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Evolution of the EU market share of Robotics: Database and Results

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Foreword

This report is published in the context of AI Watch, the European Commission knowledge service to monitor the development, uptake and impact of Artificial Intelligence (AI) for Europe, launched in December 2018. AI has become an area of strategic importance with potential to be a key driver of economic development. AI also has a wide range of potential social implications. As part of its Digital Single Market Strategy, the European Commission put forward in April 2018 a European strategy on AI in its Communication "Artificial Intelligence for Europe". The aims of the European AI strategy announced in the communication are:

- To boost the EU's technological and industrial capacity and AI uptake across the economy, both by the private and public sectors
- To prepare for socio-economic changes brought about by AI
- To ensure an appropriate ethical and legal framework.

In December 2018, the European Commission and the Member States published a "Coordinated Plan on Artificial Intelligence", on the development of AI in the EU. The Coordinated Plan mentions the role of AI Watch to monitor its implementation.

Subsequently, in February 2020, the Commission unveiled its vision for a digital transformation that works for everyone. The Commission presented a White Paper proposing a framework for trustworthy AI based on excellence and trust.

Furthermore, in April 2021 the European Commission proposed a set of actions to boost excellence in AI, and rules to ensure that the technology is trustworthy. The proposed Regulation on a European Approach for Artificial Intelligence and the update of the Coordinated Plan on AI aim to guarantee the safety and fundamental rights of people and businesses, while strengthening investment and innovation across EU countries. The 2021 review of the Coordinated Plan on AI refers to AI Watch reports and confirms the role of AI Watch to support implementation and monitoring of the Coordinated Plan.

AI Watch monitors European Union's industrial, technological and research capacity in AI; AI-related policy initiatives in the Member States; uptake and technical developments of AI; and AI impact. AI Watch has a European focus within the global landscape. In the context of AI Watch, the Commission works in coordination with Member States. AI Watch results and analyses are published on the AI Watch Portal.

From AI Watch in-depth analyses we will be able to understand better European Union's areas of strength and areas where investment is needed. AI Watch will provide an independent assessment of the impacts and benefits of AI on growth, jobs, education, and society.

AI Watch is developed by the Joint Research Centre (JRC) of the European Commission in collaboration with the Directorate-General for Communications Networks, Content and Technology (DG CONNECT).

This report addresses the objective of AI Watch of analysing the evolution of the EU market share in robotics over the last decade, by providing an overview of the EU-27 position in the global landscape as well as details of the EU-27 landscape, looking at the distinction between industrial and service robots.

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[1] Disclaimer: The views expressed in this report are solely those of the authors and may not in any circumstance be regarded as stating an official position of the European Commission.

Executive summary

Robotics is a fast-developing market driven by the development of novel and improved products. As robotics becomes a key driver of economic development and prosperity, there is a need to address the issue of measuring countries' competitiveness in the field. The International Federation of Robotics (IFR) aims to collect, process and make available statistical information about robots worldwide. There is a lack of data available to analyse the industry, and it is relevant to increase our understanding of different types of robots.

This report provides an overview of the robotics industry in Europe, as well as a description of the definitions, typologies and main differences between industrial and service robots. The aim is to build up a stronger and updated knowledge of research questions, approaches and data that scholars and policymakers could use to study robotics around the world, and more specifically in Europe. It also identifies the necessary actions to merge heterogeneous data into a meaningful and consistent dataset to estimate the shares of robotics in the EU from the demand and supply perspectives, and for both industrial and service robots. Complementing these data with other sources to enhance the value and significance of the overall estimation exercise of the EU robotics market shares provides a comprehensive overview of the production and adoption sides for both industrial and service robots. The three main objectives of the report are: to build a dataset including the market shares of robots in the EU; to describe the main trends that can be extracted from the data; and to sketch a conceptual framework to contextualise the results from the first two objectives.

Data

The two most adequate and relevant sources of information to analyse the EU robotics market shares, according to a previous AI Watch report, are the annual World Robotics reports from the IFR and the Comtrade trade data from the United Nations. The challenges that have been addressed in this work regarding data are that:

- Robotics is a highly heterogeneous industry.
- Data requirements are different since service robotics is an emerging activity while industrial robotics is a consolidated sector.
- Robotics data sources are limited.
- There is inherent complexity in combining different data sources.
- Data reported by the IFR underestimates the actual figures that should be interpreted as a minimum level of sales.

As mentioned, industrial robotics is a consolidated activity for which there is sufficient statistical information available in the two main data sources. Hence, the creation of a suitable methodology in this situation is a very straightforward process. On the other hand, service robots are an emerging activity for which there is limited statistical data that has been collected through potentially biased or incomplete samples. Another relevant issue refers to the available data at the starting point of the procedure. While the information for industrial robots refers to installations, the data for service robots focus on sales.

Industrial robots methodology

Summarising, the calculation of market shares with respect to industrial robotics sales requires three steps:

- Calculate the number of industrial robot units installed in a country and year that are from domestic origin.
- Calculate total sales of industrial robots per country and year by adding the result of the first step with the information on exports by country and year of industrial robots to all possible trade partners.
- Calculate the ratio between a country's sales of industrial robots in a given year with the summation over all countries in that year, i.e., the world's total industrial robots sales.

Service robots methodology

The methodology to calculate the market shares of service robots is more complex. First, data are aggregated at the continent level and need to be disaggregated; and second, no specific trade data exists for the different types of service robots.

The starting point is data aggregated at the continent level about service robots sales by type and year, provided by the IFR that needed to be disaggregated. Some assumptions were required which introduce uncertainty in the estimation procedure, which means that results obtained would be subject to some variance, and therefore, the corresponding confidence intervals were reported. Due to the large number of companies that do not report their number of employees, the assumption had to be included that the distribution of firm-sizes across countries is equal. The resulting dataset can be used to calculate the shares of robotics companies by country and year with respect to continent.

The calculation of market shares with respect to service robotics sales could be summarised in the following steps:

- Distribute by country by taking into consideration the total number of robotics firms by country and year extracted from Dealroom.
- Manually classify companies operating in the different segments of the robotic industry using tags.
- Calculate the shares of robotics companies by country and year with respect to the continents as referred in the IFR service robots reports.
- Calculate the market share of sales, by country and year with respect to the world total, using the proportion that each continent represents with respect to the world.
- Estimate the proportion of sales that go to the domestic market and the proportion that is exported, using the UNIDO Industrial Demand-Supply Balance Database.
- Calculate exports to each destination country from each origin country, by year.
- Calculate the corresponding market shares and the market concentration indicators.

Indicators methodology

In addition to market share, the market concentration index was also calculated to reflect the evolution of the global and EU-27 landscapes with respect to the various segments of the robotics industry. It was obtained using the Herfindahl-Hirschman Index (HHI), which is calculated as the sum of the squares of the market shares of the n companies (or nations) in the industry. This way, it contemplates both the supply and demand sides of the robotics industry.

The Robotics Value Chain (RVC)

Despite the growing attention towards robotics in general, a framework to analyse the entire robotics global value chain is still missing. In this report, we provided for the first time detailed information about the evolution of the global and EU-27 service robotics industries. We also offered a more detailed analysis of the factors that could be behind those trends.

After a careful consideration of the main trends from the analysis of the market shares, along with the conceptual framework developed, four significant patterns emerge from the data:

- A small group of countries, representing an exceptionally high concentration across the whole robotics value chain, dominate the markets for automation and robotisation processes, both globally and within the EU-27.
- Among the leading countries, the magnitude and scope of each economy’s participation in the robotics value chain varies greatly, and no country shows equally strong positions in all the different segments of the aggregated robotics industry.
- Some less developed economies, although relatively less involved in the robotics industry, have succeeded in specialising in specific stages of the robotics value chain.
- Despite the strong concentration in all the robotics segments, latecomers can enter the robotics value chain, mostly at the post-production stage.

These trends characterise the state of the robotics industry’s current worldwide industrial organisation, or robotics value chain, or RVC as we have called it. However, given the growing importance of service robotics and its more decentralised organisational structure, the current market structure may change in the years to come, perhaps significantly.

1 Introduction

Robotics has advanced significantly since the first mechanical systems were conceived several decades ago. Various technological developments in engineering, computer science, information technology, and related sciences have pushed the technical capabilities and made possible an extension of the potential applications of robots. It is expected that in the next 10 years, more and more people around the world will interact with robots every day.

