International technological collaboration in the China-Europe-US triangle:
Evidence from top corporate R&D investors

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Biography

Stephan Worack holds a PhD in economics from University Paris 1 Panthéon-Sorbonne. During his doctoral studies, he worked at the Science and Technology Observatory (OST-Paris) and the European Patent Office (Munich) and was a visiting scholar at Zhejiang and at Peking University in China. He also holds a MSc in international economics and economics of globalization from University Paris 1 Panthéon-Sorbonne and Fudan University (Shanghai) and a BSc in economics from Humboldt University (Berlin).

Dr Worack has contributed to several studies on science and technological collaboration and has a thematic focus on China's research and innovation system and Europe-China collaboration. His research interests include economics of innovation and intellectual property rights, innovation policy, foreign direct investment, emerging economies, and the cooperation of firms and countries in science and technology.

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Disclaimer

Abstract

The report examines the empirical patterns and dynamics of technological collaboration within the China-Europe-US triangle. It provides an assessment of the international knowledge collaboration and sourcing for the sample of worldwide top corporate R&D investors (EU Industrial R&D Investment Scoreboard). To this end, it exploits European Patent Office and US Patent and Trademark Office patent data and information on the location of the inventor(s) and the applicant Scoreboard firms for the decade 2005-2015. The study mainly focuses on the patenting activity of China-, EU- and US-based firms and compares the extent to which they tap into knowledge sources from abroad, as compared to domestic ones. Finally, the report explores the industry-specific patterns of international technological collaborations in the China-EU-US triangle.

Table of contents

1. Introductory section

1.1. Policy Background

During the past decades, China has gradually developed its scientific and technological capabilities, as well as a wide array of international collaborations including with Europe and the US. China's government has been increasing its investments in Science & Technology (S&T) and innovation activities, resulting in proven success to advance in these fields. For example, as illustrated by the EU Industrial R&D Investment Scoreboard, China is also increasing its presence in the world upper reaches of corporate R&D investors (Hernández et al., 2017).

Yet it appears that Europe is lagging behind in engaging in and benefitting from China's S&T rise and risks to fall back in the future, multi-polar science world (Bound et al., 2013; European Commission, 2016; Veugelers, 2017b; Veugelers and Baltensperger, 2019). Given the importance of S&T as a base for industrial competitiveness as well as the vast opportunities that these developments bring, this report contributes to Europe's current reflections on how to build up on European scientific excellence and technological strengths and "how to take sufficient advantage of the emergence of China as a technological powerhouse" (Carlos Moedas, European Commissioner for Research, Science and Innovation (European Commission, 2016, foreword)).

1.2. Research Context

The changing landscape of world S&T production, the increasing interconnections between national research and innovation systems and the identification of common global challenges have further highlighted the importance of international scientific and technological collaborations. International collaboration is considered an important factor in addressing sources of new knowledge and improving competitiveness (European Commission, 2016).

In fact, international technological collaborations are essential for firms relying on global R&D and innovation networks and developing products globally to keep their competitive advantages. Evidence from patents suggest that such technological collaborations have intensified over the past decade and that the US ranks first in terms of international co-inventions (intensity of collaboration): With regard to China, evidence show that "US is

taking greater advantage than the EU of the opportunities that come from collaborating with this emerging economy" (European Commission 2016, 11) .

The examination of these trends in the sample of world leading R&D firms constitutes relevant knowledge in order to better understand the differences and similarities in international corporate technological collaborations, especially within the China-Europe-US triangle. Thanks to the recent matching of patents data of Scoreboard companies, it is possible to explore the patterns and recent dynamics of international technological collaborations taking place within the triangle in the upper reaches of the world's R&D investments. Further, it helps to identify industry specific technological collaboration patterns in the world upper reaches of industrial R&D investment.

The next section provides an overview of the literature on international technological collaboration and specific literature revolving around the angle taken in this report. Section 3 briefly presents the dataset and the main indicators used for the analysis in the report. Section 4 contains the empirical analysis of the patterns and dynamics of technological collaboration of the world's top corporate R&D investors within the China-Europe-US triangle between 2005 and 2015. Finally, section 5 provides a discussion and concludes.

2. Overview of the literature

International technological collaboration is based on and performed through research and development networks.[1] Networks are reciprocal and build on experience and trust (Powell, 1990). Geographical, cultural as well as institutional closeness facilitate trust and, in turn, the establishment of technological collaboration (Paci and Batteta, 2003; Picci, 2010). De Prato and Nepelski (2013a, 2013b) identify several determinants in the choice for a partner country for co-inventive activities and the location of foreign R&D centres: i) Access to non-transferable and location-specific resources, ii) The macroeconomic environment and size of the host country, and iii) Cost reduction of R&D activities in countries with lower labor costs. Additionally, technological proximity between countries and their level of intellectual property rights protection drive technological collaboration between economies (Montobbio and Sterzi, 2013; see also Dosso and Vezzani (2015) for a review and study of internationalization of technological activities of the Scoreboard companies).

[1] See Dosso and Lebert (2019) for a patent-based network analysis of the world top corporate R&D investors.

Further, the characteristics of firms have a crucial role in the decision to engage in collaboration. The propensity of firms to cooperate in R&D tends to increase with their technological level as well as with their need to access complementary R&D resources (Miotti and Sachwald, 2003). Multinational firms from emerging economies, in particular China, enjoy deeper and broader access to international innovation networks than in the past (Branstetter, Li and Veloso, 2015; Chen, Jang and Chang, 2013; De Prato and Nepelski, 2013b).

With regard to technological collaboration in the China-Europe-US triangle, the EU and the US have been their respective major partner in international R&D networks. US-based inventors were responsible for more than half of the EU's WIPO PCT[2] patents with foreign co-inventors and the EU made up around 45% of the respective total of the US in 2012. China has become the number two partner in terms of co-inventing for both, the EU and the US, with a share nearly three times the share of Japan. Moreover, the European Commission's *Science, Research and Innovation Performance* 2016 report showed that the US has been engaging in such co-inventions with China-based inventors to a higher degree than the EU (European Commission, 2016, p.64f). Veugelers and Baltensperger (2019) confirm this finding in a recent report for the European Parliament where they include an analysis of international technology cooperation as measured in WIPO PCT applications of the leading S&T country (blocks) of the world. Further, the authors look at their respective shares of international co-inventions, foreign ownership and foreign inventorship of these patent applications over time. They show that both the EU and the US have become more open in terms of international co-inventions, foreign ownership and foreign inventors. On the contrary, China has shown a relative decrease in its reliance on international co-invention, in foreign ownership, and in foreign inventorship in its PCT patents during the past 15 years (Veugelers and Baltensperger 2019, 38ff). Finally, the authors investigate the ownership patterns of patents invented abroad for the country pairs based on PCT applications between 2013 and 2015: The majority of the owners of foreign owned EU inventions reside in other EU countries and the EU and the US show the strongest and most balanced reciprocal link. Both economies source a significant share of their foreign developed R&D from China

[2] The World Intellectual Property Organization "The Patent Cooperation Treaty (PCT) assists applicants in seeking patent protection internationally for their inventions, helps patent Offices with their patent granting decisions, and facilitates public access to a wealth of technical information relating to those inventions. By filing one international patent application under the PCT, applicants can simultaneously seek protection for an invention in a very large number of countries.", see at https://www.wipo.int/pct/en/

whereas the US leads this sort of engagement with China. China shows less balanced links with the EU and the US and sources twice as much inventions from the US than from the EU.

Existing analyses on the global top R&D performers reveal that both EU- as US-based firms included in the Scoreboard rely to a larger extent on inventors located abroad than the firms from Japan and China. This holds especially for patents in Information and Communication Technologies (ICT) (Hernández et al., 2017). The "home-bias" in the location of inventions appears to be much stronger for Japan and China, which both rely to less than 10% on inventors residing in foreign countries, notably 7% for Japan and 9% for China. From the viewpoint of the EU, the US is by far the most important location of non-local inventors in both considered fields (ICT: 12%, non-ICT: 15%). In contrast, China plays a smaller role (ICT: 1%, non-ICT: 4%). Interestingly, in non-ICT fields, top R&D investors with headquarters in China and Rest-of-World prefer the EU over the US for non-domestic inventive activities, while in ICT technologies, the US leads the EU. Additionally, Hernández et al. (2017) look at applicant and inventor locations of ICT related inventions. The authors illustrate that, compared to the EU, firms with headquarters in the US (as well as firms from Japan and South Korea) own a large part of the new digital technologies. Further, they are shown to have a key position in the development of ICT-related inventions and China stands out as an inventor location rather than an applicant one.

Resulting from the developments and trends described is the apparent and aggravating lagging behind of Europe in terms of attraction for and engagement with talent and leading R&D personnel in the triangle China-EU-US, as analyzed in contributions by Veugelers (2011, 2017a, 2017b). Noteworthy, in particular for the empirical analysis of the global top 2,500 R&D investors in the following part of this study, Veugelers (2013) states: "The most relevant issue for the EU is not so much if Asia's science, technology and innovation capacity will continue to increase, but who will be able to use this capacity for value creation and value capture. Corporate R&D and innovation is highly concentrated in a few global players. How these firms react to and ride on the Asian science and technology rise will be critical for assessing the impact on Europe."

3. Dataset and main indicators

3.1. Patents dataset

Patents can serve as relevant indicators in the assessment of the change in technological patterns across and between economies such as co-inventive activities. Providing information on the inventive and co-inventive performance of economic actors, patents contain details on the origin of applicant(s) and inventor(s) as well as on the technological domain and date of the invention. For the purpose of this report, we focus on the residence of inventor and applicant of the patent to define the origin of an (co-)invention. This approach is commonly used in the academic literature and institutional studies on invention collaboration (Daiko et al., 2017; Dernis et al., 2015; European Commission, 2016; Montobbio and Sterzi, 2013; OECD, 2009, 2017; Picci, 2010).

The analysis is based on the internal extensive dataset of the Joint Research Centre (JRC): the Top 2,500 R&D investors as analysed in the EU Industrial R&D Investment Scoreboard 2017 (Scoreboard) (Hernández et al., 2017). Thanks to the collaboration between the JRC and the OECD, the patent applications of the Scoreboard companies have been matched to their patent applications[3]. For this report, we use the patents applications filed at the European Patent Office (EPO) as well as at the United States Patent and Trademark Office (USPTO). This allows for an exploration and mapping of invention collaboration in the triangle China-Europe-US at the firm- and industry-level. The patent information is retrieved from PATSTAT and covers patent applications between 2005 and 2015. The analysis is based on PATSTAT version 2017b.

