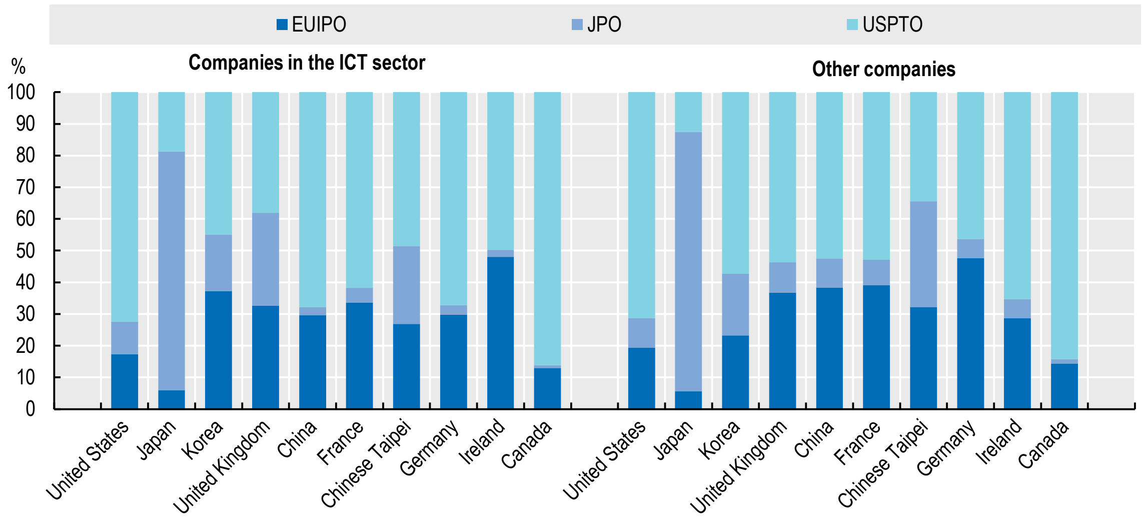
The bottom panel of Figure 5.5 highlights the importance of the US as a country for protecting inventions, in both ICT and non-ICT industries. In ICT industries, with the exception of companies headquartered in France, the USPTO is included among the offices for which protection is sought for 30% or more of the patents filed by the top R&D investors. In the case of non-ICT companies, the US remains an important target market, albeit to a lesser extent.

Generally, in all industries, Europe and the US represent key markets for Western based top R&D investors, as can be inferred from the fact that protection is sought from the EPO and the USPTO for about 56% (companies headquartered in Switzerland) to 74% (ICT companies headquartered in the UK) of patents. These values are lower in the case of top R&D performers headquartered in Asia, which exhibit a share ranging between 35% and 56% of patents protected at the EPO and the USPTO. In addition, top R&D performers generally exhibit strong home biases, whereby a high proportion of their patents is protected in the office of the country where the headquarters are located (e.g. about 40% of patents belonging to top R&D investors headquartered in the US are protected at the USPTO). Home biases are seemingly more marked in the case of ICT companies than in the case of top R&D investors in other industries.

Figure 5.6 shows the distribution of trademarks of top corporate R&D investors at the EUIPO, the JPO and the USPTO. Differences between ICT and non-ICT industries appear less marked in the case of trademarks than in that of patents. With the exception of R&D investors headquartered in Japan, USPTO-registered trademarks generally account for the biggest share.

Figure 5.6 - Trademark filing routes by headquarter location of ICT companies, 2012-14