Today, robotics is a fast-developing market increasingly driven by the development of novel and improved products in areas as diverse as manufacturing; search, rescue and retrieval; inspection and monitoring; surgery and healthcare; homes and cars; transport and logistics; and agriculture, among others. The rapid increase in the use of robots in homes and at work, in hospitals and industrial environments provides evoking images about how they can benefit society as a whole.

As robotics becomes a key driver of economic development and prosperity, there is a need to address the issue of measuring countries' competitiveness in this technology, for instance by means of their participation in this industry. Recently, some contributions have attempted to measure the improvements in the quality of robots across years (Fujiwara et al., 2021), to explore more in-depth available robotics databases for research purposes (Klump et al., 2021), to collect evidence on robot adoption by means of alternative methodologies (Liu et al, 2022), and to identify a proper global value chain for the robotics industry (Cséfalvay and Gkotsis, 2020). However, despite the efforts of the International Federation of Robotics (IFR) to collect, process and make available statistical information about robots worldwide, there is a lack of available data to analyse this industry. Apart from developing a more comprehensive analytical framework to look at pre-production, production and post-production of the entire robotics value chain, it is relevant to increase our understanding of different types of robots. To date, most studies refer to industrial robots, while the information available for service robots is almost non-existent.

A previous AI Watch report[2] (hereinafter the "methodological report") provided an overview of the robotics industry and presented the key features of the statistical sources of information that could potentially be employed for a robust estimation of the EU market shares in global robotics industries. The description of the industry, including the definitions, typologies and main differences between industrial and service robots, as well as the analysis of the most recent economics literature served to build up a stronger and updated knowledge of research questions, approaches and data that scholars and policymakers have used in order to study robotics around the world, and more specifically in Europe. The data sources identified in that report also served to provide information about the state of play of the robotics industry worldwide, and particularly in Europe. The statistical analysis contributed to provisionally place Europe in the global landscape of robotics usage and production, and it informed policy about some gaps and strengths of the European robotics industry.

In addition, the previous report highlighted the data-related and methodological challenges of estimating the EU market shares – which this report focusses on. Therefore, this methodological report also identified the necessary actions to merge heterogeneous data into a meaningful and consistent dataset to estimate the EU shares of robotics from the demand and supply perspectives, and for both industrial and service robots. Concerning the available information on robotics, the IFR provides the most complete and useful database of the most relevant facts and figures about robotics worldwide. Nonetheless, complementing these data with other sources will enhance the value and the significance of the overall estimation exercise of the EU robotics market shares. However, the other sources identified will likely require data imputation work before becoming fully suitable for the purpose. These additional sources will also require cleaning and specific checks for duplicates. Finally, the coherent combination of different sources will provide a comprehensive overview of the production and adoption sides for both industrial and service robots.

However, in order to understand the factors that would explain the trends that result from the analysis, we need a more robust conceptual framework. Although there is growing attention towards robotics in general and to the deployment of robots in particular, a comprehensive framework to analyse the entire robotics global value chain is still missing. While some attempts have already been proposed, they remain partial and largely centred on industrial robotics.

This report has three main objectives. First, to build a dataset including the market shares of robots. From the different sources of data available and the challenges to use them for the purposes of this report, we have designed and applied a methodology that allows us to build a dataset including the market shares of different

[2] Duch-Brown, N., Rossetti, F. and Haarburger, R., *Evolution of the EU market share of robotics: Data and methodology*, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-43794-9, doi:10.2760/292931, JRC124114.

types of robotics for a relatively long period of time. Second, to describe the main trends that can be extracted from this dataset. In this case, while the purpose is to increase our knowledge about the EU market shares, the dataset includes the information for many other countries. We are thus able to compare the relative position of the EU with respect to other countries or areas active in the robotics industry over a decade. Third, to sketch a conceptual framework to contextualise the results from the first two objectives. This conceptual framework could, in addition, identify relevant areas of the robotics industry where knowledge is limited, mostly because of lack of appropriate data, but also due to the absence of a coherent and comprehensive framework to understand the industrial organisation of the robotics industry and its main segments.

This report is organised in the following way. After this introduction, Section 2 summarises the main issues related to data, the final methodology employed and the indicators used to describe the trends. Section 3 shows the main trends from the database of industrial robots. This section looks at both purchases and sales of robots, and to the global and EU-27 landscapes. Section 4 describes the main trends observed in the service robot industry. Here, in addition to looking at the global and EU-27 landscapes from both purchase and sales perspectives, we also distinguish between service robots for personal and professional use. This section is complemented with an annex that includes the trends registered in the top four sub-categories of professional service robots. Section 5 provides a conceptual framework to analyse the industrial organisation of robotics. After discussing the different factors that would explain the industrial and geographic concentration patterns observed in this industry, the conceptual framework is applied to the data to review the previous results from a more structured perspective. Finally, Section 6 offers the main conclusions.

2 Data, methodology and indicators

In this section we describe the data available, the methodology employed to overcome the data limitations and the indicators calculated to study the evolution of the robotics market shares.

2.1 Data

A thorough description of the available data is provided in the methodological report. The conclusions of that report indicated that the two most adequate and relevant sources of information to analyse the EU robotics market shares are the annual World Robotics reports from the IFR and the Comtrade trade data from the United Nations. The interested reader should consult these reports to get a more detailed explanation of the characteristics of the different data sources. However, we list below the four main challenges related to data highlighted in the methodological report. Then, the next section will explain how these challenges have been addressed.

First, robotics is a highly heterogeneous industry. Robots can vary in design, functionality and degree of autonomy. Hence, elaborating a common typology is complicated. In addition, robots are used in diverse economic sectors, with different degrees of adoption. The most relevant distinction is between industrial and service robots, and there are important differences between them. Industrial and professional service robots are employed in the production of final goods and the provision of services respectively, while personal service robots are designed and produced to satisfy individuals' needs.

Second, data requirements are different. Service robotics is an emerging field while industrial robotics is a consolidated sector. Hence, the available data are much more abundant for the latter than for the former. Service robotics solutions require the integration of third-party technologies, generating an ecosystem-type of organisational solution. This makes it particularly difficult to identify all the players involved in the value chain. Moreover, industrial robot data refer to installations (demand), while the data for service robots derive from sales (supply). As a final remark, for both industries, the data available are mostly about the robots themselves and not about the peripherals or integrations that complement them, which is an important piece of missing information. The main challenge lies in an appropriate description of service robots.

Third, robotics data sources are limited. The main source of statistical information concerning robotics is the IFR data. Its main advantage consists of being the only source that covers both industrial and service robots. Furthermore, this database offers yearly data and a fine geographical granularity for industrial robots. On the other hand, its main disadvantage lies in the heterogeneity of the information provided vis-à-vis industrial and service robots. Specifically, the IFR data on industrial robots cover the stocks (i.e. the number of robots currently deployed) and the number of new installations by sector and type of application. On the other hand, the data on service robots refer to the number of units sold for a limited period of time. Moreover, the geographical breakdown is at the country level for industrial robots while it only covers continents for service robots. This feature limits the possibility to use the IFR data for an in-depth analysis of service robots at the country level, as it does not allow to perform country-by-country comparisons with the industrial robot data. The other valuable source of robotics information is Comtrade, which offers trade data on industrial robotics at the country level over a long period of time. However, this source lacks information about service robots.

Fourth, there is an inherent complexity in combining different data sources. Merging industry- with firm-level sources as well as country with continental information may be complicated, given the different nature of the data and the underlying assumptions in their preparation. In addition, some statistical series exhibit the issue of missing values. The missing information can refer to data points in a time series (i.e., data is missing for a year) or in a cross-section (i.e., data missing for a country). Moreover, IFR's data on service robotics is considered to be cross-sectional. This means that each year the sample of service robotics firms' changes, invalidating comparisons over time.

The data reported by the IFR are sample data, covering a fraction of the industry and not projected to the whole market. Hence, it underestimates the actual figures that should be interpreted as a minimum level of sales. According to the IFR, both the survey participation and the desktop research generate different sample compositions each year, suggesting the statistics presented in their reports should be considered as cross-sectional. In this respect, the IFR strongly discourages compiling data from different issues of their publication to create time-series data (IFR, 2021 p. 22).

Indeed, cross-sectional survey data are data for a single point in time. However, from a statistical point of view, repeated cross-sectional data are created where a survey is administered to a new sample of interviewees at successive time points. For an annual survey, this means that respondents in one year will be different than those in another year. Such data can either be analysed cross-section by looking at one survey year, or combined for analysis over time. Because repeated cross-sectional data take a different sample of a population over time, they are used for analysing population or group changes over time (also known as aggregate change over time). They cannot be used to look at individual change. By aggregate change, we refer to changes in population groups. If representative samples are present in consecutive years of a survey, we can compare changes in the behaviour or circumstances of different groups, especially if instead of the absolute values of specific variables, we look at relative values such as market shares.