3.2. Main indicators

The main indicators used for the analysis of companies' types of invention and international technological collaboration patterns are the following:

Domestic (co-) invention: Patent applications owned by a Scoreboard firm with (co-) inventor(s) from the (Scoreboard firm's) domestic country only.

International co-invention: Patent applications owned by a Scoreboard firm with at least one inventor from the (Scoreboard firm's) domestic country and at least one inventor from a foreign country. The ownership of an invention/a patent application is defined by the first

[3] For a detailed explanation of the matching exercise, see Daiko et al.(2017) and Dernis et al.(2015)

applicant in a patent application. Such type of invention concerns patent applications by Scoreboard firms relying "(…) on research and innovation facilities located in several economies to draw upon geographically dispersed knowledge and/or develop complementarities with foreign inventors" (OECD 2017, 133). Formulated differently, they are engaged in twofold internationalisation strategies: exploiting their own knowledge assets and accessing foreign knowledge[4].

Foreign (co-) invention: Patent applications owned by a Scoreboard firm with (co-) inventor(s) from a non-domestic country only. This type of invention is proxied by the patent applications for which the research has been entirely conducted in the foreign laboratory (subsidiary of Scoreboard firm).

4. Quantitative analysis

This section examines the patterns and dynamics of technological collaboration of the world's top corporate R&D investors within the China-Europe-US triangle between 2005 and 2015. First, it provides an overview of the sample of the patent applications of Scoreboard firms for the different countries and patent offices by type of invention as well as by industry (Section 4.1). Then it outlines the main characteristics of the technological collaboration within the 2017 Scoreboard dataset and offers an overview on companies' (co-) invention sources (Section 4.2). Subsequently, it illustrates the major partner countries of the Scoreboard companies at the EPO and the USPTO (Section 4.3). Finally, it breaks down the international co-invention distribution of Scoreboard companies for the two patent offices at the industry level (Section 4.4.).

4.1. Overview of inventions of top corporate R&D investors at EPO and USPTO

Table 1 provides an overview of the split in type of invention for the three EU/US/China firm groups in our sample: Domestic (co-)inventions still represent the most frequent pattern of co-inventions for the global top corporate R&D investors, followed respectively by the recourse to only foreign (co-)-inventions and then to international collaboration for co-inventions. Exceptions are the EU-based Scoreboard firms' patent applications at the USPTO; there, the foreign-based inventions made up more than half of their patent applications in the period 2005-2015. These facts suggest both a significant integration of research area within the EU

[4] See more detailed definitions in the OECD Patent Statistics Manual (OECD, 2009, 132)

in regard to the EU technological markets and point at the traditionally strong EU R&D presence in the US.

Table 1: Total patent applications of Scoreboard firms at EPO and USPTO for the period 2005-2015* (whole counts of patents)

	EPO			USPTO		
	EU-based firms	US-based firms	China-based firms	EU-based firms	US-based firms	China-based firms
Domestic inventions	182,576	128,746	16,379	115,606	617,523	21,327
International inventions	22,477	15,342	312	23,722	73,759	1,491
Foreign inventions	111,823	49,624	2,283	154,521	110,662	5,579

Notes :

- *Domestic (Co-) Inventions: patent applications with (co-)inventor(s) from domestic country only*
- *International co-inventions: patent applications with at least one inventor from domestic country and at least one inventor from foreign country*
- *Foreign (Co-) Inventions: patent applications with (co-)inventor(s) from non-domestic country only*
- *At EPO: Total of 455 unique EU-28, 608 unique US and 90 unique Chinese firms with complete patent application information*
- *At USPTO: Total of 448 unique EU-28, 659 unique US and 120 unique Chinese firms with complete patent application information*
- ** Whole counts, data truncation starting in 2013*

Source: Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b

Table 2 and Table 3 list total patent applications of EU-, US- and China-based Scoreboard companies by industry in the top 15 industries for EU companies at the EPO and USPTO.

Inventions of EU-based firms at the EPO are clearly led by *Automobiles & Parts*. Other major driving industries are the European R&D strongholds such as *Chemicals*, *Technology Hardware & Equipment*, *Pharmaceuticals & Biotechnology*, *Industrial Engineering*, *Electronic & Electrical Equipment*, *Aerospace & Defence*, *Health Care Equipment & Services* as well as *General Industrials*. The same industries lead the list for US companies, but with a different concentration. US top corporate R&D investors show a high number of filings by companies in the *Technology Hardware & Equipment* industry and a strong presence in *General Industrials* and *Pharmaceuticals & Biotechnology*, too. As for Chinese firms, patent applications were predominantly filed in *Technology Hardware & Equipment* at the EPO, mainly due to the high patent applications by the firms Huawei and ZTE from this industry. At the USPTO, *Technology Hardware & Equipment* spearheads the industry ranking for the Scoreboard firms from all three economies. Remarkably, US firms' filings are highly concentrated in the *Technology Hardware & Equipment* and *Software and & Computer Services* industries. Similarly to what can be observed at the EPO, filings by China-based firms were dominated by the former industry and its major players. Additionally, Chinese filings focus on *Electronic & Electrical Equipment* and *Software and & Computer Services*.

Table 2: Total patent applications of Scoreboard firms by ICB industry at EPO for the period 2005-2015 (top 15 industries)* (whole counts of patents)

ICB Industries	EU-based firms	US-based firms	China-based firms
Automobiles & Parts	69,209	6,940	215
Chemicals	29,848	14,784	87
Technology Hardware & Equipment	28,899	44,505	16,071**
Pharmaceuticals & Biotechnology	25,003	19,354	99
Industrial Engineering	24,056	9,169	510
Electronic & Electrical Equipment	19,689	9,142	846
Aerospace & Defence	18,915	13,937	1
Health Care Equipment & Services	16,395	12,357	19
General Industrials	15,915	25,204	57
Household Goods & Home Construction	14,351	8,636	3
Electricity	6,974	9	5
Industrial Metals & Mining	6,559	179	1
Oil & Gas Producers	6,083	1,935	124
Fixed Line Telecommunications	4,963	318	1
Media	4,772	556	-

Notes :

- *Industry Classification Benchmark (ICB 4-digits) sector classification*
- *Total of 455 unique EU-28, 608 unique US and 90 unique Chinese firms with complete patent application information*
- ** Ranked by EU-based firms; Whole counts, data truncation starting in 2013*
- *** 10,828 patent applications (67%) of which were filed by Chinese firm Huawei alone*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

Table 3: Total patent applications of Scoreboard firms by ICB industry at USPTO for the period 2005-2015 - top 15 industries - * (whole counts of patents)

ICB Industries	EU-based firms	US-based firms	China-based firms
Technology Hardware & Equipment	54,912	260,929	19,818**
Automobiles & Parts	33,911	26,716	188
Electronic & Electrical Equipment	30,151	26,727	3,758
Health Care Equipment & Services	25,016	38,040	24
Pharmaceuticals & Biotechnology	23,335	43,457	96
Chemicals	21,879	37,349	21
Aerospace & Defence	19,847	30,913	-
General Industrials	16,355	54,900	80
Industrial Engineering	15,914	28,739	548
Household Goods & Home Construction	8,196	13,323	1
Software & Computer Services	7,702	164,968	3,141
Oil & Gas Producers	5,586	6,076	391
Electricity	4,230	68	6
Construction & Materials	3,714	3,193	28
Fixed Line Telecommunications	3,251	9,358	4

Notes :

- *Industry Classification Benchmark (ICB 4-digits) sector classification*
- *Total of 448 unique EU-28, 659 unique US and 120 unique Chinese firms with complete patent application information*
- ** Ranked by EU-based firms; Whole counts, data truncation starting in 2013*
- *** 12,035 patent applications (61%) of which were filed by Chinese firm Huawei alone*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

4.2. Type of invention of top corporate R&D investors

This sub-section outlines the types of (co-)inventions of EU, US and Chinese top R&D investor companies at the EPO and USPTO for the three indicators listed above.

Type of invention of top corporate R&D investors at European Patent Office

Figures 1.1 - 1.3 show the shares of co-inventions by type of invention for top R&D investors based in the EU-28, the US and China at the EPO during the period 2005-2015.

The largest share in all three charts is made of inventions from domestic residents/inventors, either by a sole domestic inventor or in purely domestic inventor teams. The latter source has gained in importance in the EU, while foreign (co-)inventions tend to become of a lesser importance. International (co-)invention as a share of invention has been relatively low for all groups of firms, below 10%, during the last two years illustrated.

Chinese Scoreboard companies rely to an even lesser extent on international (co-)invention, with nearly no activity until 2009. However, since 2010, the trends seems to change, but the related total and relative figures remain below those of their EU and US counterparts.

Figure 1.1: EU-28 top corporate R&D investors
Type of invention at EPO
Total inventions*: 2005: 30,057 - 2012: 33,257

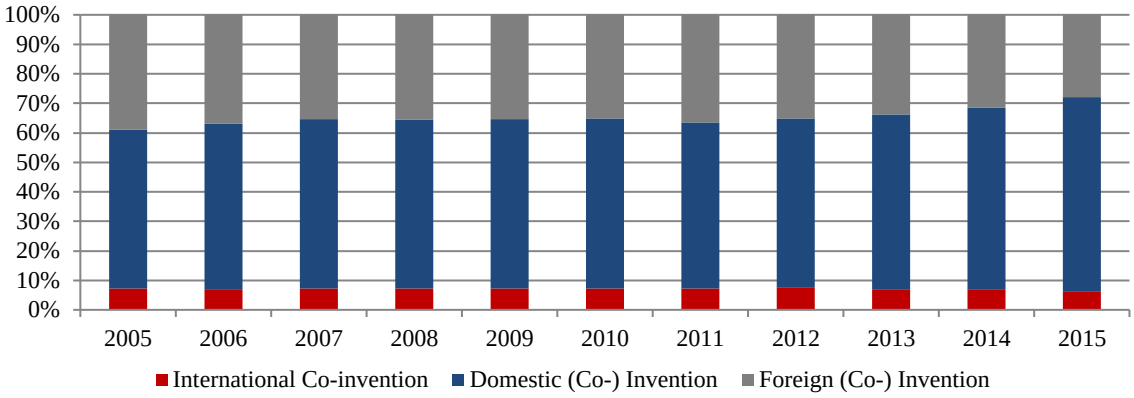


Figure 1.2: US top corporate R&D investors
Type of invention at EPO
Total inventions*: 2005: 21,926 - 2012: 20,681