Distribution of trademarks by IP offices, top 10 economies



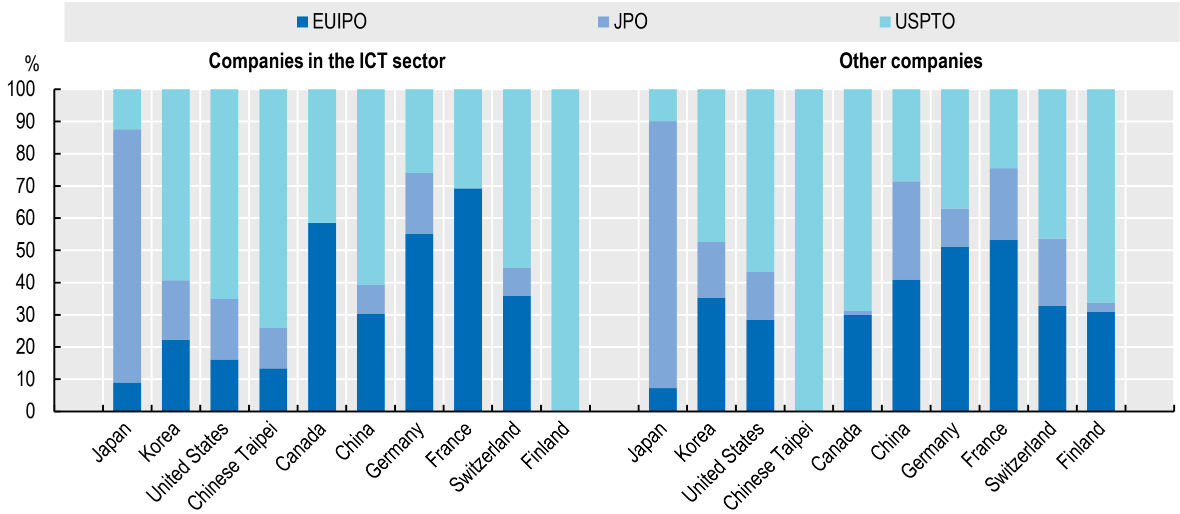
Note: Data relate to the top 10 economies of trademarking companies. Economies are ranked in proportion to the total number of trademark applications by companies in the ICT sector.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

Companies headquartered in Japan have a very pronounced home bias in their trademark registration strategies: 75% or more of the trademarks of Japanese top R&D investors are registered at the JPO. A similar home bias can also be observed for the trademarks of US-based companies. Canadian companies, however, have shares of trademarks filed at the USPTO that are even higher than those of their US counterparts.

The designs registrations of top corporate R&D investors show much more marked differences, as illustrated by Figure 5.7. ICT companies headquartered in Finland and non-ICT companies based in Chinese Taipei seem to opt almost exclusively for design registrations at the USPTO. In addition, ICT companies headquartered in Canada and France carry out little if any design activity at the JPO. Moreover, unlike in the case of trademarks, Canadian ICT companies seemingly target the European market in particular for their design registrations.

Figure 5.7 - Design filing routes by headquarter location of ICT companies, 2012-14
Distribution of designs by IP offices, top 10 economies



Note: Data relate to the top 10 economies of companies with registered designs. Economies are ranked in proportion to the total number of registered designs by companies in the ICT sector.

Source: JRC-OECD, COR&DIP© database v.1., 2017.

In general, the attractiveness of the Japanese market for top corporate R&D investors appears to be more marked in the case of designs than in the case of trademark.

6. Conclusions

The present report provides an overview of the innovation activities undertaken by the top corporate R&D investors worldwide and sheds light on the knowledge generation and appropriation strategies that these market and innovation leaders pursue. The special focus on ICT technologies and industries proposed throughout the report aims to contribute to a better understanding of the digital transformation, and to provide evidence in support of policy making, especially related to industry and innovation dynamics.

This work is the results of the well-established collaboration between the EC-JRC and the OECD Directorate for Science, Technology and Innovation. It is part of the continued efforts of the two organisations to offer up-to-date, robust and internationally comparable data, indicators and analysis based on micro level data and statistics, to be used for policy-making, research and analytical purposes.