After a thorough analysis of the available data and a detailed consideration of the associated challenges, a methodological solution to fulfil the objective of calculating the EU market share of robotics has been developed. The details of this procedure are explained in the next section.

2.2 Methodology

This section describes the methodological steps taken to overcome the limitations of the available data, while taking into consideration the challenges identified. One important element to bear in mind is the distinction between industrial and service robots. As explained in the methodological report, industrial robotics is a consolidated activity for which there is sufficient statistical information available in the two main data sources. In this case, the development of a suitable methodology constitutes a relatively simple task. Differently, service robots are an emerging field for which there is limited statistical data that has been collected through potentially biased or incomplete samples. In this case, the methodological challenges are more complex and have required more sophistication and creativity in finding the appropriate solutions. In addition, given the limited data and the elaborated methodology, the reliability of estimates is also lower in this case.

Another relevant issue refers to the available data at the starting point of the procedure. While the information for industrial robots refers to installations, the data for service robots focus on sales. This implies that the methodological requirements also differ. In the case of industrial robots, installations imply a demand-side concept: countries will install (purchase) industrial robots from local or foreign suppliers. The requirement in this case is to use trade data (imports) to uncover sales, a supply-side concept related to production, by country and year. On the other hand, sales in the case of service robots denotes a supply-side concept: service robot companies in a given country will sell service robots in the same country or in foreign countries. In this case, trade data (exports) should be used to recover the information about purchases, by country and year (and type of service robot – i.e., personal or professional) to be in a position to study demand. Hence, for the purposes of this study, the main conclusion is that the calculation of the market shares for industrial and service robots require different methodological solutions. Table 2.1 summarises the main differences feeding the methodological requirements between industrial and service robots. The two approaches are described below.

Finally, the main interest of this study lies in understanding the evolution of the EU-27 robotics market shares with respect to the worldwide robotics industries over the last ten available years. However, the datasets built for that purpose also allow to have a detailed look inside the EU-27. Therefore, in the corresponding sections, the results will be presented both for the global landscape, covering the position of the EU-27 with respect to other relevant participants in the robotics industry, and the EU-27 landscape, where the shares of the different MS will be compared and a detailed analysis of their evolution will be provided. All in all, the exercise requires the calculation of the market shares using purchases and sales for industrial robots, service robots for personal use, and service robots for professional use for both the world and the EU-27. This makes a total of 12 possible combinations. Table 2.2 shows the different dimensions of the analysis.

2.2.1 Industrial robots

The methodology to build the database needed to calculate the EU market share of industrial robots is relatively straightforward, thanks to the availability of adequate and high quality IFR data on industrial robot installations, as well as detailed trade flows data from Comtrade. To begin with, the IFR data provide information about industrial robots purchases (installations), by country and year. Summing up all the industrial robots installations at the world level per year, these data allow to calculate directly the market shares with respect to robotics purchases for the EU-27 – grouping the EU MS into one entity – and for other relevant economies. Similarly, one can calculate the number of installations per year in each EU MS as a proportion of the EU-27 total and determine the corresponding intra-EU market shares. However, this indicator only provides information about the demand side.

Table 2.1: Comparison of available and required data

Concept	Industrial robots	Service robots
Main variable in source data (IFR)	Installations (purchases)	Sales
Coverage	(Almost) Universal	Limited sample
Variable to estimate	Sales	Purchases
Original geographic detail	Country	Continent
Period	2010-2020	2010-2019*
Comtrade data	Available	Not available
Trade flow required	Imports	Exports

* Although the data from World Robotics Service Robots 2021, including statistical information for the year 2020 is currently available, it was unavailable during the phases of the project where the methodology was applied. Moreover, the IFR applied in that year a thorough revision to the classification of service robots[3]. Hence, data from 2020 is not strictly comparable to data for the period 2010-2019. Therefore, the analysis was restricted to this period.

Source: Own elaboration.

Table 2.2: Dimensions of the empirical analysis

Geographic scope	Type of robot	Indicator
World	Industrial	Purchases
EU-27	Service robots for personal use	Sales
	Service robots for professional use	

Source: Own elaboration.

To calculate the market shares with respect to the production side, we combine the IFR number of robot purchases (i.e. robots installations) per country and year with Comtrade quantities of imported and exported robots per country and year. By combining these two sources, we can calculate the difference between the total number of installations adding the total imports of industrial robots and subtracting the total exports, per country and year. This difference is precisely the number of installed robots that have been purchased from local providers. Then, we can sum this variable with the total number of industrial robots exports,[4] by country and year. This operation will produce the total sales per country and year. Summing up over all countries, calculating the corresponding market shares is straightforward. A similar procedure can be used to calculate the intra-EU-27 market shares.

Summarising, the calculation of market shares with respect to industrial robotics sales requires three steps:

1. Calculate the number of industrial robot units installed in a country and year that are from domestic origin.
2. Calculate total sales of industrial robots per country and year by adding the result of the first step with the information on exports by country and year of industrial robots to all possible trade partners.
3. Calculate the ratio between a country's sales of industrial robots in a given year with the summation over all countries in that year, i.e., the world's total industrial robots sales.

This second indicator also provides information on the supply side. Annex I provides more information about the formulas used in these calculations.

2.2.2 Service robots

The methodology to calculate the market shares of service robots is more complex. This is due to two main issues: first, the starting point is data aggregated at the continent level that needs to be disaggregated; and second, no specific trade data exists for the different types of service robots. In order to proceed, as will be detailed below, some assumptions are required which introduce uncertainty in the estimation procedure. This means that the results obtained would be subject to some variance, and the corresponding confidence intervals will be reported[5]. However, since the lack of data and relevant information applies equally to all sectors,

[3] See IFR World Robotics 2021 – Service Robots, p. 16.

[4] In a trade matrix where origin countries are in rows and destination countries in columns, each cell would represent both an import for the destination country from the origin country, or an export from the origin country to the destination country.

[5] The 95% confidence intervals plotted are calculated from the prediction of the share (or volume) resulting from estimating a quadratic regression of y (share) on x (year) and x^2.

categories, activities and countries, the proposed method could estimate more precisely the proportions (i.e., market shares) than the absolute values of service robots purchased and sold. Therefore, we believe that the results for service robots are sound and informative about trends in market shares of the period 2010-2019.

The starting point in this case is the information about service robot sales by type, continent and year provided by the IFR. In order to get the estimates for the EU-27 and other relevant players in this industry, this information needs to be disaggregated to the country level. This highly aggregated data is distributed by country taking into consideration the total number of robotics firms by country and year extracted from Dealroom.[6] According to this source, a total of 28,000[7] firms operate in the broader robotics industry worldwide. In order to classify the companies into the robotics categories of interest (industrial, service personal and service professional) we rely on the companies' description of activity and on the available tags[8] that describe their activity. Unfortunately, only 14,000 companies provide either descriptions and/or have tags, which reduces the sample size significantly. From this reduced sample, it was possible to extract around 1,000 different tags. The tags were manually classified to indicate companies operating in the different segments of the robotics industry: industrial robots, service robots for personal use, and service robots for professional use. These categories are not mutually exclusive. This means that a company that has one tag that corresponds to industrial robots and another tag representing activities under professional service robots is included in the two categories. Since the objective is to study service robots, the information about industrial robots was discarded. However, only companies that operate exclusively in the area of industrial robotics were removed while those that also operate in other categories remained in the sample. The resulting data referring to service robot categories was revised and cleaned.

Once validated, a dataset with the number of companies operating in both the personal and professional service robot categories by country and year is obtained. In order to proceed, the assumption that the distribution of firm-sizes across countries is equal was required.[9] Although unrealistic, this was needed due to the large number of companies that do not report their number of employees. With such a large amount of missing data, it was impossible to adjust the number of companies with their sizes to get a more accurate picture of their geographic distribution. The resulting dataset with the number of personal and professional robotics companies by country and year can be used to calculate the shares of robotics companies by country and year with respect to the continents as referred in the IFR service robots reports. Then, knowing the proportion that each continent represents with respect to the world, it is possible to find the market share by country and year with respect to the world total. This step already provides the market shares of sales, by country and year. In addition, these shares can be multiplied by the corresponding number of units of service robots sold to transform the shares into volumes.