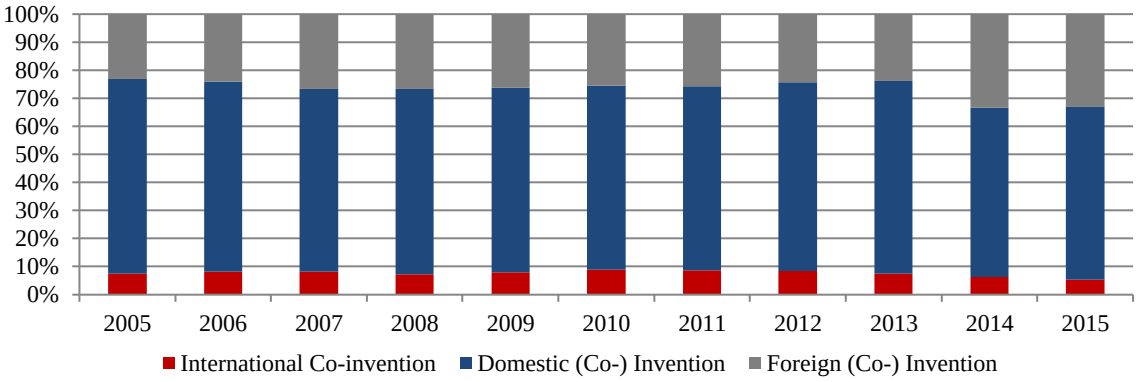
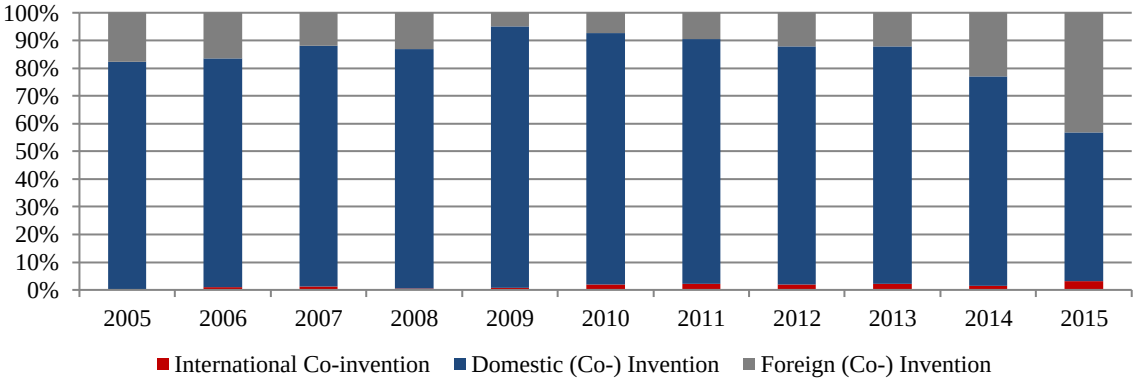


Figure 1.3: Chinese top corporate R&D investors
Type of invention at EPO
Total inventions*: 2005: 744 - 2012: 3,530



Notes :

- *International co-inventions: patent applications with at least one inventor from domestic country and at least one inventor from foreign country*
- *Domestic (Co-) Inventions: patent applications with (co-)inventor(s) from domestic country only*
- *Foreign (Co-) Inventions: patent applications with (co-)inventor(s) from non-domestic country only*
- *Total of 455 unique EU-28, 608 unique US and 90 unique Chinese firms with complete patent application information*
- ** Whole counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

Type of invention of top R&D investors at United States Patent and Trademark Office

Figures 1.4 - 1.6 show the distributions of co-inventions by type of invention for top corporate R&D investors based in EU-28, the US and China at the USPTO during the period 2005-2015

USPTO figures show different patterns and dynamics than the overview at the EPO above: Here, European firms rely to a greater extent on foreign (co-)inventions while domestic (co-) inventions dominate at US-based and China-based top corporate R&D investors. International (co-) invention as a share of invention has been relatively constant for Europe and US at around 8-10%, with slightly higher shares for US companies and a slight increase of the latter in recent years.

China-headquartered Scoreboard companies rely to a greater extent on international (co-)invention in their patent applications at the USPTO than at the EPO. However, the corresponding shares in the two offices generally remain well below 10% of their total inventions over the period examined.

Figure 1.4: EU-28 top corporate R&D investors
Type of invention at USPTO
Total inventions*: 2005: 30,187 - 2012: 30,429

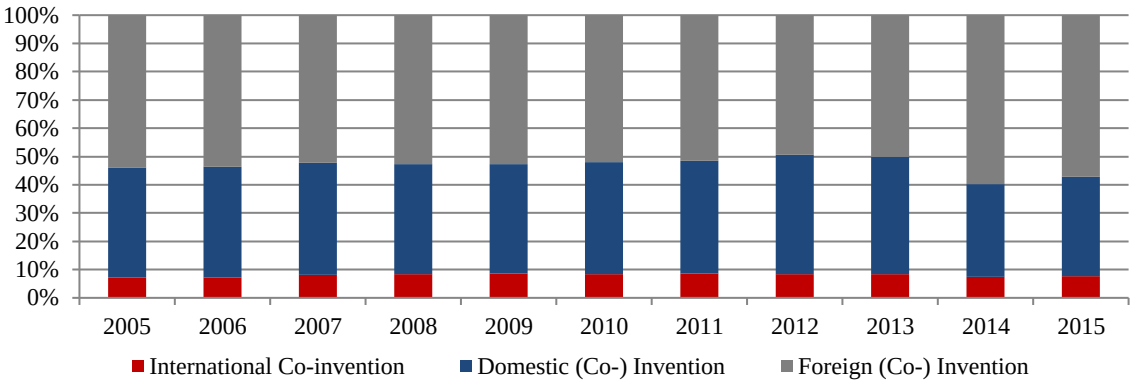


Figure 1.5: US top corporate R&D investors
Type of invention at USPTO
Total inventions: 2005: 78,429 - 2012: 85,582*

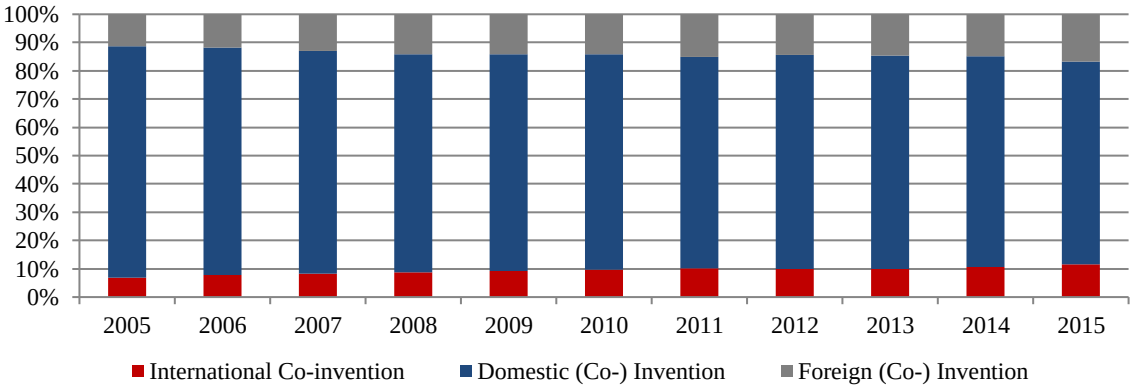
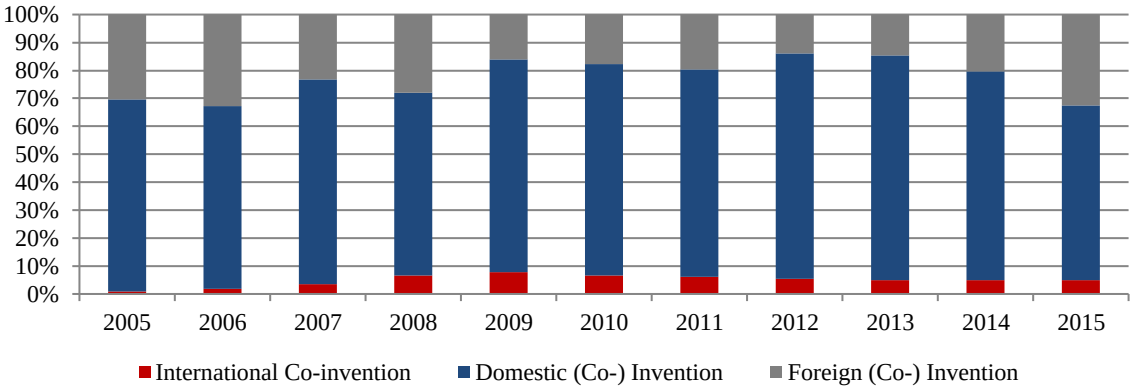


Figure 1.6: Chinese top corporate R&D investors
Type of invention at USPTO
Total inventions: 2005: 1,010 - 2012: 4,706*



Notes:

- *International co-inventions: patent applications with at least one inventor from domestic country and at least one inventor from foreign country*
- *Domestic (Co-) Inventions: patent applications with (co-)inventor(s) from domestic country only*
- *Foreign (Co-) Inventions: patent applications with (co-)inventor(s) from non-domestic country only*
- *Total of 448 unique EU-28, 659 unique US and 120 unique Chinese firms with complete patent application observations in Scoreboard*
- ** Whole counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

4.3. International co-invention of top corporate R&D investors

This section examines the distribution of international (co-)inventions by country at the EPO and at the USPTO for European, US and Chinese top corporate R&D investor companies. As defined in section 3 above, these international (co-)inventions concern all patents applications with at least one inventor from the domestic country of the Scoreboard firm and at least one inventor from a foreign country. For comparison, they correspond to the part of Scoreboard inventions highlighted in red ("International Co-invention") in Figures 1.1 - 1.6 above.

International co-invention at EPO

Figures 2.1 - 2.6 show the shares of international (co-)inventions by country for top R&D investors based in the EU-28, the US and China at the EPO for the periods, 2005-2009 (left side) and 2010-2015 (right side).

The domestic and international inventions of EU-based top R&D investors (Figure 2.1 and Figure 2.2) show major reliance (80%) upon other EU member countries. The US has been the largest non-EU-28 international co-invention partner. Only small changes can be observed in the composition of the contributing partners over time.