This second edition offers newer insights on the innovation output of the world's top corporate R&D investors. In addition, compared to the 2015 publication (Dernis et al., 2015), this report brings in a more comprehensive coverage of the industrial property strategies pursued by these top corporations, by analysing the full set of industrial property rights (i.e. patents, trademarks and designs). It sheds new light on the innovative, creative and branding strategies of top R&D investors worldwide, on their contribution to the digital transformation, and on the technological developments underpinning it. It does so by looking at the extent to which world-leading innovative corporations focus on the development of ICT-related technologies and products across key international markets, and the extent to which leading ICT corporations worldwide penetrate other sectors of the economy and develop non-ICT technologies.

The evidence provided suggests that top corporate R&D investors have fully embraced the digital transformation, and that digital technologies represent a pillar of their strategic behaviours on markets worldwide. Almost half of the IP5 patent families filed during the period considered (2012-14) and more than a quarter of their trademarks and designs relate to ICT. Moreover, these companies stand as key players in the digital space, as they own about 75% and 60% of global ICT-related patents and designs, respectively. Noteworthy, and contrary to what is often believed, the ‘Computer and Electronics’ industry emerges to be the most IP intensive, with about one third of the total IP portfolios of top corporate R&D investors belonging to firms operating in that very industry. Other industries owning a relatively high shares of IP rights include ‘Transport equipment’, ‘Machinery’, ‘Chemicals’, ‘Electrical equipment’ and ‘Pharmaceuticals’.

Statistics on the geographical and industrial distributions of these conglomerates confirm the global scope of activities of top corporate R&D performers (mainly through their subsidiaries), although with different degrees across industries. Overall, ICT industries, representing about a quarter of top corporate R&D investors, seem to operate on a relatively narrower geographical scale than the other industries. Fast-growing economies such as India, China, Malaysia and Singapore show a marked orientation towards ICT, suggesting that ICT industries may be playing an important role in driving economic growth.

IP activities appear to be concentrated also among top R&D investors themselves. A closer look at the top 50 IP assignees indicates that Asia-headquartered corporations account for the majority of patenting activities, which are in turn dominated by companies originating from the ICT sector. In contrast to the case of designs - which is closer to the ranking observed in the case of patents -, few ICT-operating companies feature among the top trademarking firms. Overall, these patterns confirm the advanced state of penetration of ICT-technologies, designs and brands in the whole range of products we use in our day life.

Top corporate R&D investors appear to be highly reliant on the US market for the protection of their ICT-related IPs. This holds particularly true in the case of patents and for ICT industries; with the noticeable exception of France-headquartered companies, the USPTO actually receives more than 30% of the total patent filings.

The IP portfolios of ICT operating companies are in general more concentrated both in terms of technologies (patents) and products (trademarks and designs) than their non-ICT counterparts. The analysis further shows that ICT-related patents are generally characterised by a narrower scope than non-ICT ones, with the exception of ICT patents filed by top R&D investors operating in few industries, including ‘Transport services’ and ‘Electrical equipment’.

An analysis of technological specialisation and product differentiations suggests that geography matters and that the type of inventive activity pursued varies depending on the location of the headquarters. A broad technological knowledge base can be observed in the case of top R&D performers with their home base in the EU, US and Japan. Conversely, Korea and China appear to be mainly the home of ICT-specialised conglomerates. Moreover, European and US-headquartered top R&D investors seem to dedicate substantial efforts in developing technologies related, for instance, to health and environment, which are fundamental to address major societal challenges.

Top corporate R&D investors make extensive use of the full IP bundle, and combine patents, trademarks and designs to protect their innovative output. In particular, this holds true for more than two third of companies operating in ‘Other manufacturers’, ‘Machinery’ and ‘Wood and paper’ industries.

The recourse to inventors and designers located abroad to source creative ideas and access new technological knowledge appears to be frequent among top R&D investors. Notable differences can nevertheless be observed across industries and depending on the type of industrial property considered. ‘Pharmaceuticals’ appears to be the most internationalised industry and reports the largest teams of inventors. However, it also exhibits a concentrated geographical distribution of its activities. In other words, pharmaceutical companies, for instance, resort to many inventors located in relatively few countries. In general, teams of inventors are larger than teams of designers, which are in turn more internationalised, as can be seen from the frequency with which designs are generated by international teams of creators.