Once the allocation of robotics sales by category, country and year is obtained, we can proceed to estimate the proportion of sales that go to the domestic market and the proportion that is exported. This is precisely the information needed to calculate the volume and shares of purchases of services robots, by country and year. To do that, we rely on the UNIDO Industrial Demand-Supply Balance Database,[10] which contains highly disaggregated data on the manufacturing sector for the period 1990 onwards and includes information about domestic output and exports. From this information, we calculate the proportion of sales that correspond to domestic sales and exports. However, in the official statistics there are no such sectors as service robots for personal or professional use, which calls for the identification of reasonable sectoral proxies.

In the case of robots for personal use and according to IFR data, the category robots for domestic use and entertainment represents more than 90% of sales. Hence, we assume that service robots for personal use follow a distribution similar to a weighted average[11] of the two manufacturing sectors that represent the best match: (i) electrical machinery and equipment and parts thereof; and (ii) toys, games and sports requisites. The first sector includes vacuum cleaners and other household appliances such as lawns mowers and pool cleaning,

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[6] https://dealroom.co/ is a global data platform for intelligence on start-ups, innovation, high-growth companies, ecosystems and investment strategies. See the methodological report for a more detailed description as well as information on the number of robotics companies identified in past exercises.

[7] This is the number of companies as of November 2021. In the methodological report, it was reported that Dealroom provided information for about 5,000 robotics companies back in 2019.

[8] This is a feature offered by Dealroom in which they extract information about some properties of the companies included in their database, and provide text strings. Users can the use this information (tags) to perform further categorisations.

[9] This is much less unrealistic than assuming that all firms have the same size. We thank a reviewer for this insight.

[10] https://stat.unido.org/content/dataset_description/idsb-2021%252c-isic-revision-4#. Last accessed on 20 April 2022.

[11] The weights are precisely the shares of each category in the total volume of sales. These figures vary from 66% in 2010 to 80% in 2019 in the case of robots for domestic tasks while it went from 34% to 19.9% for entertainment robots. The remaining category, robots for elderly and handicap assistance, represents a residual share.

while the second includes toy/hobby robots. These categories represent collectively more than 90% of sales of service robots for personal use. However, using these sectors as proxies will introduce some level of uncertainty and bias in the estimates.

When dealing with robots for professional use, things are a more complicated. First, this is because this type of robot implies a wider scope of activities. While service robots for personal use can be classified in three main application areas, service robots for professional use have 13 categories. Second, the shares of these categories are more equally distributed and hence it is not possible to assume that a single sector can capture the trade flows of such a wide variety of activities. However, after a detailed analysis, it was not possible to match each application area of service robots for professional use with one economic sector as defined by common industrial classifications.[12] Then, in order to avoid introducing more uncertainty in the estimations by selecting a large number of (possibly unrelated) sectors, it was confirmed that the International Standard Industrial Classification (ISIC) code 28 (manufacture of machinery and equipment not elsewhere classified) was the best match since it includes, among other economic activities, the "manufacture of robots performing multiple tasks for special purposes". Here the underlying assumption is that the trade flows of professional service robots can be approximated by the trade flows of this particular sector.

Having calculated the shares of sales by country and year, and knowing the proportion of sales to the domestic market and to foreign markets as described in the previous paragraphs, information about the destination of these international sales is required to calculate exports to each destination country from each origin country, by year. Here, we rely again on data from Comtrade to understand the origin-destination pairs for the sales of service robots. As before, the trade flows for service robots for personal use have been approximated by a weighted average of domestic appliances (ISIC code 2750) and games and toys (ISIC code 3240). For service robots for professional use, we have again used the ISIC code 28, manufacture of machinery and equipment and equipment not elsewhere classified. Once these trade flows are computed, we can finally calculate the total purchases of service robots of a given country. For a given destination country, these are the result of the sum of purchases of service robots in the domestic market plus imports of service robots from the different origin countries. Having calculated the purchases of service robots by country and year, it is easy to calculate the market shares.

With the information on service robot sales disaggregated by country and year, and the information on purchases of service robots by country and year we can proceed to calculate the corresponding market shares and the market concentration indicators described below. For more details of the methodology, please see the Annex II.

2.3 Indicators

In order to describe the evolution of the global and EU-27 landscapes in relation to the different segments of the robotics industry, in addition to the market share, the market concentration index will be also calculated. Both indicators will be computed using sales and purchases. This will provide information about the demand and supply sides of the robotics industry. The formulas used in the calculation of the indicators are shown in Annex III.[13]

The market share is the proportion over total sales (purchases) in an industry or market that corresponds to a particular player (e.g. company or country). Market shares are calculated by taking the player's sales (purchases) over the period of analysis and dividing it by the total sales (purchases) of the industry over the same period. The robotics industry market shares when referred to purchases provide information about the demand side, while the market shares taking sales as the relevant indicator illustrate the conditions on the supply side.

In addition, in this report market concentration[14] as a measure summarising the distribution of the market shares, will also be calculated separately for industrial and service robots, for purchases and sales, and for the global and the EU-27 landscapes. Market concentration is a measure of the intensity of competition or of

[12] The NACE Rev. 2 is the one used in the EU, while the ISIC (International Standard Industrial Classification) is frequently employed for international comparison purposes. However, correspondence tables exist that allow to link both classifications. Since this project deals with international comparisons, the industrial classification used is that of the ISIC, unless explicitly reported.

[13] The information available can be used to calculate several additional indicators, which for obvious reasons fall far beyond the scope of this report. Some of these indicators are, among others: the Revealed Comparative Advantage index; instability or volatility indexes; other measures of market concentration such as entropy or Gini indexes; several indicators of trade such as indexes of intra-industry or inter-industry trade.

[14] The various measures of market concentration that are used in practice incorporate, usually implicitly, the assumption that there is a clear definition of the market. Clearly, this is not the case in many real-world settings.

control. It provides information about the relative size distribution of firms (or countries) in a specific market. The higher the concentration in a market, the less competitive the market is. In this report, the Herfindahl-Hirschman Index (HHI), defined as the sum of the squares of the market shares of the n firms (or countries) in the industry, will be used to measure market concentration.

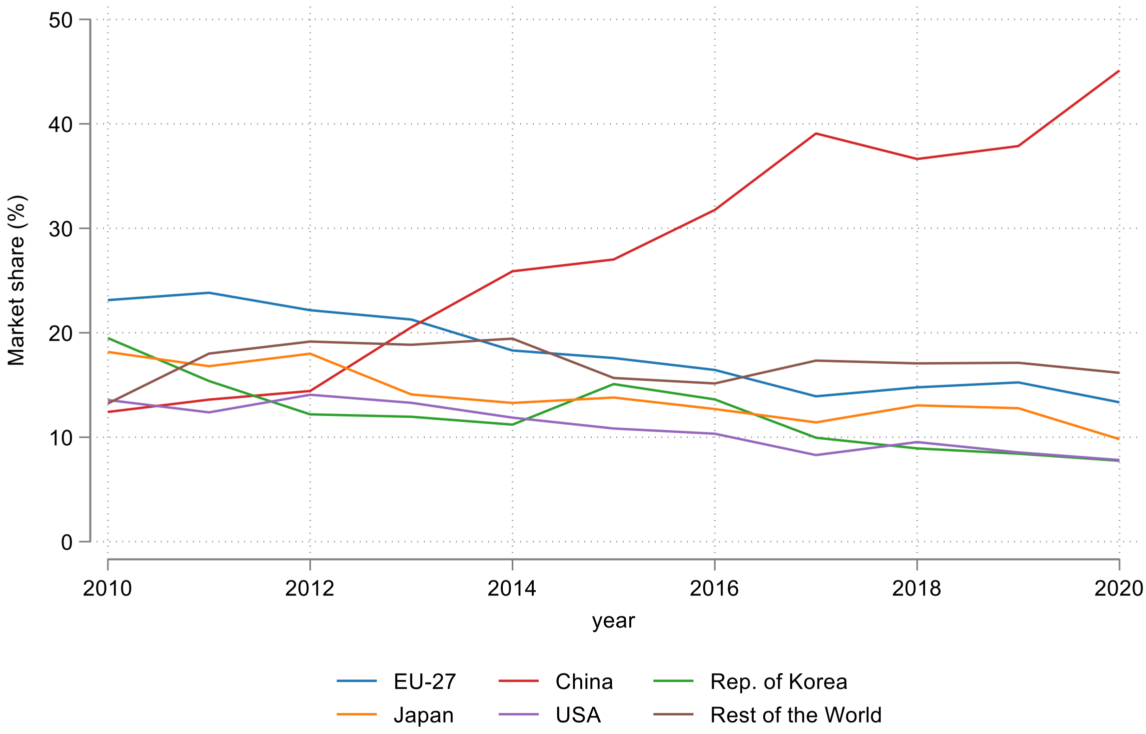
3 Market share dynamics of industrial robots