As for US top R&D investors (Figure 2.3 and Figure 2.4), EU-28 co-inventors make up a quarter of all US international co-inventions. For both, US and EU-28 firms, Chinese co-inventors have gained some importance over time, as illustrated by the slightly increasing share For US-headquartered Scoreboard companies, it represented 5 % in the time period 2010-2015, compared to 3% for EU-28 companies.

With regard to China-based Scoreboard companies (Figure 2.5 and 2.6), the share of non-domestic co-inventors in their international co-inventions has also grown. US based co-inventors represent about a third thereof. The share of EU-28 co-inventors decreased between the two time periods observed and lied at 8% for the period 2010-2015.

Figure 2.1: EU-28 top R&D investors
Shares of international co-inventions at EPO by partner country, 2005 - 2009*

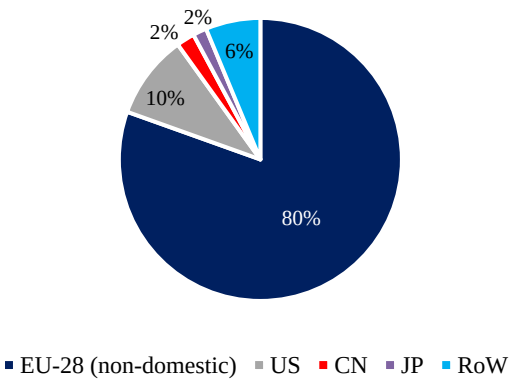


Figure 2.2: EU-28 top R&D investors
Shares of international co-inventions at EPO by partner country, 2010 - 2015*

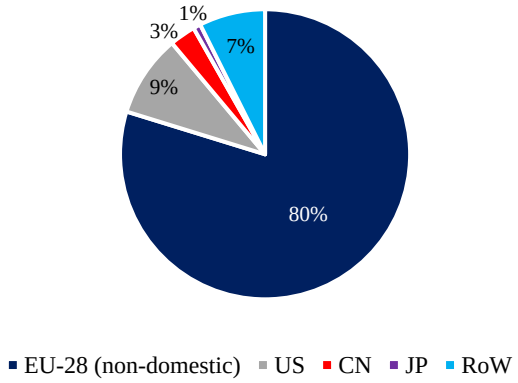


Figure 2.3: US top R&D investors
Shares of international co-inventions at EPO by partner country, 2005 - 2009*

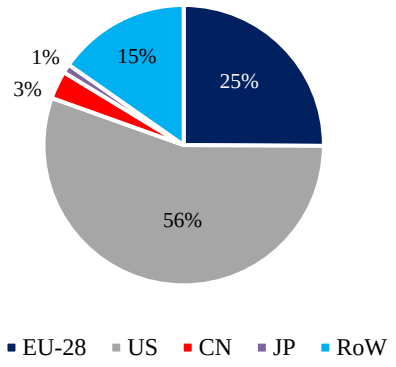


Figure 2.4: US top R&D investors
Shares of international co-inventions at EPO by partner country, 2010 - 2015*

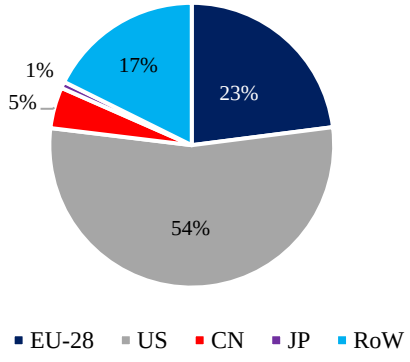


Figure 2.5: Chinese top R&D investors
Shares of international co-inventions at EPO by partner country, 2005 - 2009*

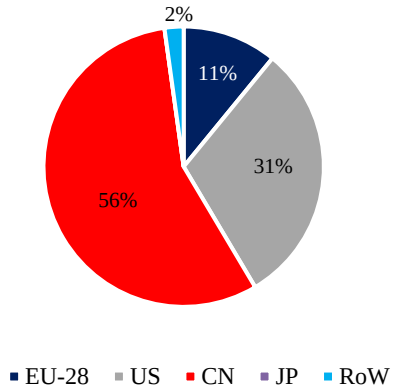
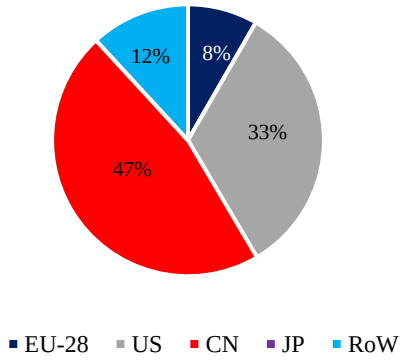


Figure 2.6: Chinese top R&D investors
Shares of international co-inventions at EPO by partner country, 2010 - 2015*



Notes:

- *International co-invention: patent applications from Scoreboard firm with at least one inventor from domestic country and at least one inventor from foreign country*
- ** Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

International co-invention at USPTO

Next, Figures 2.7 - 2.12 show the shares of international (co-)inventions by country for top R&D investors based in EU-28 countries, the US and China at the USPTO for the two periods, 2005-2009 (left side) and 2010-2015 (right side).

EU-28 top R&D investors rely, for about 75% of their international co-inventions, upon their EU neighbours. Both, the US-based and China-based investors contribution slightly grew: US based co-inventors contributed to up to 16%-17% of the international co-inventions of EU-headquartered Scoreboard companies while China-based inventors made up 3% between 2010 and 2015.

As for US-based companies, EU-28 based co-inventors represent the largest group, after Rest-of-World, with a share of 16% of US-based companies' international co-inventions. While this share slightly decreased, the shares of China and Rest-of-World based co-inventors rose. Between 2010 and 2015, China based co-inventors contributed with 5% to the international co-inventions of US-headquartered top R&D investors in the Scoreboard.

China-based Scoreboard companies (Figure 2.11 and 2.12) increasingly rely on foreign based inventors in their international co-inventions: The weight of domestic inventors within those international co-inventions decreased from 59% to 52%. Further, the firms rely for about 25% on co-inventors residing in the US. The contribution of EU-based co-inventors slightly fell from 12% to 10%. At the same time, co-inventors which are not from the EU, nor from Japan, neither from the US clearly gained in importance; RoW represents about 10% between 2010 and 2015.

Figure 2.7: EU-28 top R&D investors
Shares of international co-inventions at USPTO by partner country, 2005 - 2009*

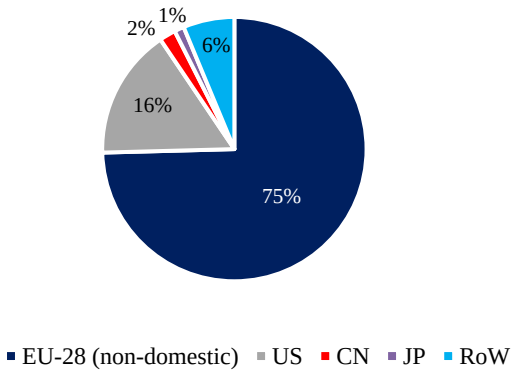


Figure 2.8: EU-28 top R&D investors
Shares of international co-inventions at USPTO by partner country, 2010 - 2015*

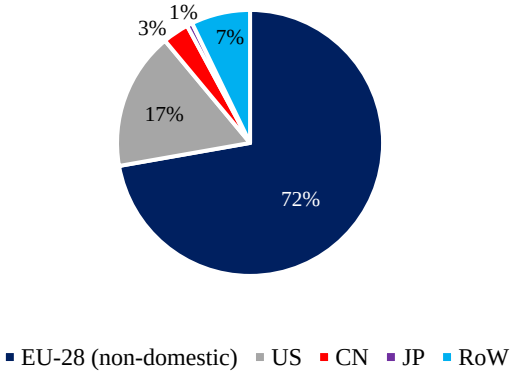


Figure 2.9: US top R&D investors
Shares of international co-inventions at USPTO by partner country, 2005 - 2009*

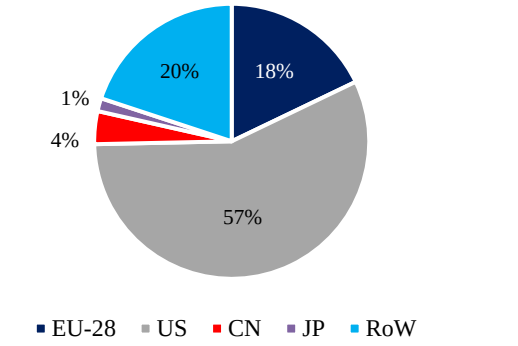


Figure 2.10: US top R&D investors
Shares of international co-inventions at USPTO by partner country, 2010 - 2015*

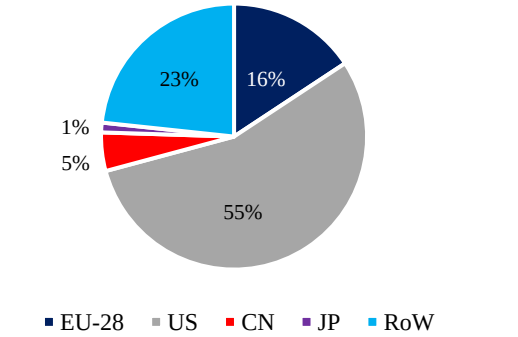


Figure 2.11: Chinese top R&D investors
Shares of international co-inventions at USPTO by partner country, 2005 - 2009*

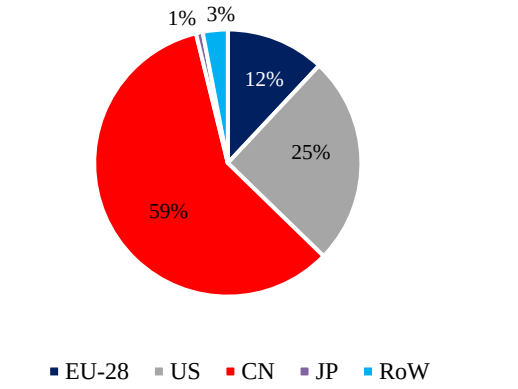
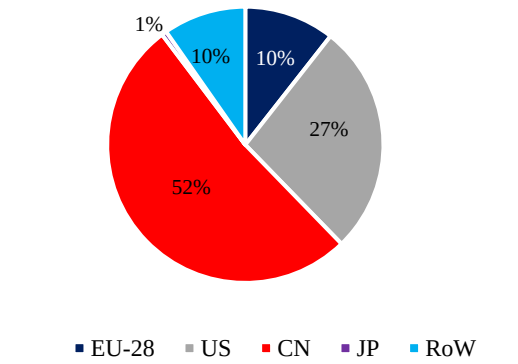


Figure 2.12: Chinese top R&D investors
Shares of international co-inventions at USPTO by partner country, 2010 - 2015*



Notes:

- *International co-invention: patent applications from Scoreboard firm with at least one inventor from domestic country and at least one inventor from foreign country*
- **Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

4.3. Foreign inventions owned by top corporate R&D investors

This section focuses on the distribution of foreign inventions by partner country for EU- and US-headquartered top R&D investing companies. As defined in section 3 above, these foreign (co-)inventions concern all of their patents applications, filed at the EPO and at the USPTO, with inventor(s) only located in a non-domestic country. For comparison, this section deals with the part of Scoreboard inventions highlighted in grey ("Foreign (Co-)invention") in Figures 1.1 - 1.6 above.

