European Commission

SCIENCE FOR POLICY BRIEFS

EU in the global Artificial Intelligence landscape

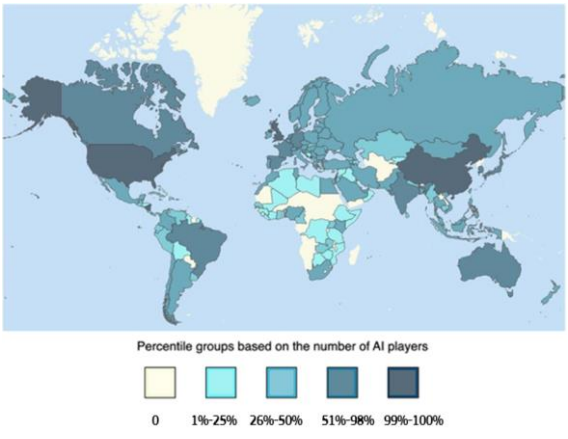
Headlines

- The EU is number three globally in number of AI players (firms, research institutes, or governmental institutions involved in AI), the US leads followed by China. When accounting by the size of the economy, the EU is eighth (among the top 10), with 0.34 players per € bn GDP, and is fifth by number of AI activities per AI player (1.4).
- The EU demonstrates a comparative advantage in some thematic areas (namely Robotics and AI services).
- The AI thematic area of AI services is the most frequent among firms worldwide, with a predominant role of business to business activity.
- Among AI firms, there is polarisation between those with a core business in AI but without patenting activity (most firms in the US and the EU are in this group) and firms with a core business different than AI but with AI-related patenting activity (mostly firms in China).
- EU players establish more relevant collaborations and strategic partnerships in R&D in comparison to their global counterparts. This should favour EU players' future activity and resilience in the landscape. In the EU, French players are the ones that establish the most relevant collaborations in frontier research.
- EC-funded research programmes have a substantial role in the EU AI landscape. The number of EU AI players almost doubles when compared to the number of EU AI players in the global landscape, which does not include EC-funded projects for comparability reasons.
- EC-funded programmes have reinforced the collaborations between players and countries, and help balancing the geographical distribution of AI activities in the EU.
- In the EU, the key specialisation areas are AI Services (19 Member States are specialised in this area), Robotics, Automation and Internet of Everything (11 each), and Machine Learning Fundamentals (10).

The size of the AI landscape

The **EU hosts 13% of worldwide AI economic players**[1] (5,900 out of 44,600), **coming third after the US and China** (31% and 26%, respectively). The UK, India and Canada follow (Figure 1 and Figure 2). **At the country level** (considering EU Member States (MSs) separately), **Germany** (with 1,140 players) and **France** (1,100) are the only EU MSs among **the top 10 countries globally**, holding the 6th and 8th positions respectively. To contextualise these results we provide two **indicators of AI intensity**: one with respect to countries' economic size, computed as the ratio between the number of AI players and GDP (AI player intensity); another one accounts for the intensity of AI activity[2] per player. The relative position between the US, China and the EU in AI player intensity remains unchanged when compared to the size of their landscapes (Figure 3). However, they are no longer in the leading positions: we observe a higher AI player intensity in Israel, one of the emerging economies in the AI field, which hosts 2.5 AI players

Figure 1: AI Players by country, 2009-2020
(Percentiles of number of players)



[1] Economic players are firms, research institutes, or governmental institutions that are involved in AI-related industrial, innovative or research activities.

[2] We take into account the different types of AI-related innovation and research activities performed by AI players and firms whose main activity is AI-related.

Figure 2: AI Players by country (top 10), 2009-2020

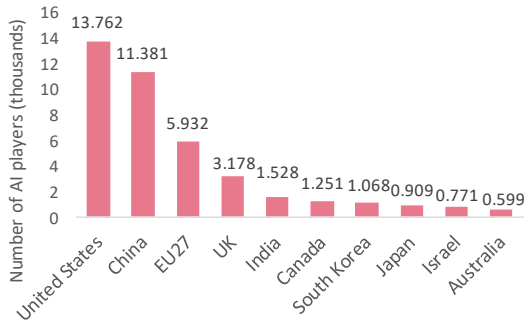
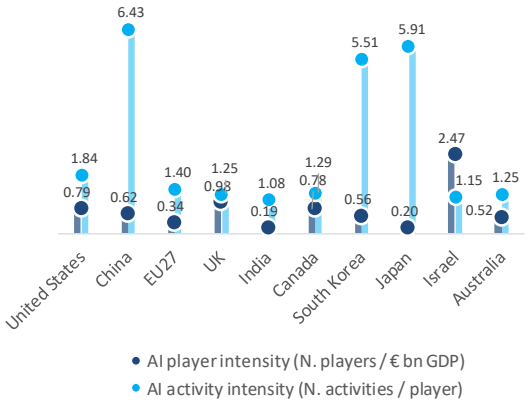


Figure 3: AI intensity by country (top 10), 2009-2020



per € bn GDP, followed by the UK, the US and Canada. **The EU holds the 8th position among the top 10, with 0.34 players per € bn GDP**. Countries with a higher AI player intensity might reflect policies in support of a large AI industry and very active research centres, although further investigation would be needed to confirm this hypothesis. We must, however, take into account that this indicator measures the size and intensity of the AI landscape, but it does not consider other characteristics such as the amount of innovation and research activity, or firm size –which is on average bigger in China and smaller in the US and the EU. **The AI activity intensity indicator** partially fills this gap, by looking at the average amount of activity per player. In this regard, **China, Japan and South Korea are by far the most activity-intense countries**, with around 6 activities per player, in comparison with the remaining (among the top 10), led by the US and followed by the EU (5th), which lie below the threshold of 2 activities per player (Figure 3).

Box 1. The TES approach

The Techno-Economic Segment (TES) analytical approach allows to map the AI worldwide landscape by considering the main AI-related industrial, innovation and research activities, and all the economic players that are involved in them (i.e. firms, research institutes, governmental institutions). The TES approach takes into account information about location, technological aspects, and interactions, in order to build a holistic and interconnected view of the worldwide AI landscape from 2009 to 2020. Other dimensions such as AI in public services, AI in education or other societal aspects are not considered in the scope of the TES approach.