According to the IFR, installations of industrial robots have been growing globally at an average rate of 12.6% per year in the past decade, reaching an operational stock of 3 million industrial robots worldwide (IFR, 2021). In 2020, close to 400.000 industrial robots were installed wordwide, a figure that is more than three times larger than the number of industrial robots' installations in 2010. This trend is explained not only by the fact that countries or regions traditionally active in this area have been deepening their automation processes, but also due to the fact that new countries have joined the robotisation race (Cséfalvay and Gkotsis, 2020). This section uses the datasets resulting from the application of the methodology described in the previous section and looks at the market share dynamics of industrial robots in the period 2010-2020 from two perspectives. First, it describes the global landscape and compares the aggregated EU-27 figures with those of other relevant countries in terms of purchases and sales. Second, it takes a closer look at the evolution of the EU-27 MS also in terms of the two selected variables.

3.1 The global landscape

This section describes the evolution of the global industrial robots market shares. For that purpose, it looks in detail at the relative participation of the EU-27 and other relevant economies in this industry worldwide, over the period 2010-2020 in terms of the number of units[15] of industrial robots purchased and sold. Figure and Table 3.1 below, show the evolution of global market shares of industrial robots purchases.

Figure 3.1: Evolution of the global market shares of industrial robots purchases, 2010-2020.



Source: Table 3.1.

[15] Trends in units and values, where available, present similar patterns, therefore a dedicated graph for values is left out to save space but is available upon request. However, Annex IV provides and overview of the evolution of the number of robots purchased and sold, by category.

Table 3.1: Evolution of the global market shares of industrial robots purchases, 2010-2020.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	12.4	13.6	14.4	20.5	25.9	27.0	31.8	39.1	36.6	37.9	45.1
EU-27	23.1	23.8	22.2	21.3	18.3	17.6	16.4	13.9	14.8	15.2	13.3
Japan	18.2	16.8	18.0	14.1	13.3	13.8	12.7	11.4	13.0	12.8	9.8
Rep. of Korea	19.5	15.4	12.2	12.0	11.2	15.1	13.6	10.0	8.9	8.4	7.7
USA	13.6	12.4	14.1	13.3	11.9	10.8	10.3	8.3	9.5	8.5	7.8
Rest of the World	13.2	18.0	19.2	18.9	19.4	15.7	15.1	17.3	17.1	17.1	16.2

Source: EC JRC calculations based on data from the International Federation of Robotics.

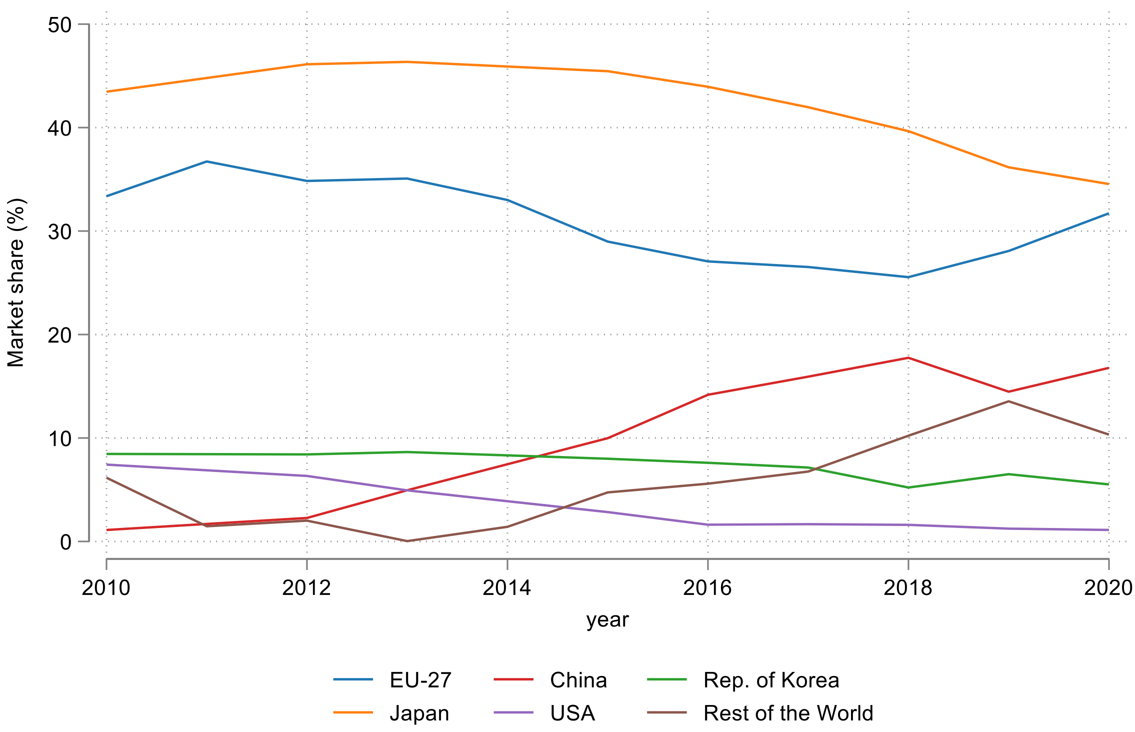
As shown in the Figure and the Table, over the last decade China has become the world's largest industrial robot purchaser, as compared to the other economies considered. At the beginning of the period the EU-27, Japan and Korea had the largest shares of industrial robots purchases showing however a steady decline over the whole period. China's share of industrial robots purchases moved from 12% in 2010 to 45% in 2020. This increase was particularly intense in the first part of the period, while it has slowed down from 2017 onwards. The market share of the EU-27 reached 13% at the end of the period while it started at 23%. Similarly, Korea which ranked 2nd in 2010 with a market share of 20%, declined in its relative market participation to less than 10%, moving down a couple of positions in the ranking. Japan's market share declined steadily from 18% in 2010 to 10% in 2020, a similar trend as that seen by the USA (from 14% in 2010 to 8% in 2020).

Looking in detail at these trends, Korea is the country that lost the greatest share (-12 percentage points) followed by the EU-27 (-9), while obviously China is the country that has gained the largest share (+22 percentage points). However, while these six economies represented 87% of the world's purchases of industrial robots in 2010, they were only responsible for 82% of the purchases in 2020. Hence, despite the trends followed by the top purchasers, entry into this industry by new countries willing to participate of the "robotisation race" with a relatively important share of purchases – of around 5% – is an interesting phenomenon that deserves further research.

Turning now the market share of sales of industrial robots, Figure 3.2 and Table 3.2 shows the trends obtained from the datasets constructed with the methodology employed, for the same group of economies and the same period.

Figure 3.2 shows that, in the last decade, Japan and the EU-27 preserved their positions as the world's largest industrial robots sellers. In addition, China became the third largest industrial robot seller already by 2015. In 2020, Japan has the highest share in industrial robotics sales of around 35%. However, the trend shows a steady decline from the 43% registered in 2010. Japan is closely followed by the EU-27, which started the period with a share of 33% and ended it with a slightly lower share of 32%. However, the evolution of the EU-27 share has two different periods. Until 2018, the EU-27 market share declines until reaching 26%, and then sharply raises in the last two years. Korea and the USA, with shares of 9% and 7% respectively, both decrease their relative participations. By 2020, Korea represented 6% of the market share of industrial robots sales, while the USA went down more severely until reaching 1%. A remarkable increase in the industrial robotics sales market share has been recorded by China, which started from close to 1% in 2010 increasing to 17% in 2020.

Figure 3.2: Evolution of the global market shares of industrial robots sales, 2010-2020



Source: Table 3.2.