Foreign inventions at EPO

Figures 3.1 - 3.6 show the shares of foreign inventions by country for top R&D investors based in the EU-28, the US and China at the EPO for the periods 2005-2009 (left side) and 2010-2015 (right side).

For EU-based top R&D investors (Figure 3.1 and Figure 3.2), US based inventors are the most important source of foreign inventions in their patent applications at the EPO. However, this share decreased from 75% to 65% when comparing the two different time periods. China based inventions showed a remarkable increase to 9%. Rest-of-World also experienced an increase, while Japan based inventions as source for European patent applications at the EPO stagnated at 3%.

As for US top R&D investors (Figure 3.3 and Figure 3.4), EU-located inventors represent the by far largest share for these companies at the EPO with around three quarters of foreign inventions. The Japanese contribution slightly dropped, differently from China- and RoW-based inventors between the time periods covered.

With regard to Chinese top R&D investors (Figure 3.5 and Figure 3.6), the EU-28 countries increased their presence as co-inventors vis-à-vis other major partner countries: The EU-28 share rose from 42% to 57% while the US share fell from 51% to 29%. Similar drop are observed in Japan, where the RoW stand now at 13% (against 2% in 2005-2009); this highlights the extension of Chinese foreign R&D activities in other foreign countries.

Figure 3.1: EU-28 top R&D investors
Shares of foreign inventions (non EU-28) at EPO by partner country, 2005 - 2009*

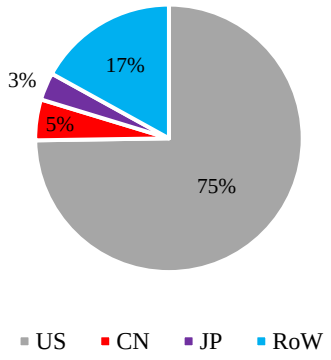


Figure 3.2: EU-28 top R&D investors
Shares of foreign inventions (non EU-28) at EPO by partner country, 2010 - 2015*

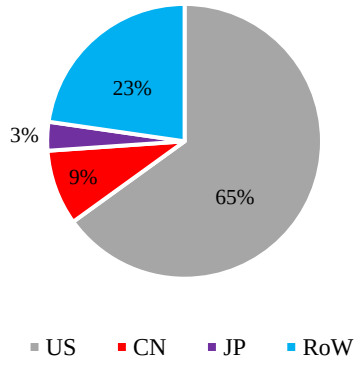


Figure 3.3: US top R&D investors
Shares of foreign inventions at EPO by partner country, 2005 - 2009*

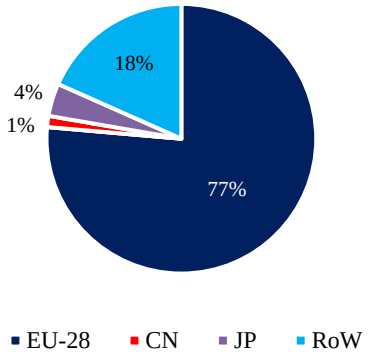


Figure 3.4: US top R&D investors
Shares of foreign inventions at EPO by partner country, 2010 - 2015*

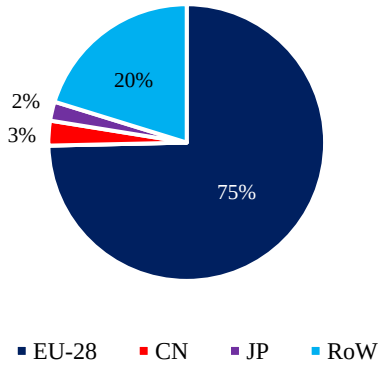


Figure 3.5: Chinese top R&D investors
Shares of foreign inventions at EPO by partner country, 2005 - 2009*

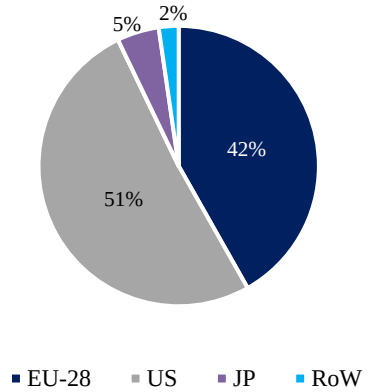
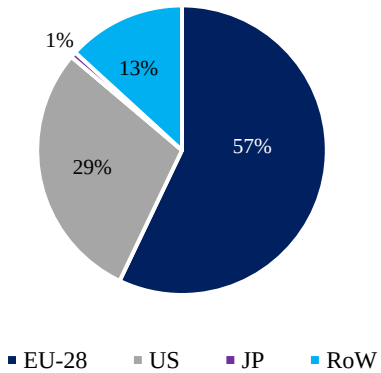


Figure 3.6: Chinese top R&D investors
Shares of foreign inventions at EPO by partner country, 2010 - 2015*



Notes:

- *Foreign (Co-) Inventions: patent applications with (co-)inventor(s) from non-domestic country only*
- ** Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

Foreign inventions at USPTO

In this sub-section, Figures 3.7 - 3.11 show the shares of foreign inventions by country for top R&D investors based in EU-28 and the US at the USPTO during the periods 2005-2009 and 2010-2015.

For EU-based companies, US-located inventors dominate as a source of foreign inventions at the USPTO. Noteworthy, inventors based in the Rest-of-World and China seem to gain in importance.

As for US companies, EU-28 countries based inventors are responsible for nearly half of their foreign inventions. However, as for Japan-based inventors, this share has decreased, for instance in favour of other countries and, to a lesser extent, China.

The distribution of foreign inventions at the USPTO for China-ranked Scoreboard companies has also evolved. Importantly, the share of US-located inventors dropped for about 15 percentage points between the two periods. Another major change can be observed for the share of Rest-of-World which grew from 4% to 19%. Similar to EPO figures above, this development suggests **an increased invention sourcing of China-headquartered top R&D investors from countries outside the traditional technology triad Europe, US and Japan**.

3.7: EU-28 top R&D investors
Shares of foreign inventions (non EU-28) at USPTO by partner country, 2005 - 2009*

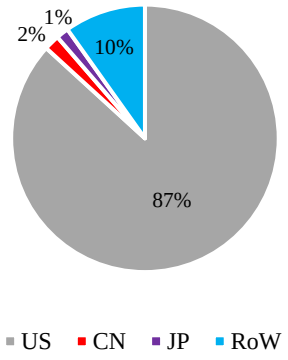


Figure 3.8: EU-28 top R&D investors
Shares of foreign inventions (non EU-28) at USPTO by partner country, 2010 - 2015*

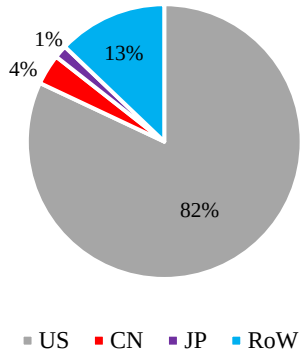


Figure 3.9: US top R&D investors
Shares of foreign inventions at USPTO by partner country, 2005 - 2009*

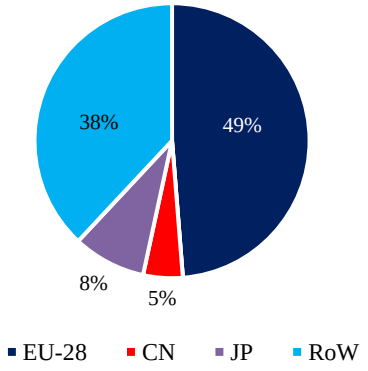


Figure 3.10: US top R&D investors
Shares of foreign inventions at USPTO by partner country, 2010 - 2015*

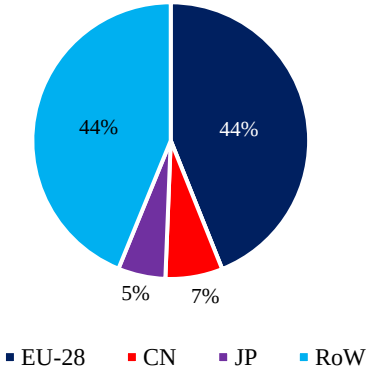


Figure 3.11: Chinese top R&D investors
Shares of foreign inventions at USPTO by partner country, 2005 - 2009*

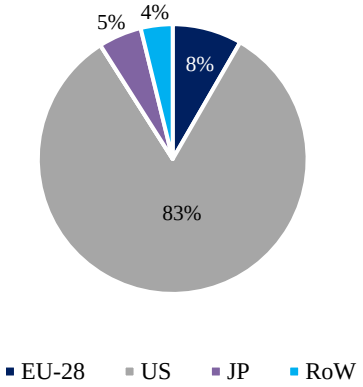
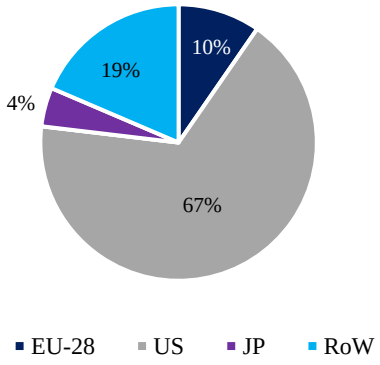


Figure 3.12: Chinese top R&D investors
Shares of foreign inventions at USPTO by partner country, 2010 - 2015*



Notes:

- *Foreign (Co-) Inventions: patent applications with (co-)inventor(s) from non-domestic country only*
- ** Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

4.4. International co-invention of top corporate R&D investors at industry-level

This section provides an overview on the shares of international co-inventions for European and US top corporate R&D investor companies at the EPO and USPTO at the industry level.