The quantitative analysis carried out informs policy making with a novel and integrated view of the AI landscape. It provides details on the size and composition of the AI landscape, patterns of specialisation in AI thematic areas, the evolution of firms over time, and does so with a methodology that allows comparability across countries and over time, and which shows different concurrent perspectives. The TES analysis also focuses on the specificities of the EU and its strengthening of research, development and innovation (R&D&I) through projects funded by the European Commission (EC).

See Box 5 for information on data sources.

The EU specialises in Autonomous Robotics and AI Services

Based on the different types of AI-related activities performed by AI players (innovation and research) and the description of the firms' main activity, we identify **nine AI thematic areas or technological subdomains** in which AI players are active in the period 2009-2020 (see Box 2 for the description of AI areas). Among those, the EU demonstrates specialisation in **Autonomous Robotics** and **AI Services**, showing a higher concentration of activities in these areas than most countries in the world.

In **Autonomous Robotics**, the EU has one of the world's highest **specialisation** (measured through the *revealed comparative advantage* (see Box 2): the EU has 3.5 times the world's average activity share on Autonomous Robotics, 1.6 times that of the US, 1.9 times that of the UK, and 26 times that of China (Figure 4). **The EU hosts 22% of the worldwide activities in Autonomous Robotics** (Figure 5), ranking second after the US. EU activities are more concentrated in this AI area (7.4% of EU's activities) than the world average (2.1%). The data confirms the **key role that AI-enhanced robotics have in the EU AI landscape**. Autonomous Robotics is expected to positively affect the EU's competitiveness and sustainability in industry and services[3], and is increasingly impacting many sectors such as health, logistics or manufacturing, among others[4]. **Three of the world's largest producers of industrial robots are located in the EU**, although not all are EU owned[5], **and are recently engaging in AI-related R&D activities in the field of Autonomous Robotics**. Besides the support provided by the EC through the Robotics Public-Private Partnership (2014-2020), several EU countries promote public and private

[3] Robotics will support increased efficiency, optimisation, quality and sustainability, in both industry and services. Cf. Alaveras, G., N. Duch-Brown and F. Rossetti (2020) Evolution of the EU market share of robotics: data and methodology. JRC Science for Policy Report.

[4] Source: Coordinated Plan on AI, European Commission, 2021.

[5] KUKA: German-based but acquired by the Chinese Midea Group in 2016; ABB: Swedish-Swiss; Comau: Italian.

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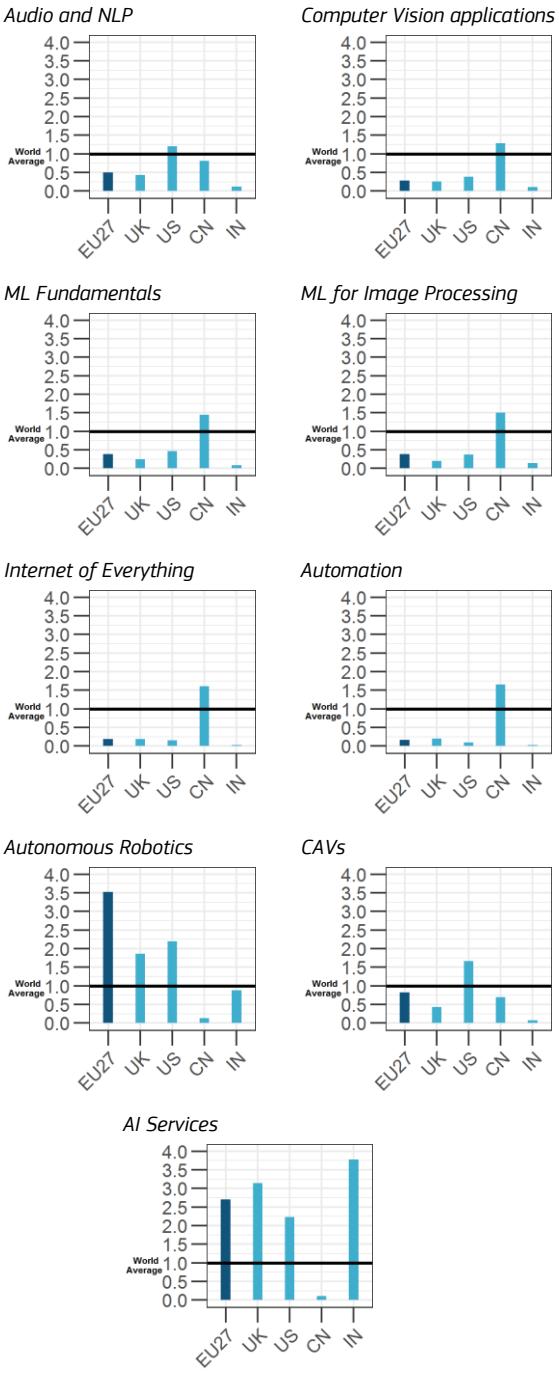
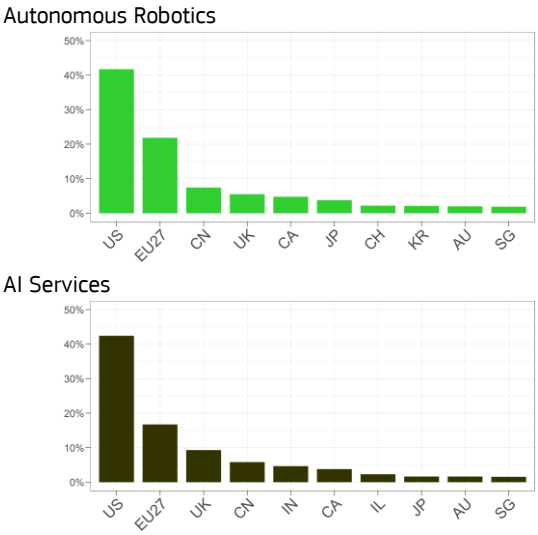
Figure 4: Revealed Comparative Advantage (RCA) by AI thematic area, 2009-2020



Note: The revealed comparative advantage (RCA) indicator compares each country's breakdown of activities by AI thematic area against the world average's. A value of RCA above 1 means that the proportion of activities in that area and country is higher than in the world average, and therefore the country reveals a comparative advantage in the AI thematic area.

Figure 5: Number of AI activities by country in Autonomous Robotics and AI Services (% over world total in each AI area), 2009-2020



investment plans for robotics (e.g. France, Italy, Germany, Luxembourg). A more detailed analysis on this segment will be useful to identify key strengths and potential areas for development, so that the EU can keep and reinforce its leading role.