Table 3.2: Evolution of the global market shares of industrial robots sales, 2010-2020

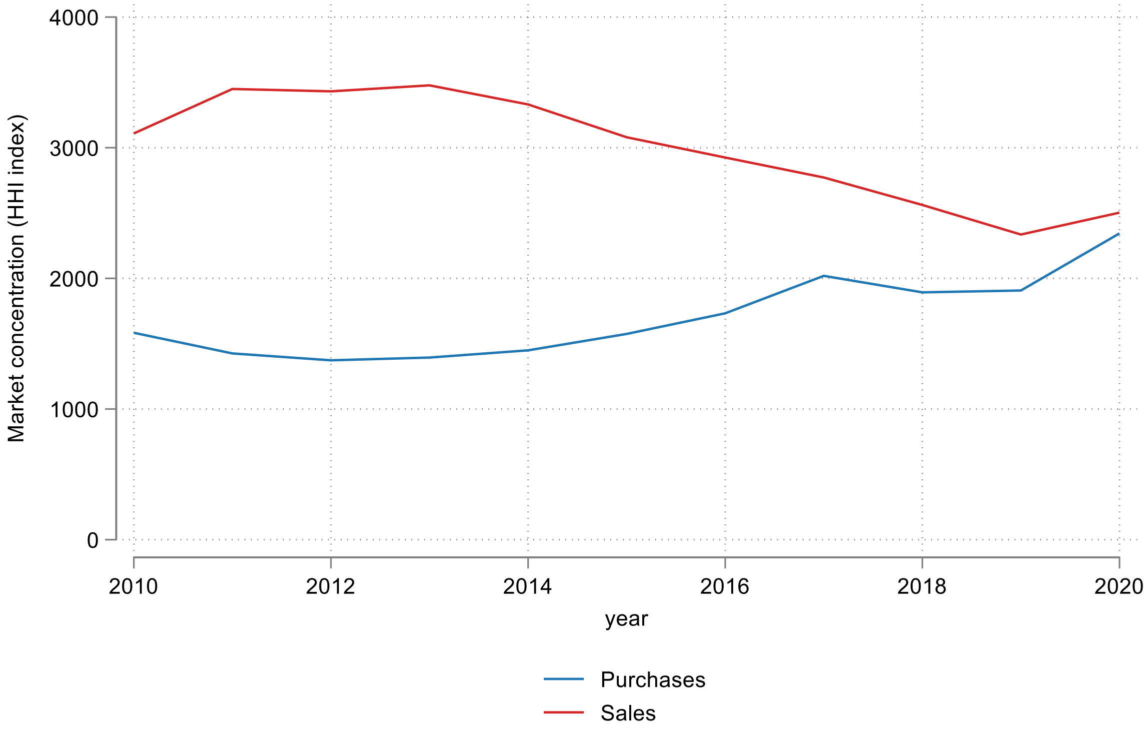
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	1.1	1.7	2.3	4.9	7.5	10.0	14.2	15.9	17.8	14.5	16.8
EU-27	33.4	36.7	34.8	35.1	33.0	29.0	27.1	26.5	25.5	28.1	31.7
Japan	43.5	44.8	46.1	46.4	45.9	45.5	43.9	42.0	39.7	36.2	34.5
Rep. of Korea	8.5	8.4	8.4	8.6	8.3	8.0	7.6	7.1	5.2	6.5	5.5
USA	7.4	6.9	6.3	4.9	3.9	2.8	1.6	1.7	1.6	1.2	1.1
Rest of the World	6.2	1.5	2.0	0.0	1.4	4.7	5.6	6.8	10.2	13.5	10.3

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Again, looking at the changes in market shares over the period of analysis, the two countries with larger reductions in their relative participations are Japan and the USA, with declining shares of about 8 and 6 percentage points. Korea and the EU-27 also recede in their shares, but with less significant impacts of 3 and 1 percentage points. China is once more the winner, moving its market share forward by 16 percentage points. Collectively, the six analysed economies represented, in 2010, around 94% of the world's industrial robots sales, while for 2020 it is 92%. Even if their joint share is lower at the end of the period, the change is not as pronounced as in the case of purchases. Hence, this group of countries collectively effectively control the world's sales of industrial robots.

Figure 3.3 and Table 3.3 show the evolution of the global market concentration of industrial robots purchases and sales from 2010 to 2020.

Figure 3.3: Evolution of the global market concentration of industrial robots, 2010-2020



Source: Table 3.3.

Table 3.3: Evolution of the global market concentration of industrial robots, 2010-2020

Variable	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Purchases	1584	1426	1373	1394	1449	1575	1733	2019	1893	1907	2344
Sales	3110	3449	3431	3477	3331	3080	2925	2772	2562	2336	2503

Source: EC JRC calculations based on data prepared following the methodology described in Section 2.

Figure 3.3 shows, first, that sales of industrial robots are more concentrated than the purchases, although there is a clear convergence at the end of the period. Second, the figure also indicates an increasing concentration in purchases and a slight decrease in the concentration of sales. From the purchases side, the trend is consistent with the sharp increase of China's market shares in industrial robots purchases which implies an increasingly dominant position. To what extent this fact can be attributed to monopsonistic[16] practices remains a subject for further research. Looking at the values of the HHI, in the last decade the global market of industrial robots purchases went from being somewhat competitive (i.e. HHI less than 1,500) to moderately concentrated (i.e. HHI of 1,500 to 2,500). On the sales side, Figure 3.2 shows a polarised distribution of market shares at the beginning of the period, but a more uniform one at the end of the period. This is consistent with the observed trend in Figure 3.3 of a reduction in market concentration. In the last decade, the global market of industrial robots sales went from being highly concentrated (i.e. an HHI of 2,500 or greater) to moderately concentrated (i.e. HHI of 1,500 to 2,500).

[16] A monopsonist is an economic agent that enjoys market power (i.e., the ability to influence the price it pays) when buying or procuring an input, different from the monopoly in which the market power is exerted when selling a product or a service.

3.2 The EU-27 landscape

As indicated in the previous section, the EU-27 is a relevant player in the global industrial robots industry, being the second largest purchaser and seller in 2020, just behind China and Japan respectively. In this section, we look at the composition of purchases and sales inside the EU-27 by looking in detail at the relative participation of the different MS in these two main activities.

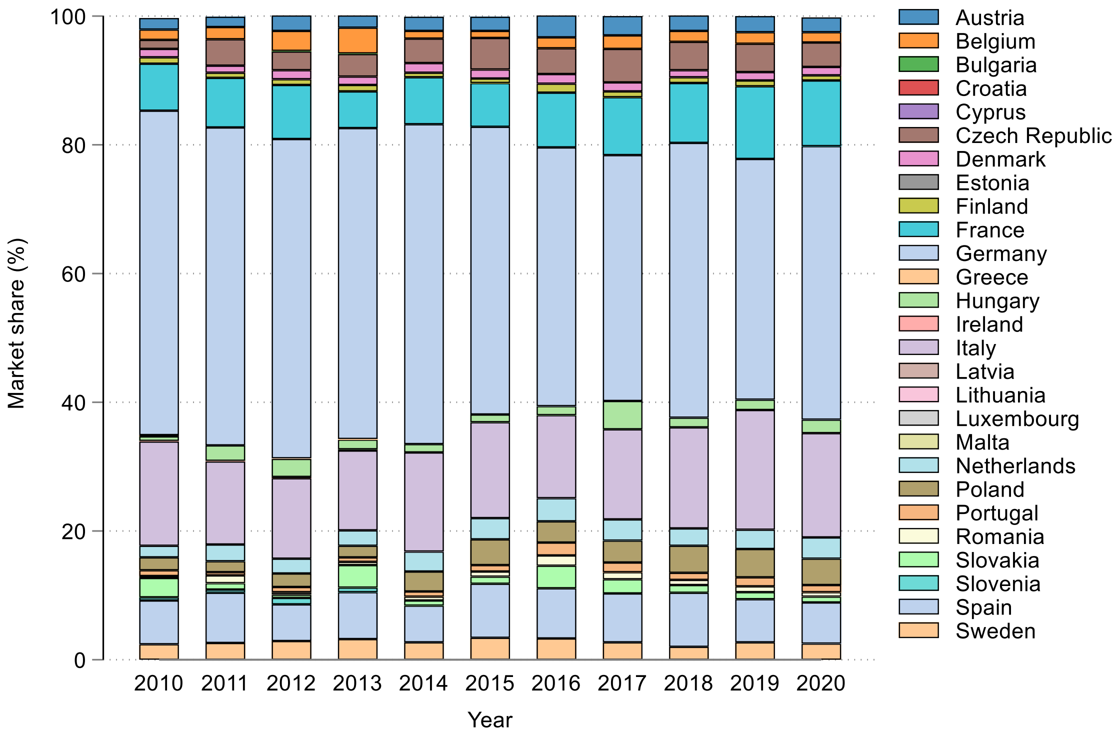
According to the data on purchases from the IFR, only 25 of the 27 EU MS purchased (installed) industrial robots in the period under study. The two EU countries that do not appear in the IFR data at any moment are Cyprus and Luxembourg. Similarly, these two countries do not report any type of trade flow over the period of analysis as reported by Comtrade. Other EU MS have very low numbers of purchases of industrial robots, which makes their market shares to be close to zero.[17] These MS are: Latvia, Malta, Croatia, Lithuania, Estonia, Bulgaria, Ireland, Greece and Slovenia. The last five are characterised by showing some industrial robots installation activity in the period 2010-2013, and none afterwards. The rest of the MS are actively purchasing industrial robots with different intensities. Figure 3.4 shows the evolution of the market shares of industrial robots purchases in the EU-27 in the period 2010-2020.[18]