International co-invention at industry-level at EPO

Figures 4.1 - 4.4 show the shares of international co-inventions for top R&D investors based in EU-28 and the US at the industry level (Industry Classification Benchmark) at the EPO on 2005- 2015. Note that Chinese top R&D investors were excluded due to their low totals.[5]

For European top R&D investors (Figure 4.1 and Figure 4.2), the EU-28 neighbour countries (taken together) are the most important partner in their international co- inventions at the EPO over all industries.

When excluding other EU countries as partners, the US is the single most important co-inventor especially (>50% of non-EU-28 co-inventions) in *Aerospace & Defence, Chemicals, Construction & Materials, Electronic & Electrical Equipment, Forestry & Paper, Media, Mining, Oil & Gas Producers, Personal Goods and Pharmaceuticals & Biotechnology*.

China based co-inventors also play a significant role in a number of industries, notably (>10% of non-EU-28 co-inventions) *Automobiles & Parts, Fixed Line Telecommunications, Food Producers, Forestry & Paper, Gas Water & Multi-utilities, Household Goods & Home Construction, Personal & Household Goods, Personal Goods, Pharmaceuticals & Biotechnology* and *Technology Hardware & Equipment*.

As for US-based R&D investors co-inventions at the EPO (Figures 4.3 and Figure 4.4), **EU-based inventors (taken together) often make up the largest part of non-US co-inventors in the international teams**. The European presence as a co-inventor in US co-inventions at the EPO is particularly high in *Automobiles & Parts, Food Producers, Health Care Equipment & Services, Household Goods & Home Construction and Industrial Engineering*. China-located co-inventors have a relatively more important presence in as co-inventors in the industries of *Chemicals, Construction & Materials, Electronic & Electrical Equipment, General Industrials, Leisure Goods, Personal Goods* and *Technology Hardware & Equipment* (Figure 4.4).

[5] In reference to Figure 1.3 (whole counting): Only 312 international (co-)inventions were recorded for China-based Scoreboard firms during the whole period 2005 - 2015. When using fractional counting, there are not enough observations to break down the shares at the industry-level.

Figure 4.1: EU-28 top corporate R&D investors
International co-inventor distribution at EPO
By partner country and ICB industry, 2005 - 2015*

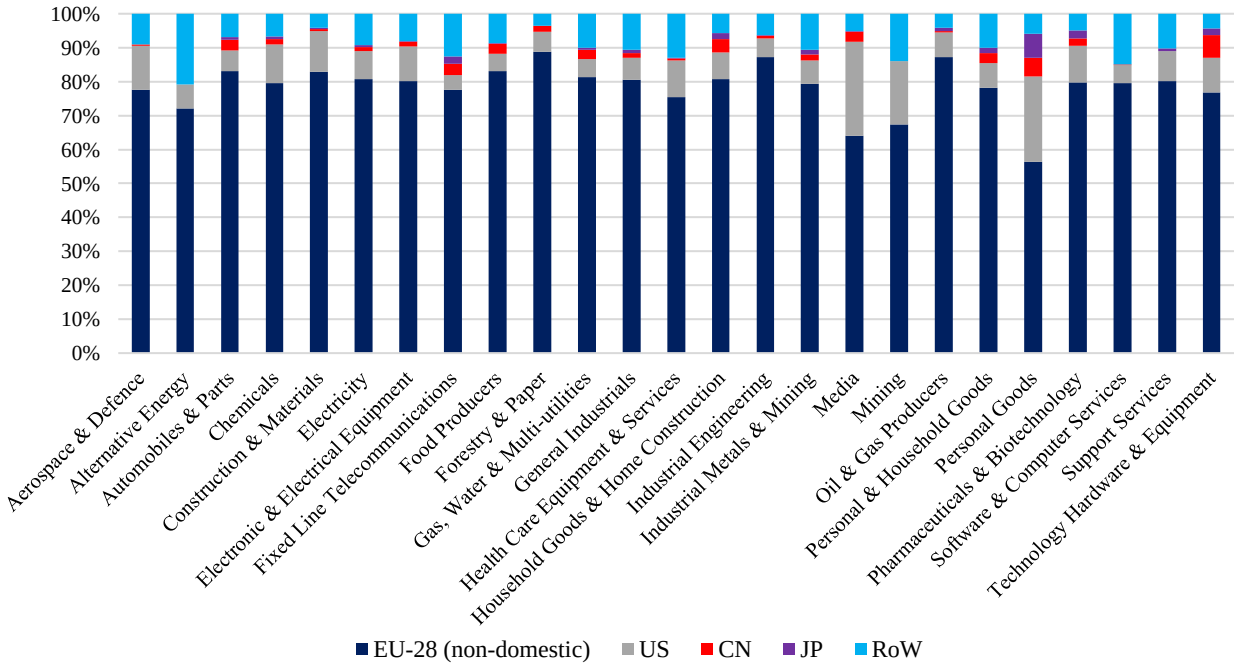
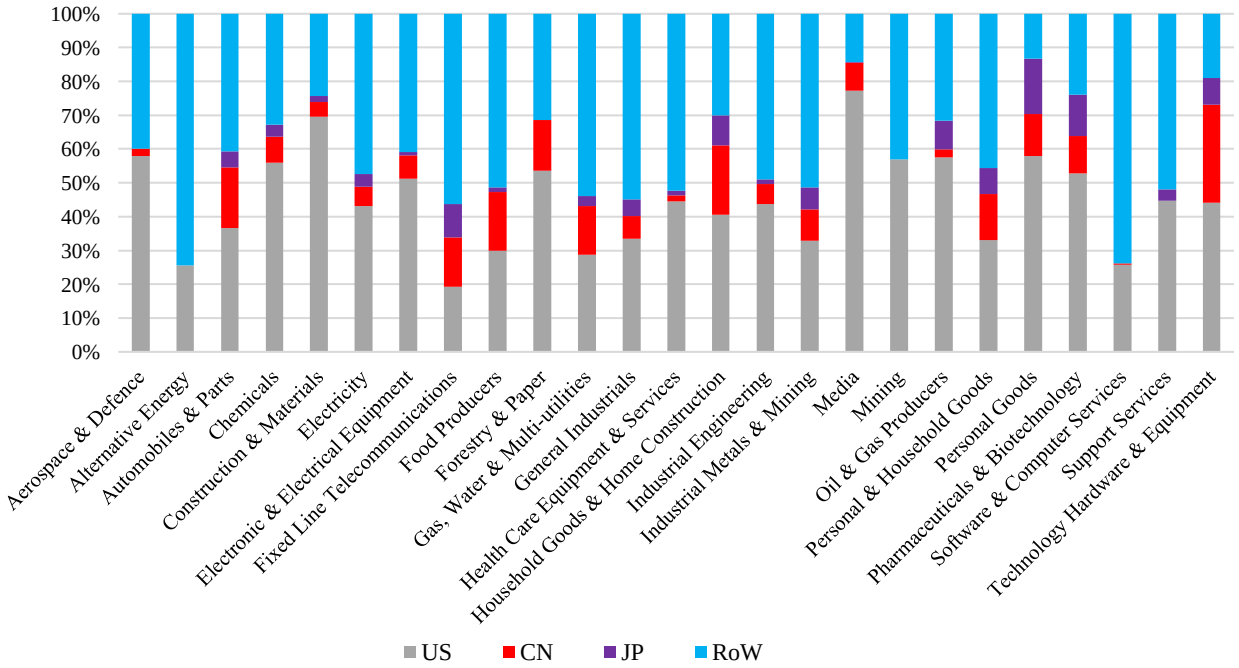


Figure 4.2: EU-28 top corporate R&D investors
Zoom: International co-inventor distribution **(non EU-28)** at EPO
By partner country and ICB industry, 2005 - 2015*



Notes:

- *International Co-invention: patent applications from Scoreboard firm with at least one inventor from domestic country AND at least one inventor from foreign country*
- *Total of 328 unique EU-28 firms with complete patent application observations in Scoreboard*
- *All industries with at least 50 inventions/patent applications (refers to Figure 4.1)*
- **Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

Figure 4.3: US top corporate R&D investors
International co-inventor distribution at EPO
By partner country and industry, 2005 - 2015*