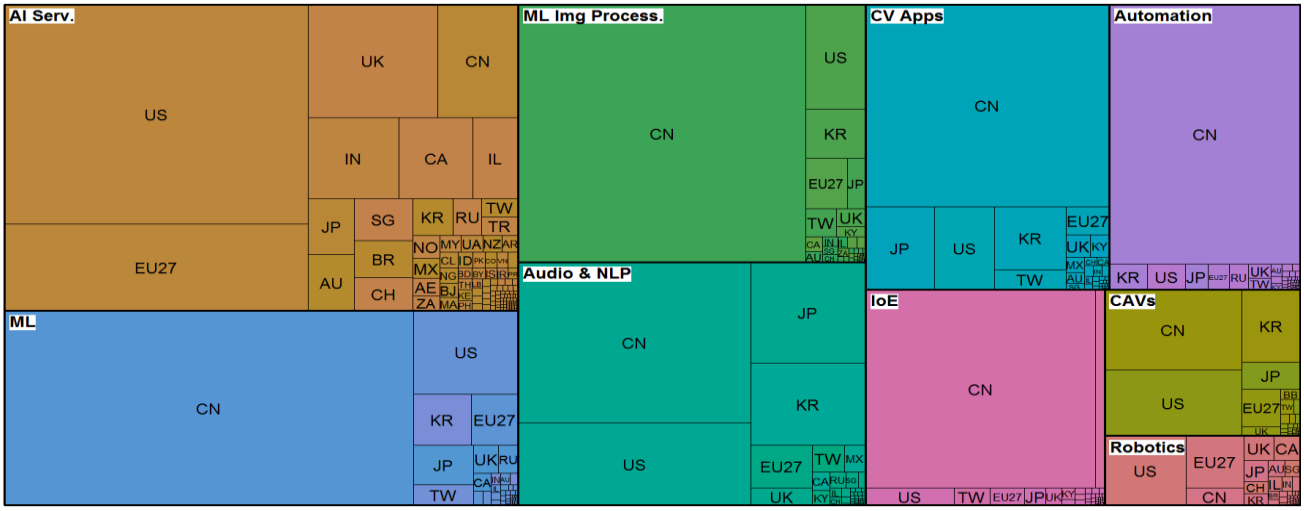
The EU also specialises in AI Services, with 2.7 times the world average share of activities in the area, and 1.2 times that of the US (Figure 4). These are services provided by firms to other firms (B2B) in any economic sector, or to the end consumer (B2C)[6], and may be seen as the transmission channel of AI uptake in the economy. A strong and widespread production and use of AI services is therefore a **good sign of AI adoption by companies**. The EU ranks second, after the US, in number of activities in this thematic area, accounting for 17% of worldwide activity (Figure 5). India has the highest level of specialisation in AI Services, with 3.8 times the world average, while hosting 4.6% of worldwide activities. The UK has 3.1 times the world average level of specialisation, and 9.3% of the worldwide AI services activities.

The **US** hosts most of the worldwide activities in the areas of AI services (42.4%) and Autonomous Robotics (41.7%). **China** leads in the remaining seven thematic areas, hosting a high percentage of worldwide activities in general Machine Learning Fundamentals, Machine Learning for Image Processing, Audio & NLP, Computer Vision applications, IoE, Automation, and CAVs (Figure 6).

Among other **Asian countries**, Japan, South Korea, Taiwan and Singapore show a revealed comparative advantage in Autonomous Robotics, as well as in Audio & NLP, Computer Vision applications, and CAVs.

[6] Examples of AI services include the use of any AI technology, such as machine learning, computer vision, natural language processing, to perform high level applications such as business intelligence, predictive analytics, forecasting, optimisation, failure detection, etc., applied to different business functions: marketing, production processes, enterprise management, logistics, etc. AI services may be used by any economic sector: agriculture (e.g. crop and soil monitoring), oil and gas (e.g. failure prevention), manufacturing (e.g. predictive maintenance), electricity and gas supply (e.g. grid management), transportation (e.g. route optimisation), trade (e.g. product recommendation), health (diagnosis), etc.

Figure 6: Distribution of AI activities by AI thematic area and country, 2009-2020



Box 2. AI thematic areas and specialisation

Based on the textual information contained in the activities of the collected microdata, we infer their technological content. Through a topic model, we identify the following thematic areas or technological subdomains of AI:

- ***Audio and Natural Language Processing (NLP)**: Audio Processing: AI systems allowing the perception or generation (synthesis) of audio signals, including speech, but also other sound material (e.g. environmental sounds, music). Natural Language Processing: Machine's ability to identify, process, understand and/or generate information in written and spoken human communications.*
- ***Computer Vision applications**: Activities that identify human faces and objects in digital images, as part of object-class detection.*
- ***Machine Learning (ML) Fundamentals**: The ability of systems to automatically learn, decide, predict, adapt and react to changes, improving from experience, without being explicitly programmed.*
- ***ML for Image Processing**: Machine Learning methods used for image processing activities.*
- ***Internet of Everything (IoE)**: Activities referring to the interconnectivity of various technologies, processes and people. The human interaction in this context allows people to monitor or configure devices and processes through interfaces.*
- ***Automation**: Activities related to the production or use of physical machines, computer software and other technologies to perform repetitive tasks, for which they are specifically designed and programmed. They can have several degrees of freedom, e.g. in terms of movement, and they may include intelligent control modules to interact with the environment in a controlled setting, e.g. using a temperature sensor. However, they are limited to a set of actions for which they are designed to operate, and have to be re-programmed for new or additional operations. The use of AI in automated machines is mainly related to the adaptation of the defined set of operations as a reaction to external parameters.*
- ***Autonomous Robotics**: Activities related to the development or use of robotic systems that are meant to operate in a relatively-complex environment involving interaction with other machines or humans. Autonomous robots perform multiple operations without any prior exact set of instructions, nor programmed sequence of actions. AI allows autonomous robots to have this higher degree of autonomy when compared to automated machines.*
- ***Connected and Automated Vehicles (CAVs)**: Technologies of autonomous vehicles, connected vehicles and driver assistance systems, considering all automation levels and all communication technologies (V2X).*
- ***AI Services**: Activities related to the provision of (online) AI services and applications, including infrastructure, software and platform services (e.g., cognitive computing, ML frameworks, bots and virtual assistants, etc.)*