A visual inspection of Figure 3.4 indicates that the distribution of the market shares of industrial robots purchases in the EU-27 followed a relatively stable evolution over the period under study. However, there are several relevant issues to be highlighted. The EU-27 MS representing the highest share of industrial robot purchases over the entire period is Germany. Nevertheless, its share went down from 50% of the total EU-27 industrial robots purchases in 2010 to 43% in 2020. Similarly, Italy is the second largest EU-27 industrial robot purchaser, with a market share of 16% both in 2010 and 2020, but with oscillations in between. As a matter of fact, Italy reaches its lowest market share of 12% in 2013 and its highest market share of 19% in 2019. The third place is contested between France and Spain. At the beginning of the period, in 2010, both MS had a market share of 7%. Moreover, while France managed to gradually increase its market share up to 10% in 2020, Spain registered a more fluctuating evolution ending with a market share of 6%. However, in several years of the period, the Spanish market share is above the French. An interesting case of an EU-27 MS industrial robot purchaser in 2010, in relative terms, was Slovakia. From a 3% market share in that year, Slovakia ends up with a market share of 1% in 2020 but with a couple of peaks every three years that push its market share up to 4% in 2013 and 2016. In contrast, the fifth largest industrial robot purchaser within the EU-27 in 2020 was Poland. Departing from a market share of 2% that remained somewhat stable until 2013, Poland's market share started to grow steadily from then onwards to reach values slightly above 4% in 2020. Finally, the group of remaining MS – including Romania, Finland, Portugal, Denmark, Hungary, Belgium, Austria, Sweden, Netherlands and Czech Republic – is comprised by countries that have been consistently purchasing industrial robots over the entire period but with varying intensities. This fact, along with the market share dynamics registered by other countries, has an effect on this group's market shares that move from 0.3% in Romania in 2010, to 5% in the Czech Republic in 2017. However, looking at the average over the period, this group of MS would be ranked below the top six EU-27 MS described above.

[17] These shares are statistically zero when the figures are rounded at one decimal number.

[18] Trends in units and values present similar patterns, therefore a dedicated analysis for values is left out to save space but is available upon request.

Figure 3.4: Evolution of the EU-27 market shares of industrial robots purchases, 2010-2020



Source: Table A.IV.3 in Annex IV.

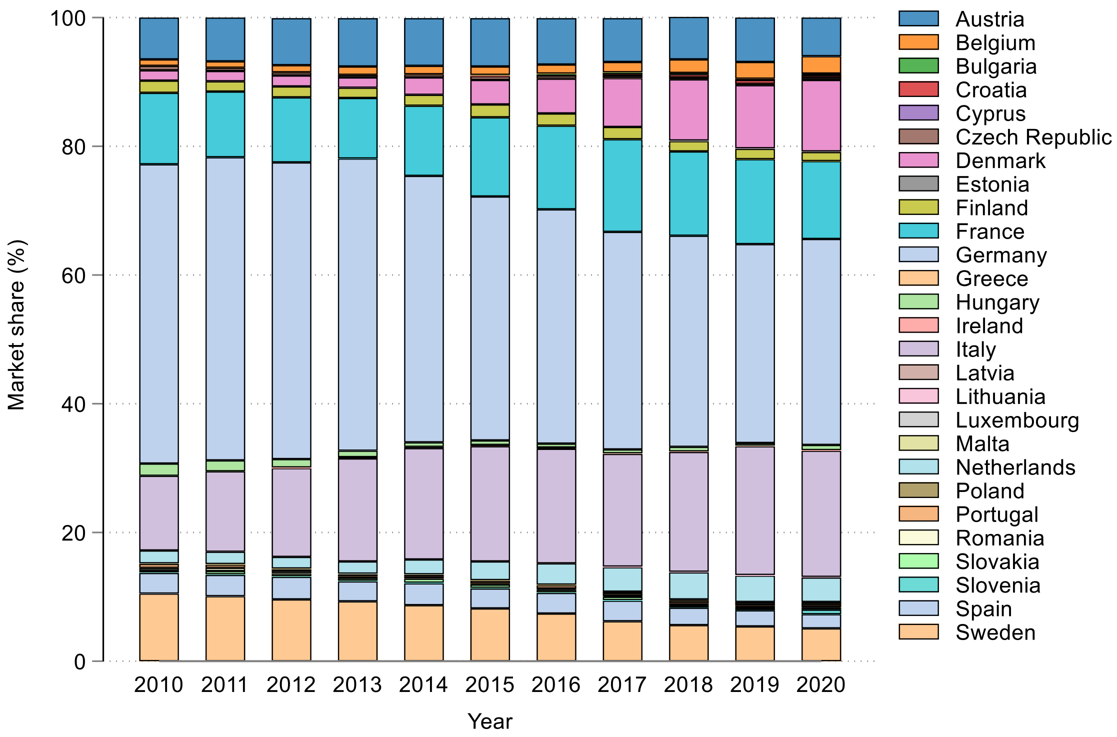
Table 3.4: Evolution of the EU-27 market shares of industrial robots purchases, 2010-2020

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Germany	50.4	49.4	49.6	48.3	49.7	44.7	40.2	38.2	42.7	37.4	42.5
Italy	16.2	12.9	12.5	12.4	15.4	14.9	12.9	14.0	15.7	18.6	16.2
France	7.3	7.7	8.4	5.7	7.3	6.8	8.5	9.0	9.3	11.3	10.2
Spain	6.8	7.8	5.7	7.3	5.7	8.4	7.8	7.6	8.4	6.7	6.4
Poland	2.0	1.7	2.1	1.8	3.1	4.0	3.3	3.4	4.2	4.4	4.1
Rest of the EU-27	17.2	20.5	21.8	24.5	18.8	21.1	27.3	27.7	19.6	21.6	20.5

Source: Table A.IV.3 in Annex IV. [EC JRC calculations based on data from the International Federation of Robotics.]

Next, we look at the market shares of industrial robot sales, and Figure 3.5 and Table 3.5 present the data. As shown there, from a relatively stable evolution two main trends stand out: first, the noticeable reduction in the German and Swedish market shares, and second, the notable increase in the Danish and Italian market shares. Besides being the EU-27 country with the highest share in industrial robots purchases, Germany is also its top seller of industrial robots, registering the highest market share over all the period of analysis. However, its evolution follows a similar path as that of purchases: it starts at a high market share of 47% in 2010 but shows a constant downward trend that stops at 32% in 2020. Similarly, Sweden ranks 4th in 2010 with a market share of 11%, but since then shows a descending trend that takes its market share to only 5% in 2020. On the other hand, in the period under study, Denmark manages to take its market share of industrial robot sales to 11% in 2020, departing from a mere 2% in 2010. Similarly, Italy succeeds in staying as the second largest industrial robot seller in the EU-27, while at the same time significantly increasing its market share that moves from 12% in 2010 to 20% in 2020. Two other relevant changes come from the market share evolution of the Netherlands and Belgium. Both MS enlarge their market shares by two percentage points in the period under study. In the case of the Netherlands, it moves from 2% in 2010 to 4% in 2020, while in the Belgian case this goes from 1% in 2010 to 3% in 2020. The rest of the countries show a relatively stable trend. France, for instance, shows an oscillating market share of around 11% all over the period, keeping its role as the third largest industrial robot seller in the EU-27. With different levels of industrial robots sales market shares, similar trends are registered by other MS such as Poland, Slovakia, Romania, Portugal, Czech Republic, Hungary, Finland, Spain and Austria. Finally, as with industrial robots purchases, Cyprus, Luxembourg, Malta, Latvia, Croatia, Greece, Estonia, Ireland, Lithuania, Bulgaria and Slovenia hardly participate in this industry, registering market shares of sales of industrial robots statistically zero. One relevant exception is Slovenia that manages to reach a market share of 0.7% in 2020 departing from a market share below 1% in 2010.