All-in-all, the evidence produced points to the existence of specific corporate management practices for the generation of creative ideas and new technologies. This should be carefully considered by policy makers dealing with the knowledge economy and calls for further evidence in support of policy design.

The research presented in this report represents an important but nevertheless small part of the wealth of information that can be extracted from the dataset constructed for the analysis, especially when linked to other sources of information. For this reason, the EC-JRC and the OECD provide an open access to the dataset accompanying this report, the JRC-OECD's COR&DIP© database v.1. (2017), to all those requesting it. We hope that researchers, analysts and all those interested will use the public good we have produced to generate statistical and econometric evidence in support of policy making.

A better understanding of the challenges and opportunities that the digital transformation is bringing about is key to secure our future growth and well-being.

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Appendices

Annex A - List of industries, ISIC rev. 4

38 industries, ISIC rev. 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 administration and defence
85	Education
86	Health services
87-88	Care & social work
90-93	Arts & entertainment
94-96	Other services

Annex B - Definition of the ICT sector

ICT economic activities (industries) are defined according to the general definition that follows:

"The production (goods and services) of a candidate industry must primarily be intended to fulfil or enable the function of information processing and communication by electronic means, including transmission and display".

The list of ICT industries (ISIC Rev. 4) that meet this condition is provided below:

ICT manufacturing industries

2610 Manufacture of electronic components and boards
2620 Manufacture of computers and peripheral equipment
2630 Manufacture of communication equipment
2640 Manufacture of consumer electronics
2680 Manufacture of magnetic and optical media

ICT trade industries

4651 Wholesale of computers, computer peripheral equipment and software
4652 Wholesale of electronic and telecommunications equipment and parts

ICT services industries

5820 Software publishing

61 Telecommunications

6110 Wired telecommunications activities
6120 Wireless telecommunications activities
6130 Satellite telecommunications activities
6190 Other telecommunications activities

62 Computer programming, consultancy and related activities

6201 Computer programming activities
6202 Computer consultancy and computer facilities management activities
6209 Other information technology and computer service activities

631 Data processing, hosting and related activities; web portals

6311 Data processing, hosting and related activities
6312 Web portals

951 Repair of computers and communication equipment

9511 Repair of computers and peripheral equipment
9512 Repair of communication equipment

Source: OECD (2007), Information Economy – Sector definitions based on the International Standard Industry Classification (ISIC 4) DSTI/ICCP/IIS(2006)2/Final.

Annex C - Linking company data to IP data: a matching approach

Characterising the IP portfolio of companies requires data on IP rights to be linked with enterprise data. To this end, the names of the top corporate R&D investors and of their subsidiaries were matched to the applicants' names provided in published patent, trademark and design documents. The matching was carried out on a by-country basis using a series of algorithms contained in the Imalinker (Idener Multi Algorithm Linker) system developed by IDENER in 2013 (http://www.idener.es/).

The matching exercise carried out was implemented over a number of key steps:

- The names of top corporate R&D investors and subsidiaries and of the firms included in the data on IP rights were separately harmonised using country-specific 'dictionaries'. These aimed to dealing 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. Failing to account for such features of the data might mistakenly lead to excluding a company (not considering only because its name had been misspelt or shortened in some places), or double counting a company (because different spellings of its name made it appear to be different entities). The compilation of suitable country- and language-specific dictionaries required country-level and language-related knowledge.
- 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 – were 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 depended on minimising the number of false positive matches, was ensured through a selection of pairs of company names/ IP rights owners made on the basis of high-score thresholds imposed on the algorithm.
- A post-processing stage was handled manually and involved reviewing the results of the matches; assessing the proportion of non-matched firms (possibly false negatives, that is, firms that the algorithm had failed to recognise as part of the sample) among the top R&D performers and affiliates; and identifying new matches on a case-by-case basis (e.g. allowing for lower thresholds for a given algorithm), by correcting and augmenting dictionaries and through manual searches.