*To analyse the **specialisation** of geographic areas in the AI thematic areas, we compute the revealed comparative advantage (RCA) indicator, which compares performance of countries against the world average. We first compute the **country profile**, in other words, the country's activity distribution in the nine thematic areas, which tell us the proportion of the country's activity in each area. The RCA compares the country profile with the world profile. A value of RCA above 1 for a given AI area and country means that the proportion of activities in that area and country is higher than in the world average, and therefore the country reveals a comparative advantage in the AI thematic area.*

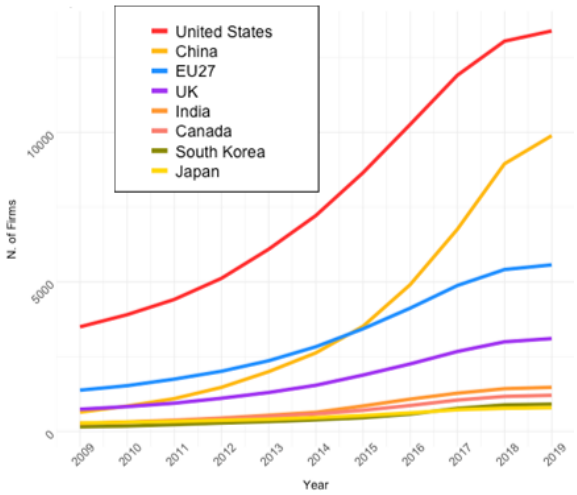
*To identify the **national hotspots** of each AI thematic area, we rank the countries according to their number of activities in each thematic area.*

From the lab to the market

AI Firms

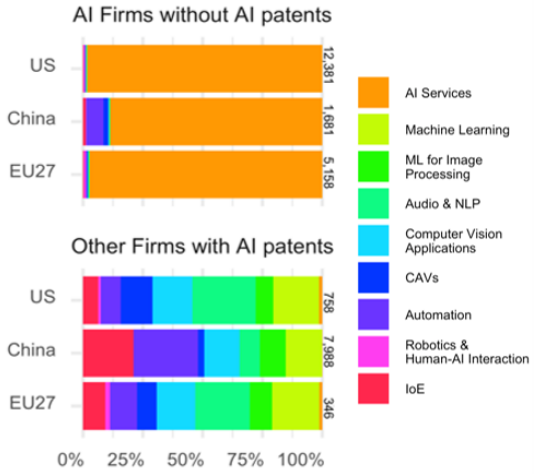
AI firms have a leading role in the AI landscape, representing 94% of players. All countries have experienced a sharp increase in their number of firms in the last decade. The **US was the first country to enter in the AI landscape and to lead it**, and shows a rapid expansion, especially after 2011-2012 (Figure 7). The number of firms in the **EU increases consistently but at slower pace**, with the UK showing a similar trend. **China's** expansion appears **with a delay of 2-3 years** with respect to the US (especially from 2014-2015 onwards), but with higher growth rates. **China surpassed the EU in number of firms in the AI landscape in 2016**. Other countries like India or South Korea started their AI-related acceleration later, around 2015-2016.

Figure 7: Firms' entry year in the AI landscape (top 8 areas), 2009-2020



AI firms show very different patterns in what concerns their AI thematic areas of activity and geographical distribution depending on their core business and innovative activity[7]. Firms **with a core business in AI but without patent activity** (Figure 8 - above) **are concentrated in the US** (over 12 thousand firms) **and the EU** (over 5 thousand), with relatively little presence of China (1.7 thousand). The AI thematic area on which they mainly base their businesses is **AI Services**, that entails selling AI-based services[8]. These firms are providing a **wide range of different AI solutions**, thus **sustaining also other firms that are active in potentially any sector, to take advantage of the digital transition**. Firms willing to enter in this niche may be the natural beneficiaries of initiatives to support SMEs in the development of AI, such as Testing and Experimentation Facilities, Digital Innovation Hubs, the AI-on-demand platform[9], data spaces. Further work should monitor whether a lack of technological development in the

Figure 8: AI firms by AI business type and AI thematic area, 2009-2020



Note: Values to the right of each bar represent the number of firms in the subset.

form of patents may narrow down firm's future innovativeness. Recent regulatory changes that relax eligibility criteria for AI patents in countries such as China, Japan, or even the US in its most recent regulatory update is expected to increase the number of AI patent applications from these countries, which may increase the gap between the EU and other competing countries in this regard.

Firms with a **core business not in AI but with AI-related patent activity** (Figure 8 - bottom), are mainly located in China (8 thousand firms). Many of these are active in the manufacturing sector, but also in mining, energy or other sectors, and show a **balanced spectrum of activities in all AI thematic areas**. China is very concentrated on Automation and IoE, but also on Computer Vision applications and Machine Learning. The EU firms with AI patent applications focus mainly on Audio & Natural Language Processing, Machine Learning (both Fundamentals and for Image Processing) and Computer Vision applications; the US shows a very similar pattern.

Box 3. How is AI industry analysed?

To address the analysis of AI industry, we consider the firms detected as part of the AI landscape. With information regarding the firm's activity and founding date, we infer the year in which their involvement in the AI domain started, and their kind of involvement, with respect to both the type of activities and the AI thematic areas in which they are active.

[7] Big AI players (i.e., those having a core-business in AI and also developing AI patents) are excluded from this analysis, as they represent a minor part of AI firms and this report focuses on main aspects of the AI landscape. However, the exploration of these firms is possible through the AI TES Dataset 2020, European Commission, Joint Research Centre, 2021. https://data.jrc.ec.europa.eu/collection/id-0126

[8] See footnote 6 for examples of AI services.

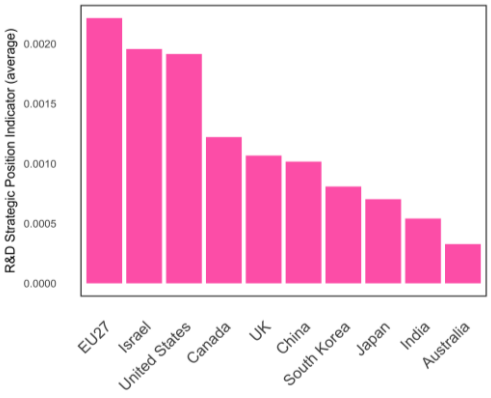
[9] The EU-funded AI4EU is building the first European AI On-Demand Platform and Ecosystem that will share resources, tools, knowledge, algorithms and more between MSs. https://cordis.europa.eu/project/id/825619

AI R&D Capacities

EU players have the **highest worldwide capacity to generate relevant collaborations and strategic partnerships in R&D** (Figure 9), and therefore may act as bridges that interconnect other players in the network (see Box 4). This constitutes a double advantage: first, **innovativeness of a system** (or a part of it) is usually positively affected by the players' ability to develop strategic interactions; second, a **good ability to structure relationships** should guarantee in the future the **opportunities to establish the appropriate collaborations to tackle new challenges**, or face unexpected shocks of any nature (e.g. geopolitical, health-related, economic). In this sense, the good average centrality of EU players in R&D networks appears to be a good signal regarding the future resilience of the EU in the AI landscape.