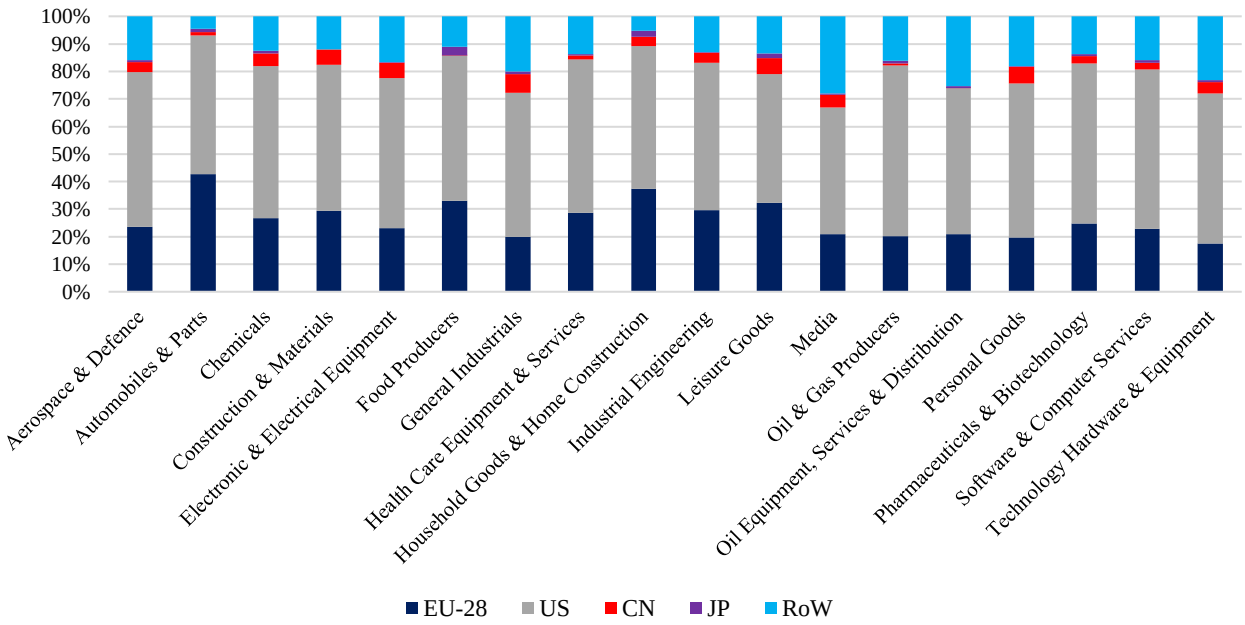
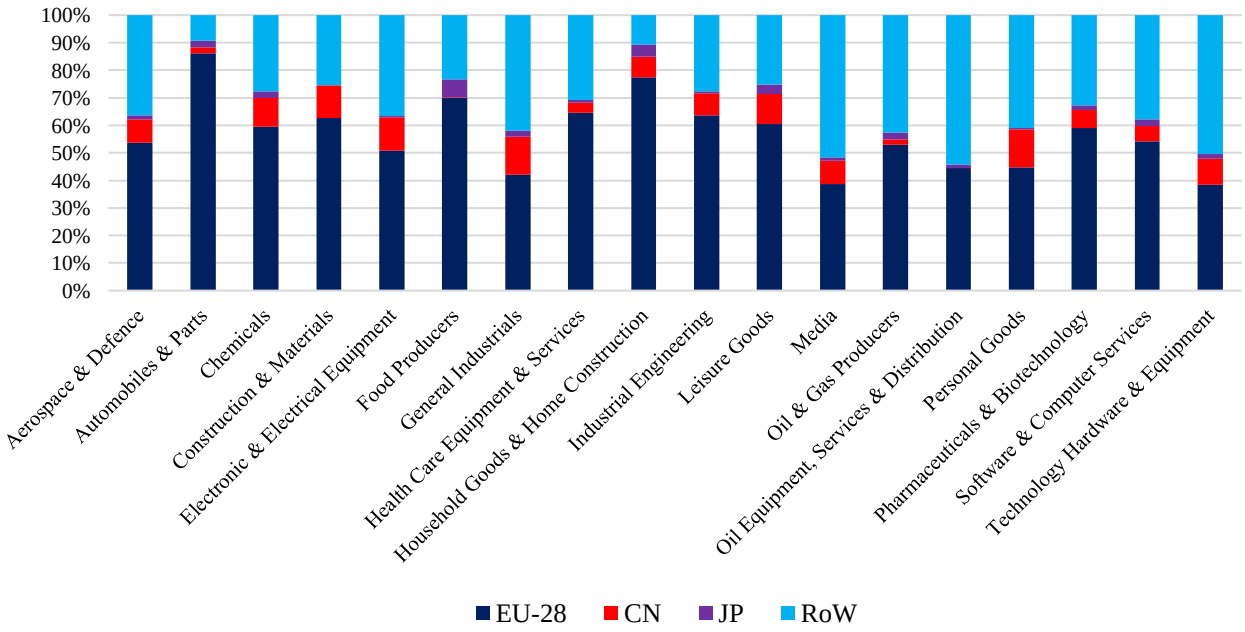


Figure 4.4: US top corporate R&D investors
Zoom: International co-inventor distribution **(non US)** at EPO
By partner country and industry, 2005 - 2015*



Notes:

- *International Co-invention: patent applications from Scoreboard firm with at least one inventor from domestic country AND at least one inventor from foreign country*
- *Total of 442 unique US firms with complete patent application observations in Scoreboard*
- *All industries with at least 50 inventions/ patent applications (refers to Figure 4.3)*
- **Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

International co-invention at industry-level at USPTO

Figures 4.5 - 4.8 show the shares of international co-inventions for top R&D investors headquartered in EU-28 and the US at the industry level (Industry Classification Benchmark - ICB - categorization) at the USPTO between 2005 and 2015. Please note that Chinese top R&D investors were excluded due to their low totals.[6]

For EU-based top R&D investors (Figure 4.5 and Figure 4.6), throughout all industries, the EU-28 neighbouring countries (taken together) are the most important partner in their international co-inventions at the EPO. The US is the single most important co-inventor with a dominance of over 50% in all industries except *Alternative Energy, Fixed Line Telecommunications* and *Software & Computer Services*. China based co-inventors show a stronger presence in *General Industrials, Household Goods & Home Construction,* and *Technology Hardware & Equipment*.

Excluding US co-inventors (Figure 5.8), one can observe that EU-based inventors represent the largest group with a share standing at about 50% in almost half of the industries shown, and a particular strong presence in *Financial Services, Food Producers, Household Goods & Home Construction* and *Mobile Communications.*

In reference to Chinese co-inventors in US companies' international co-inventions at the USPTO, higher shares can be observed as compared to the figures at the EPO , for instance, in *Aerospace & Defence, Construction & Materials, Electronic & Electrical Equipment, General Industrials, Household Goods & Home Construction, General Retailers, Leisure Goods, Media, Mobile Telecommunications, Personal Goods, Software & Computer Services* and *Technology Hardware & Equipment*.

[6] 1,491 international (co-)inventions at the USPTO were recorded (whole counting) for Chinese Scoreboard firms during the entire time period 2005-2015 observed. 1,286 of these fall into the industry of *Technology Hardware & Equipment* and were mostly filed by Huawei. Using fractional counting in the calculations below, there are not enough observations to break down the distribution at the industry-level.

Figure 4.5: EU-28 top corporate R&D investors
Shares of international co-inventions at USPTO
By partner country and industry, 2005 - 2015

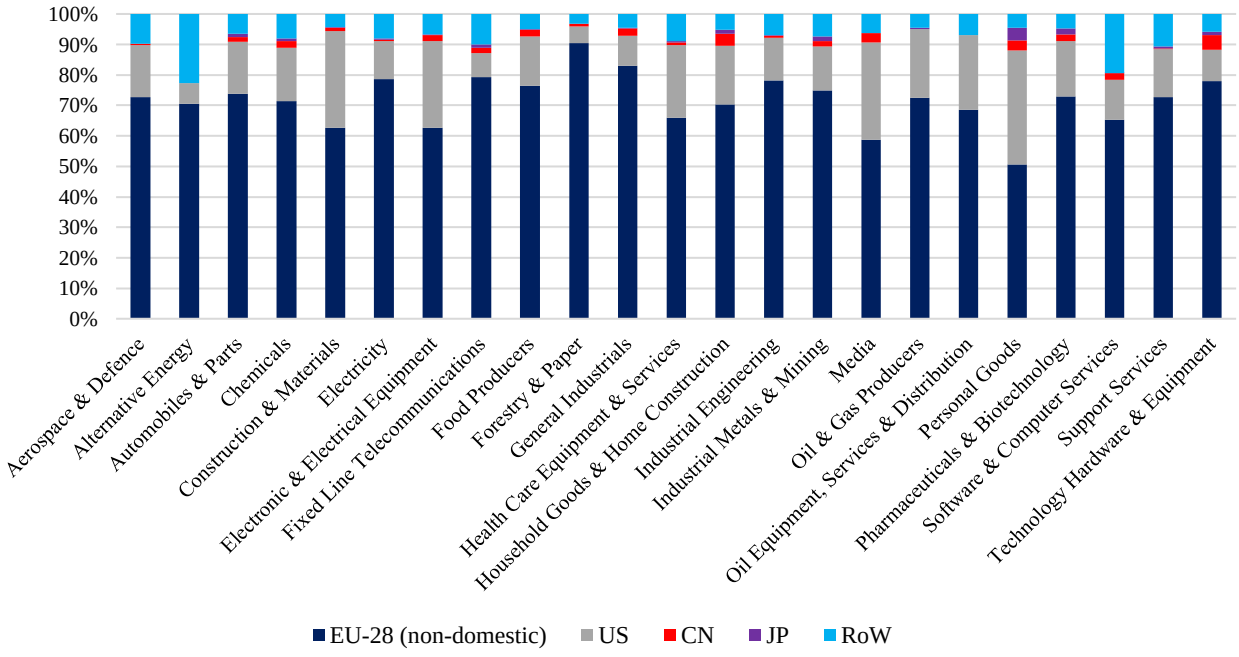
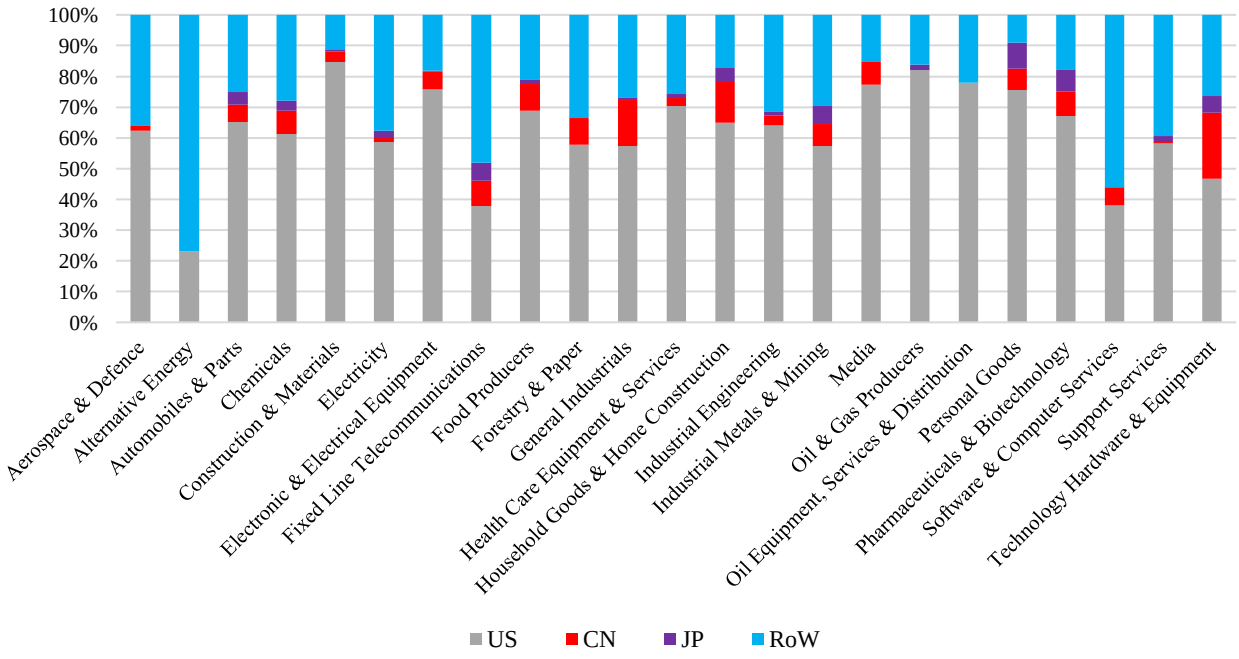