The matching was performed using the names of both the top corporate R&D investors and their subsidiaries. IP portfolios were aggregated at the level of the headquarters: patents, trademarks and designs owned by a given subsidiary were thus fully attributed to the parent company of the group, regardless of the precise structure of the group. In practical terms, this choice meant that the patents, trademarks and designs of a certain subsidiary were attributed to the parent R&D performer under all circumstances, and regardless of the exact share of the affiliate that the parent company owns (whether, for example, 60% or 70%).

Overall, 98% of top R&D-performing companies could be matched to at least one patent applicant, either directly or through one or more subsidiary firms. The same overall matching rate was observed for trademark applications (96%) and for registered designs (92%).

Annex D - List of technological fields for patents

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 E – List of design products

Aggregation of Locarno classes in type of design products
Advertising
20. Sales and advertising equipment, signs
32. Graphic symbols and logos, surface patterns, ornamentation
Agricultural and food products
1. Foodstuffs
27. Tobacco and smokers' supplies
31. Machines and appliances for preparing food or drink, not elsewhere specified
Clothes, textiles and accessories
2. Articles of clothing and haberdashery
3. Travel goods, cases, parasols and personal belongings, not elsewhere specified
5. Textile piece-goods, artificial and natural sheet material
11. Articles of adornment
Construction
23. Fluid distribution equipment, sanitary, heating, ventilation and air-conditioning equipment, solid fuel
25. Building units and construction elements
29. Devices and equipment against fire hazards, for accident prevention and for rescue
Electricity and lighting
13. Equipment for production, distribution or transformation of electricity
26. Lighting apparatus
Furniture and household goods
6. Furnishing
7. Household goods, not elsewhere specified
30. Articles for the care and handling of animals
Health, pharma and cosmetics
24. Medical and laboratory equipment
28. Pharmaceutical and cosmetic products, toilet articles and apparatus
ICT and audio-visual
14. Recording, communication or information retrieval equipment
16. Photographic, cinematographic and optical apparatus
18. Printing and office machinery
Leisure and education
17. Musical instruments
19. Stationery and office equipment, artists' and teaching materials
21. Games, toys, tents and sports goods
22. Arms, pyrotechnic articles, articles for hunting, fishing and pest killing
Packaging
9. Packages and containers for the transport or handling of goods
Tools and machines
4. Brushware
8. Tools and hardware
10. Clocks and watches and other measuring instruments, checking and signalling instruments
15. Machines, not elsewhere specified
Transport
12. Means of transport or hoisting

For detailed information on Locarno classes, see http://www.wipo.int/classifications/nivilo/locarno.htm

Annex F - Definition of ICT-related patents, designs and trademarks

ICT-related patents

Patents in ICT-related technologies are identified using the 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 the details provided about the ways in which the 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 device 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, simulation, 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*
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
	Semiconductor	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/*

Digital registered designs

Digital registered designs are identified using the international classification used for the purposes of the registration of industrial designs, the Locarno classification.

Locarno classification	Description
14	**Recording, communication or information retrieval equipment**
14-01	Equipment for the recording or reproduction of sounds or pictures
14-02	Data processing equipment as well as peripheral apparatus and devices
14-03	Communications equipment, wireless remote controls and radio amplifiers
14-04	Screen displays and icons
14-99	Miscellaneous
16	**Photographic, cinematographic and optical apparatus**
16-01	Photographic cameras and film cameras
16-02	Projectors and viewers
16-03	Photocopying apparatus and enlargers
16-04	Developing apparatus and equipment
16-05	Accessories
16-06	Optical articles
16-99	Miscellaneous
18	**Printing and office machinery**
18-01	Typewriters and calculating machines
18-02	Printing machines
18-03	Type and type faces
18-04	Bookbinding machines, printers' stapling machines, guillotines and trimmers (for bookbinding)
18-99	Miscellaneous

Source: WIPO, Locarno Classification, http://www.wipo.int/classifications/nivilo/locarno.htm

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