Israel and the United States follow in strategic positioning, with very similar players' average score, and Canada, UK and China compose a third group. Despite China's huge effort in AI patenting[10], which fuels most of their R&D activity, Chinese players do not develop a network of relationships that can qualitatively sustain their network connectivity.

Figure 9: Average R&D Strategic Position Indicator, 2009-2020

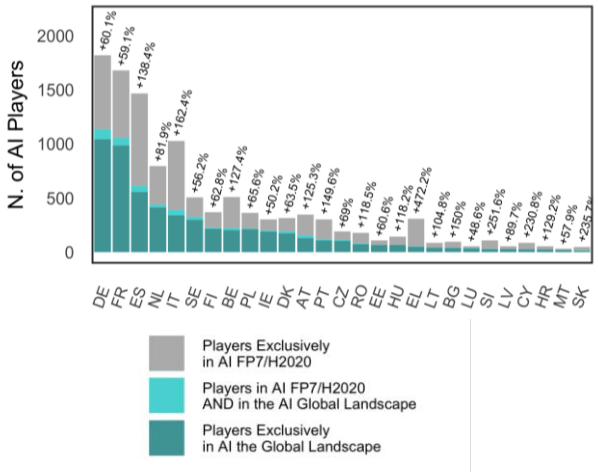


Analysis of the EU landscape

Impact of EC-funded Projects

EC funding has a substantial role in the development of the EU's strengths in AI. Because access to EC-funded research programmes is granted only to EU MSs and other few countries, for comparability reasons the related information is not included in the worldwide landscape analysis. Nonetheless, when focusing on the European landscape, we can consider actors involved in AI-related projects publicly funded in the reference period of this analysis (i.e. through the EC's Framework Programmes FP7 and H2020). By doing so, we observe that **the number of EU AI players almost doubles when compared to the number of players in the global landscape** (5932 players in the global landscape, 5402 additional players considering those only involved in EC-funded projects) (Figure 10). This indicates that many players participating in EC-funded projects do not have a core business in AI, nor any other AI-relevant activity, such as patent applications or publishing in top international AI conferences.

Figure 10: AI Players in EU Member States, 2009-2020



Note: Percentages refer to the number of players only involved in EC-funded projects that are added to the number of players in the global landscape (grey part over the sum of light and dark green parts).

Out of the players participating in EC-funded projects, only a small proportion (8%) leave additional trace in the global AI landscape (in Figure 10: light green over the sum of light green and grey). Considering only research institutions (22% of EC project's participants), the percentage of players with additional AI activities reaches 15% overall, with two of the top 10 countries (Germany and Italy) surpassing 20%.

Box 4. Measuring R&D strategic capacity

By means of information about co-participation in AI R&D activities (frontier research and patents), we consider the network of players and their interconnections and analyse the position of players in such network. Then, in order to evaluate the strategic position of geographical areas, we consider the players' ability to connect with other players for R&D purposes. This ability is measured through the 'weighted betweenness centrality', a measure of players' capacity to act as connecting bridges between other players (Freeman 1979, Brandes 2001). It is therefore a proxy of the influence that players can exert on the rest of the network thanks to the structure of collaborations in which they are involved.*

* *Freeman, L.C.. Centrality in Social Networks I: Conceptual Clarification. Social Networks, 1, (1979) 215-239.*

Brandes, U., A Faster Algorithm for Betweenness Centrality. Journal of Mathematical Sociology 25(2) (2001):163-177.

[10] *China has experienced an unprecedented increase in the number of AI patent applications in the last years. In fact, we detect many of China's players through their patenting activity. This is influenced by the Chinese government's support in local AI patenting since 2015, which may come to an end in 2021, as announced by the Chinese government as a way to boost the country's innovation and high-quality intellectual property services.*

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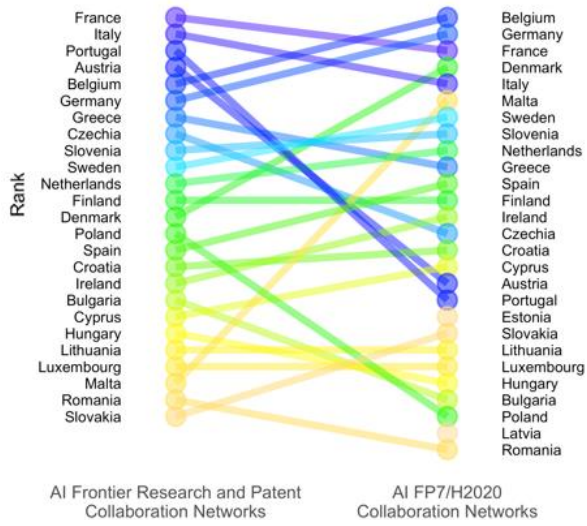
Further analysis on characteristics and network position of projects' participants would clarify their role within the EU AI landscape as well as on the global scene. It can be argued that: (i) most of the participating research and governmental institutions (28% of participants) may have broader and multiple objectives, which do not make them participate in AI international conferences or file AI patent applications. In cases where the player develops a stronger interest in AI, we could expect to capture these in a later stage in the global AI landscape. (ii) Most firms participating in EC-funded projects (72% of participants) may be of two typologies : (a) firms whose economic activity is in technological areas closely related to AI (e.g. robotics), but for which AI is not, or not yet, their main core business (and therefore remain out of the boundaries of the AI landscape), and that have the capacity to participate in an AI-related project; or (b) firms active in non-technological sectors but with the ability and experience to participate in multi-disciplinary consortia. Thus, EC-funded projects capture firms for which AI is not part of the core business, but which may use AI techniques for a specific aspect of their business and develop this within an EC-funded research and innovation project.