Figure 4.6: EU-28 top corporate R&D investors
Zoom: Shares of international co-inventor distributions **(non EU-28)** at USPTO
By partner country and industry, 2005 - 2015*



Notes:

- *International Co-invention: patent applications from Scoreboard firm with at least one inventor from domestic country AND at least one inventor from foreign country*
- *Total of 332 unique EU-28 firms with complete patent application observations in Scoreboard*
- *All industries with at least 50 inventions/ patent applications (refers to Figure 4.5)*
- **Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

Figure 4.7: US top corporate R&D investors
Shares of international co-inventions at USPTO
By partner country and industry, 2005 - 2015*

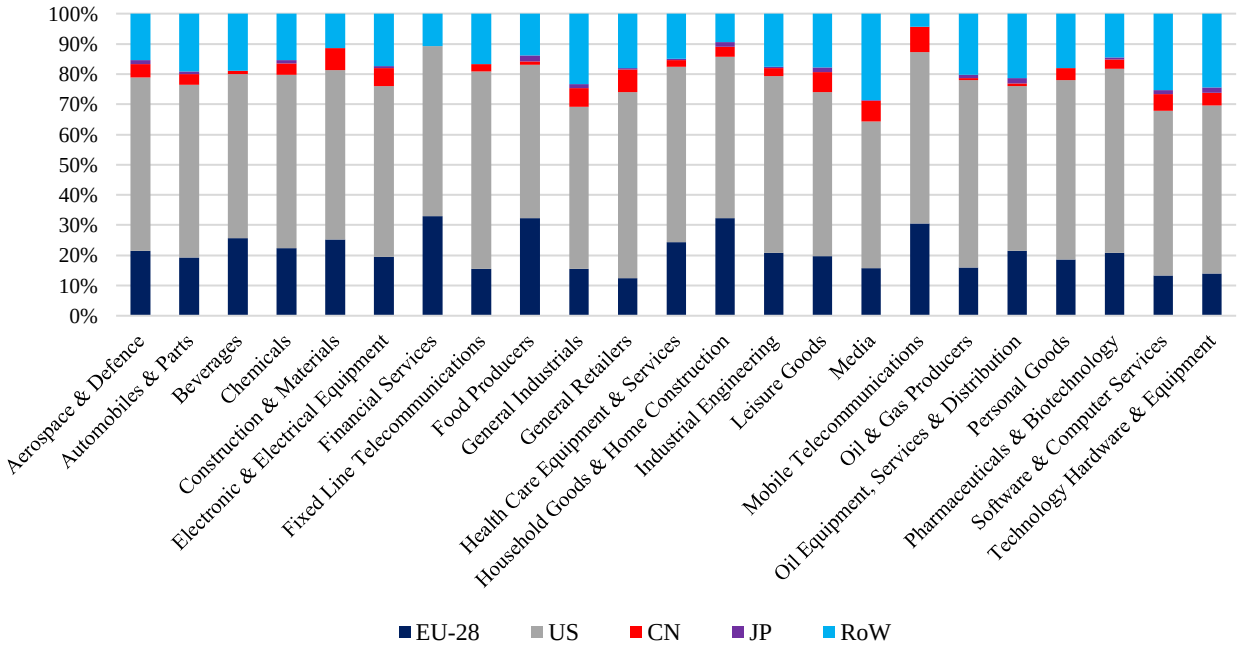
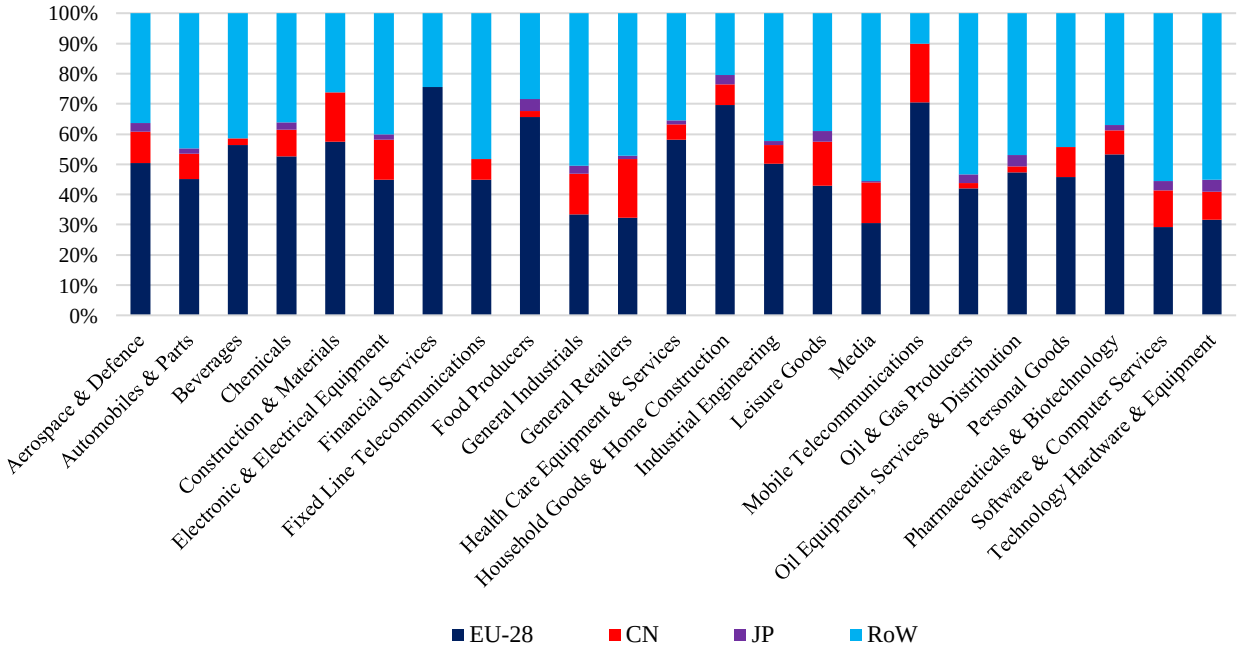


Figure 4.8: US top corporate R&D investors
Zoom: Shares of international co-inventions **(non US)** at USPTO
By partner country and industry, 2005 - 2015*



Notes:

- *International Co-invention: patent applications from Scoreboard firm with at least one inventor from domestic country AND at least one inventor from foreign country*
- *Total of 559 unique US firms with complete patent application observations in Scoreboard*
- *All industries with at least 50 inventions/patent applications (refers to Figure 4.7)*
- **Fractional counts, data truncation starting in 2013*

Source:

- *Author's calculations, based on The 2017 EU Industrial R&D Investment Scoreboard, European Commission JRC/DG RTD, and PATSTAT version 2017b*

5. Conclusion

The present report exploits patent data to examine the patterns of technological collaborations for a sample of the world's top corporate R&D investors as ranked in the EU R&D Scoreboards of the Joint Research Centre (JRC).

The analysis confirmed that **domestic (co-)inventions still represent the most frequent pattern of co-inventions for the global top corporate R&D investors**, followed respectively by the recourse to only foreign (co-)inventions and then to international collaboration for co-inventions. Differently, the foreign-based inventions made up more than half of the applications for EU-based investors' patent applications at the USPTO on the period 2005-2015. These facts support the observations about a significant integration of the research area within the EU with respect to the EU technological markets and point at the strong EU R&D presence in the US. International (co-)invention activity has been relatively constant (below 10%) for EU- and US-based companies, while China-based Scoreboard firms rely to a much lesser extent on international collaborations for co-inventions.

Further the analyses of international co-inventions confirm that the EU and the US have been mutually preferred external partner in international co-inventions. However, there is a remarkable increase of co-invention with countries outside the traditional technology triad EU, US and Japan. In particular **China has gained some importance as partner country for R&D activities leading to inventions at the EPO and USPTO**.

The report also looks at the shares of the different economies in the inventions of the top R&D investors which are developed only by inventors located abroad, labelled foreign co-inventions. The EU and US are the major external inventor source for each other's top R&D companies at both offices. The respective shares have sunk and other countries, especially China, have grown in importance as source of invention for these firms.

China-based Scoreboard firms resort increasingly to EU-based inventors for their applications at the EPO, in line with the increased presence of Chinese R&D facilities in the EU-28. **Another trend that could be observed for the firms from all three economies is the increased R&D sourcing from countries outside the entities in focus**.

Additionally, the report develops statistics on the industrial distribution of the international co-inventions between 2005 and 2015. A strong heterogeneity across industries and across partner economies exists in the extent to which the Scoreboard firms engage in co-inventions. Over all industries, EU-headquartered top R&D investors rely to a large extent on co-

inventors from other EU-28 countries in their patent applications at both offices, followed by US-based co-inventors, even though the proportion varies greatly. The contribution of China-based co-inventors is nearly non-existing in some industries, but it has reached around one fourth of extra-EU co-inventions at the EPO in a few industries, for instance in *Technology Hardware and Equipment*.

With regard to US-based top corporate R&D investors a similar picture emerged: EU-based co-inventors appear as the first preferred partner in all industries covered. Nevertheless, the **US Scoreboard firms also increasingly embrace new sources in their international R&D network, where China seems to play a growingly prominent role**. The extent to which the US firms engage China-based co-inventors vary greatly across industries, ranging from very low or inexistent in *Financial Services* to about 20% in the *General Retailers* and *Mobile Telecommunication* industries for applications at the USPTO.

As the report illustrates, top corporate R&D investors increasingly extend the geographical scope of their co-inventions and R&D sourcing activities. The evidence provided suggests that EU Scoreboard companies have been engaging less than the US with China as co-invention hub in their R&D development. However, the analysis also showed that **EU-based top R&D investors overall increasingly resort to China-based inventors for their patents applications at the EPO and this to a larger extent than US firms at the USPTO for their inventions developed abroad**.

Additional research is encouraged to uncover the industry-specific drivers for these developments within the world's upper reaches of industrial R&D investment. Furthermore, regular monitoring and assessments of the patterns and trends at the industry and technology levels constitute valuable knowledge in order to better understand the differences and similarities in international corporate technological collaborations and to anticipate upon important changes in global innovation networks.

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