Germany, France and **Spain** lead the EU AI landscape, with the highest number of AI players in the EU, either if we consider the global international perspective (green sections in Figure 10) or the European perspective (sum of green and grey sections). They are followed by **the Netherlands** and **Italy**, which exchange positions with each other depending on whether participation in EC-funded projects is considered or not. Although this analysis does not assess the effectiveness of EC funds in generating future participation in the AI segment, we observe that **the proportion of players participating in EC-funded projects varies across countries**. Among the countries with highest weight in the AI landscape, the number of players in **Spain, Italy, Belgium and Austria increases by more than 125%** thanks to participation in EC-funded projects. For **Germany, France, Sweden, Finland and Poland, the increase is around 60%**, and 80% for the Netherlands. EC funding boosts the number of AI players by more than 200% in Greece, Slovenia, Cyprus and Slovakia.

When we compare the **EU MSs players' average strategic position** in the context of EC-funded projects (FP7 and H2020, Figure 11 - right) with their position in the context of not funded R&D activities, such as frontier research[11] and patents (Figure 11 - left), we observe different country rankings. **France, Italy, Belgium and Germany are among the top 6 in both rankings**. This suggests that EC funds are able to support MSs that already have a key role in AI R&D, which **may favour** the **formation** of **excellence networks**. But as the performance and future competitiveness of a system depends also on the capacity of all its components to be functionally integrated and involved, support to countries which are more marginal in the R&D network is also key. Countries like **Portugal** or **Austria**, whose players are on average well positioned in frontier research and patents in the global landscape (3rd and 4th respectively), lose several positions in terms of their centrality in EC-funded projects. This suggests that there **is potential for additional EC support in these**

Figure 11: Strategic Position of EU Member States in AI R&D: Frontier research & Patenting vs EC-funded projects (rank in each subnetwork), 2009-2020



countries. In contrast, **Denmark** holds a modest strategic position in the network of AI frontier research and patents (13th), but **presents a very relevant role in the network of EC-funded projects** (4th). This reveals a **good ability to develop research projects** with structured partnerships.

International Collaborations

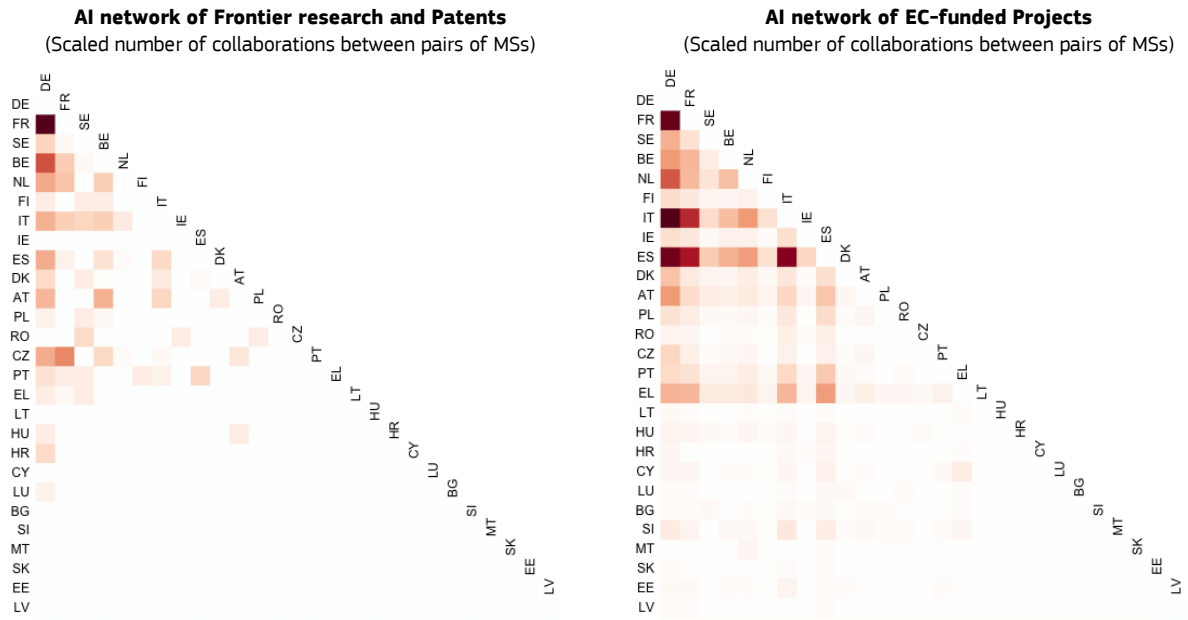
The **network of international collaborations** gives an idea of the structure and magnitude of **knowledge exchange and diffusion** that EU MSs promote and from which they benefit[12]. The right part of Figure 12 shows the scaled number of international collaborations in the network of EC-funded projects (which by design promote collaboration of consortia from multiple countries), and the left side shows the scaled number of international collaborations in the spontaneous network of frontier research and patenting activity in which EU MSs participate. The **international collaboration network observed in AI-related frontier research and patents** is very **concentrated** in **Germany and France**. High amount of collaborations are also detected between Germany and Italy, and between Belgium and Germany. The **contribution of EC-funded projects appears crucial in balancing this concentration**, where inter-country relationships are much more geographically spread than in the network of frontier research and patents. Intense collaborations are still detected to involve Germany and France, but now also Italy, Spain, the Netherlands, Greece and Belgium.

The **strategic position** of players in the network is computed through a network centrality measure, as a proxy of players' capacity to influence the rest of the network (see Box 4). The **average strategic position of French players in the frontier research subnetwork is the highest among MS**. French players thus appear as the most able to structure relevant R&D relationships and partnerships, becoming **key**

[11] We define frontier research as publication of scientific articles in the top AI and Robotics international conferences.

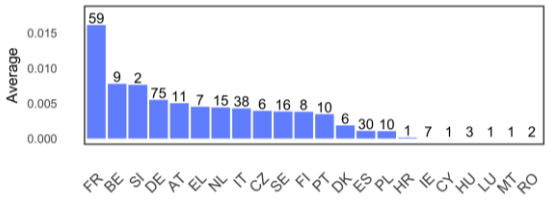
[12] This analysis leaves intra-national collaborations aside. Further exploration of the latter may also be very useful to identify national hubs.

Figure 12: Number of international collaborations between EU Member States in R&D. Subnetworks comparison (scaled in [0-1]), 2009-2020



Note: The number of collaborations between MSs is scaled in the interval [0,1] in each subnetwork. The darker the red, the more collaborations are detected between the countries.

Figure 13: Average R&D Strategic Position indicator in Frontier research



Note: Values indicate the number of players that are active in AI frontier research (with publications in top AI and Robotics international conferences).

connecting actors in AI frontier research networks (Figure 13). In terms of number of players that are active in AI frontier research, France comes second with 59 players, only surpassed by Germany (75).

AI areas of activity and specialisation

When adding EC-funded projects, **the area of Autonomous Robotics gains weight in the EU's activity profile with respect to the picture in the global landscape**: 24% of the EU's activities are on this area, versus 7% when considering only the frontier research and patents in the global landscape. **AI Services is still the AI area in which the EU stands out most**, with 54% of EU AI activity.

Germany is the EU MS with **most AI activities (21%** of activities in the EU), followed by **France** (16%), **Spain** (10%) and **Belgium** (7%). **Germany ranks first in seven out of the nine AI thematic areas**, all except Audio & Natural Language Processing and Computer Vision applications, where it ranks second after Belgium (Figure 14). German players carry out between 18% and 33% of EU's activities, depending on the AI thematic area. The highest shares are in CAVs (33%), Machine Learning for Image Processing (30%), Machine Learning Fundamentals (28%) and IoE (27%). **France is significantly active in Autonomous Robotics and AI Services, ranking second after Germany** with 15% and 18% of EU's activities in these areas respectively. France ranks 3rd in the other AI areas, **except in CAVs** (where it is 6th).

The **CAVs** area is dominated by **the countries that host the biggest automobile manufacturers in Europe** (Figure 14). Activities of Volkswagen Group (including among other the brands of Audi and Porsche), BMW, Daimler (parent of the Mercedes-Benz company) enable **Germany** as the most active country in the CAVs AI area. Although Scania and Volvo are currently subsidiaries of the German Volkswagen Group and the Chinese Zhejiang Geely Holding Group respectively, they keep activities in **Sweden** (Volvo has headquarters in Gothenburg), enabling the country **as the second most active in the CAVs** AI area, with 24% of EU's activities. **Belgium** appears very involved in CAVs mainly as a result of a big tech company (Intel) that **provides hardware and software for automated driving**.

In **Autonomous Robotics**, **Germany has the highest involvement** (Figure 14), with 20% of the total number of activities in Europe. The following most involved MS are **France, Spain, Italy and the Netherlands. Italy** considers robotics one of its priority sectors[13]. **Italy's advances in the field qualify it as potential strong partner in the**

[13] The Istituto Italiano di Tecnologia has robotics as one of its four research domains and a significant value of patent portfolio, fundraising exceeding the 60 million € for the period 2018-2023, and additional investments such as a public investment fund of 4.5 million € for technology transfer support. In addition, the recently created Italian Institute for AI (I3A) , which involves the robotics sector, aims to become one of the main players for AI in Italy.

European robotics industry. It should be noted, however, that the aforementioned countries do not greatly differ in the number of activities, which indicates a **more even distribution of Autonomous Robotics** activities when compared to other AI areas.

As we measure specialisation in relative terms (see Box 2), **MS's specialisation patterns depend on their activity profile**, rather than on their amount of activity. A country is specialised in an AI area if the country's share of activities in said area is higher than that of the EU average: 18 the EU MSs have between two and four areas of specialisation, 5 MSs have only one, and 4 MSs have five or six. The **most common areas of specialisation are AI Services** (19 MSs)[14], **Autonomous Robotics, Automation and IoE** (11 each), and **ML Fundamentals** (10).

If we look at **strong specialisation** (we define it when a country's share of activities in an AI area is at least 1.5 times the EU's average activity share), **we can see high comparative advantage in between 1 and 3 MSs per AI thematic area** (Figure 15). This does not necessarily mean that these countries are competitive in big scale activities, but it points out the AI thematic areas in which they concentrate their activity, even if in limited amounts for small countries, as a hint of their specialisation pattern.

In **AI Services**, Estonia and Latvia have strong comparative advantage. In **Autonomous Robotics**, Greece and Italy. The significant majority of activities in this area are **research-led, most in the framework of Horizon 2020 programmes** and to a less extent by FP7. This indicates that the **EU-funded research programmes have initiated the collaborations** between players and countries. A follow-up study may assess the path followed by collaborating partners, in terms of their continuation and even specialisation in Autonomous Robotics, either independently or in mutual collaboration. In **Audio and NLP**, Belgium, Ireland and Finland excel. In **Machine Learning Fundamentals** we see Belgium, Ireland and Finland with strong advantage with respect to the EU average. Finland and Belgium have higher advantage also in **Machine Learning for Image Processing**. In **CAVs** Sweden, Belgium and Germany highlight. Only Belgium has revealed advantage in **Computer Vision applications**. **IoE** is a strong specialisation for Belgium, Finland and Sweden. In **Automation, Romania, Poland and Spain are strongly specialised** (Figure 15).

Countries with revealed comparative advantage in specific AI areas are potential partners with which other countries that want to catch up in the same areas **may establish twinning and networking activities**.

Figure 14: Distribution of AI activities by AI thematic area and EU Member State, 2009-2020

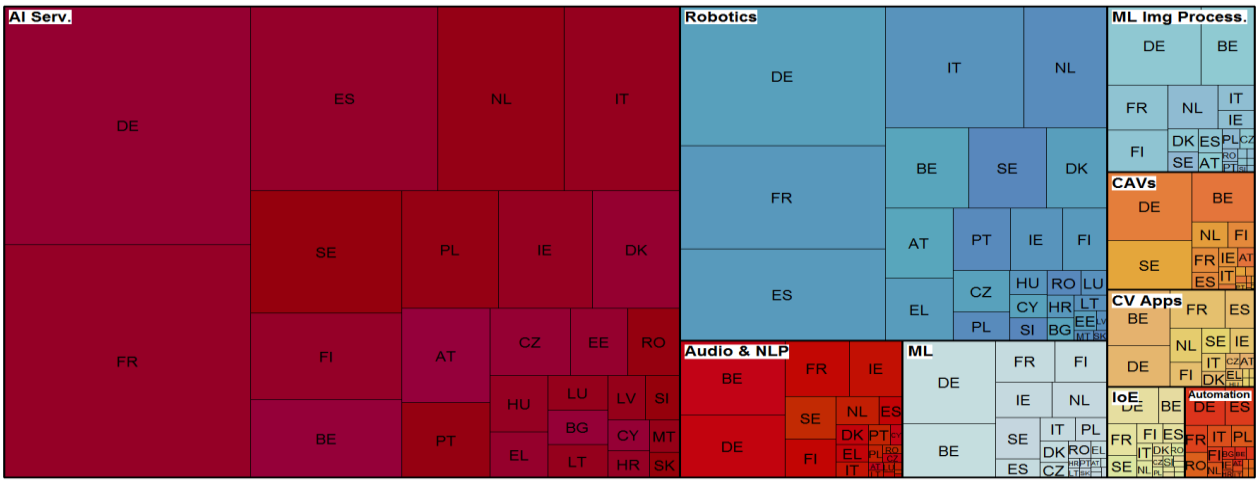
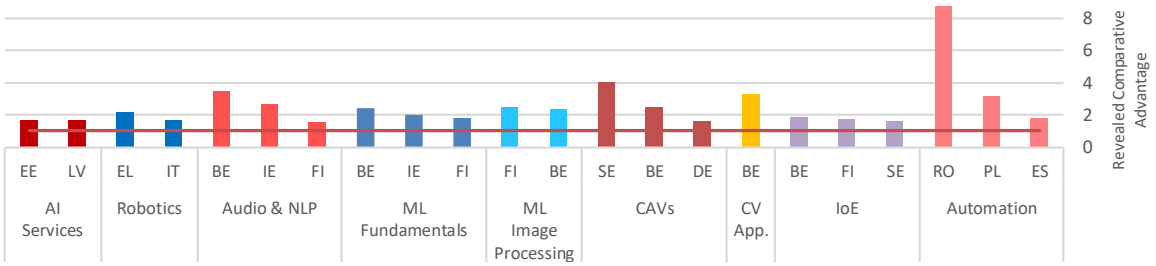


Figure 15: EU Member States' Strong Specialisation in AI Thematic Areas, 2009-2020



Note: By strong specialization we refer to values of the RCA indicator above 1.5. Only combinations of country and AI area with at least 5 activities are shown.

[14] This high number of countries specialised is explained by the fact that the indicator compares country profiles with the EU profile. Countries with a big weight in the landscape, such as Germany, Belgium, Italy or the Netherlands, are not specialised on this thematic area, what contributes to the EU having a relatively low share in AI services when compared to that of the remaining individual MSs.

Conclusions

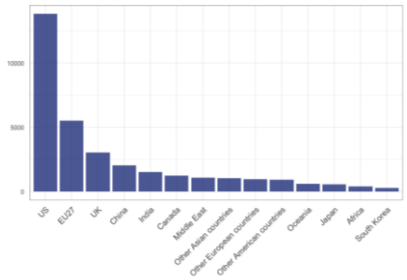
- The analysis **shows the key role of the EU in the worldwide AI landscape**, which accounts for 13% of AI players active in the period 2009-2020.
- The EU has a very strong comparative advantage in **Autonomous Robotics**, explained by the EU's concentration of activities in this AI area when compared to other geographical areas. This result suggests that **the EU is well positioned to maintain its global leadership and harness the potential of robotics to increase economic competitiveness, sustainability and strategic autonomy**.
- The EU also specialises in AI Services, showing a strong comparative advantage in this AI area, and also accounts for a big share (17%) of worldwide activity. Since **AI services** use AI technologies to improve the performance of business functions, they **have the potential to enable AI uptake** among all sectors of the economy. **The abundance of firms providing AI services in the EU is a promising sign of current and future uptake of AI by EU companies**.
- **EU AI Players hold more strategic relationships and partnerships in R&D than the world average, which should provide good prospects for players' future activity and an advantageous position in the international landscape.**
- **EC funding has a crucial role in the size of the EU AI landscape and a substantial impact on the diversity (participant backgrounds) of AI activity in the EU AI Landscape.**
- EU MSs with highest **number of AI players** are **Germany, France, Spain, Italy** and the **Netherlands**.
- In terms of **AI activity**, **Germany** dominates the ranking in seven AI thematic areas, while **Belgium** stands out as the fourth MS, being the most active in two AI thematic areas.
- The most active MSs in **Robotics** are Germany, France, Spain and Italy.
- Among the EU MSs with a critical mass of AI activity, we find most AI areas represented. Germany has comparative advantage on Connected and Automated Vehicles, Spain in Automation, Belgium has strong comparative advantage in six AI areas: all except AI Services, Robotics and Automation, Italy specialises on Robotics, Sweden on Connected and Automated Vehicles and Internet of Everything, Finland on Audio and Natural Language Processing, Machine Learning for Image Processing. **The concurrence in a MS of a high number of activities and strong specialisation in an AI thematic area may point this country as a good candidate with whom to establish collaboration in said AI area**.

Box 5. AI TES2020 Data Sources

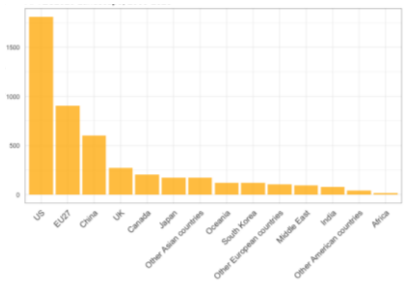
The AI TES2020 dataset is based on multiple data sources. They can be categorized in 3 groups: business activities (i.e. firms with a core business in AI), research activities (i.e. scientific articles in top AI and Robotics international conferences), innovation activities (i.e. AI-related filed priority patent applications). Additionally, a fourth group is considered: the AI-related EC-funded projects. International comparability is granted when the first three groups are used. EC-funded projects are only used for the in-depth analysis of the EU and its MSs. The AI TES Dataset 2020 is accessible through the JRC Data Catalogue: https://data.jrc.ec.europa.eu/collection/id-0126

AI activities by source group and geographical area, 2009-2020

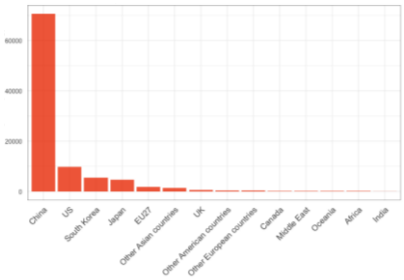
AI business activities



Research activities



Innovation activities



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