Figure 3.5: Evolution of the EU-27 market shares of industrial robots sales, 2010-2020



Source: Table A.IV.4 in Annex IV.

Table 3.5: Evolution of the EU-27 market shares of industrial robots sales, 2010-2020

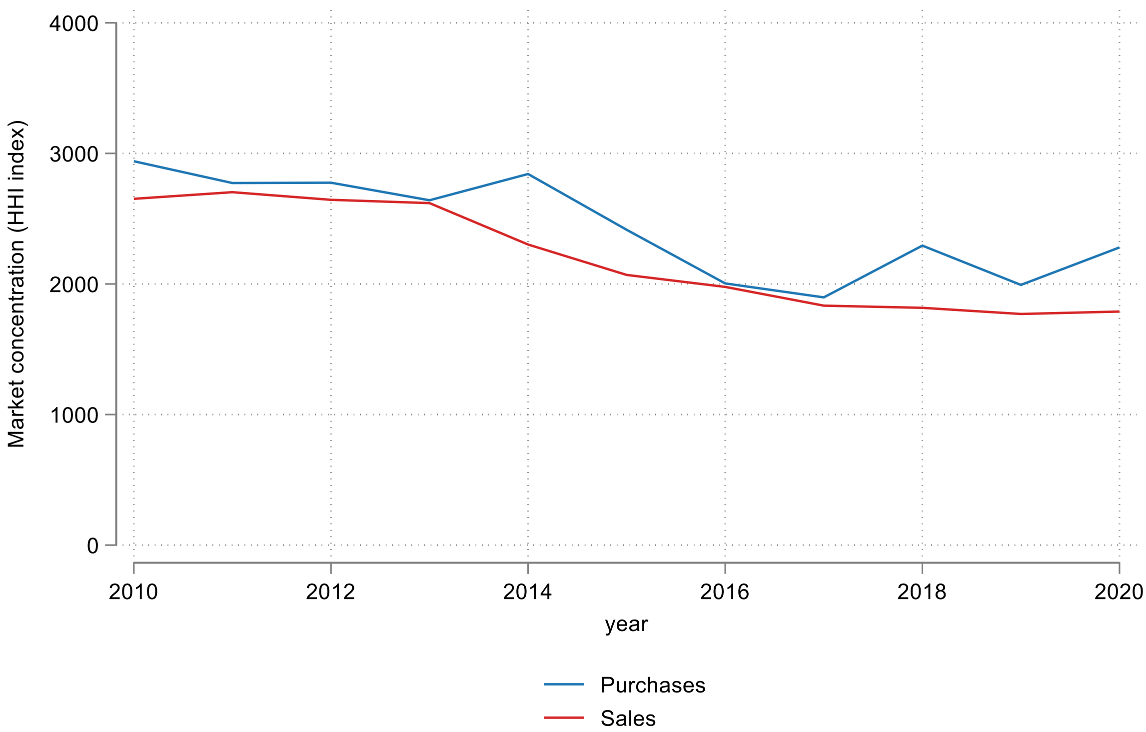
Country*	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Germany	46.5	47.1	46.1	45.4	41.4	37.9	36.4	33.8	32.8	30.9	32.0
Italy	11.6	12.5	13.8	16.0	17.3	17.9	17.8	17.5	18.6	20.0	19.6
France	11.1	10.2	10.1	9.4	10.9	12.3	13.0	14.4	13.1	13.2	12.1
Denmark	1.6	1.6	1.7	1.6	2.7	3.8	5.4	7.6	9.5	9.8	11.1
Austria	6.5	6.8	7.3	7.5	7.4	7.5	7.2	6.8	6.6	6.9	6.0
Rest of the EU-27	22.8	21.8	21.1	20.1	20.3	20.5	20.2	19.9	19.4	19.1	19.2

* Top 5 countries selected on the basis of their shares in 2020.

Source: Table A.IV.4 in Annex IV. [EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.]

Having analysed the main insights that emerge from the analysis of the evolution of the EU-27 MS market shares by using information about industrial robots purchases and sales, now we look at the evolution of market concentration. Figure 3.6 and Table 3.6 show the changes of the corresponding HHI indexes calculated with the relevant market shares from 2010 to 2020. As the graph shows, both concentration measures follow a decreasing trend over the whole period. However, while the trend for sales moves smoothly downwards, the purchases HHI follows a more volatile evolution, with increases in 2014, 2018 and 2020. This general evolution contrasts with what happens at the international level, where we have shown (Figure 3.3) that the market concentration of sales is decreasing while the corresponding purchases is increasing. Another interesting issue to highlight is that while, in the case of the global landscape, the market concentration of sales is higher than that of purchases, in the case of the EU-27 this is reversed: the concentration of purchases is (slightly) higher than the concentration of sales. In the last decade, the EU markets for industrial robots purchases went from being highly concentrated (i.e. an HHI of 2,500 or greater) to moderately concentrated (i.e. an HHI of 1,500 to 2,500).

Figure 3.6: Evolution of the EU-27 market concentration of industrial robots, 2010-2020



Source: Table 3.6.

Table 3.6: Evolution of the EU-27 market concentration of industrial robots, 2010-2020

Variable	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Purchases	2940	2773	2776	2641	2843	2415	2005	1898	2294	1993	2280
Sales	2652	2703	2645	2620	2302	2070	1978	1834	1818	1770	1789

Source: EC JRC calculations based on data prepared following the methodology described in section 2.

4 Market share dynamics for service robots

In this section the analysis of the evolution of the market shares for service robots is presented. As was extensively discussed in the methodological report, the standard ISO 8373:2012 code is used to define robotics in general and includes both industrial and service robotics. There, it is explained that "the classification into industrial robot or service robot is done according to its intended application. Industrial robots are robots 'for use in industrial automation applications', while a service robot 'performs useful tasks for humans or equipment excluding industrial automation applications'". (IFR, 2021 p. 11). The cited standard further distinguishes personal from professional service robots.[19] According to it, a personal service robot is a "service robot used for a non-commercial task, usually by laypersons", while professional service robots are "service robots used for a commercial task, usually operated by a properly trained operator". The operator is a "person designated to start, monitor and stop the intended operation of a robot".[20]

The service robot industry is more diverse and less tangible than the industrial robot industry. It is also a less consolidated activity in which many companies may still be in the development phase and thus not commercialising any product. New entrants try to win market share and yet others leave the industry in search of better business opportunities elsewhere or because of bankruptcies. In the period 2010-2020,[21] the service robotics industry worldwide grew at a compound annual rate of 25% in terms of units. This means that sales went from around 2 million service robots in 2010 to around 20 million in 2020. In terms of value, the industry registered revenues of USD 11 billion in 2020, up from USD 4 billion in 2010.

The rest of this section is organised as follows. First, we look at service robots for personal use, where we will analyse both the global and the EU-27 landscapes. Second, we will look at service robots for professional use, and the structure of the section will follow the first one. In this section, however, after looking at professional service robots from an aggregated perspective, we will also analyse the evolution of the market shares of four categories of professional robots, namely: (i) field robotics; (ii) professional cleaning, inspection and maintenance, construction and demolition; (iii) logistic systems; and (iv) medical robotics. In this case, however, we will present the main trends as bullet points under the corresponding figures.

4.1 Service robots for personal use

As explained above, service robots for personal use do not require professional training, meaning that anybody can use them. Examples are domestic cleaning robots, automated wheelchairs, and toys and social interaction robots. Hence, this type of robot is a consumer good, intended for mass markets with specific pricing strategies and marketing channels. So far, service robots for personal use are mainly present in the areas of domestic (household) robots, which include vacuuming and floor cleaning robots, gardening (mainly lawn-mowing) robots, outdoor cleaning (mainly pool cleaning) robots, and for early technology education. But there is also a growing market for care at home robots. The new IFR classification distinguishes three segments consisting of robots for domestic tasks (IFR class AC1), robots for social interactions or education (AC2), and robots for elderly and handicap assistance (AC3). In what follows, we will look at service robots for personal use as a single category, since no disaggregation was possible. This segment of the service robotics industry represents the largest part in terms of the units sold (19 million versus 131,000 professional robots in 2020) but a relatively minor share of revenues (USD 4 billion versus USD 7 billion from professional robots in 2020). The analysis of the evolution of the global landscape is presented first, followed by the description of the main changes registered at the EU-27 level.

4.1.1 The global landscape

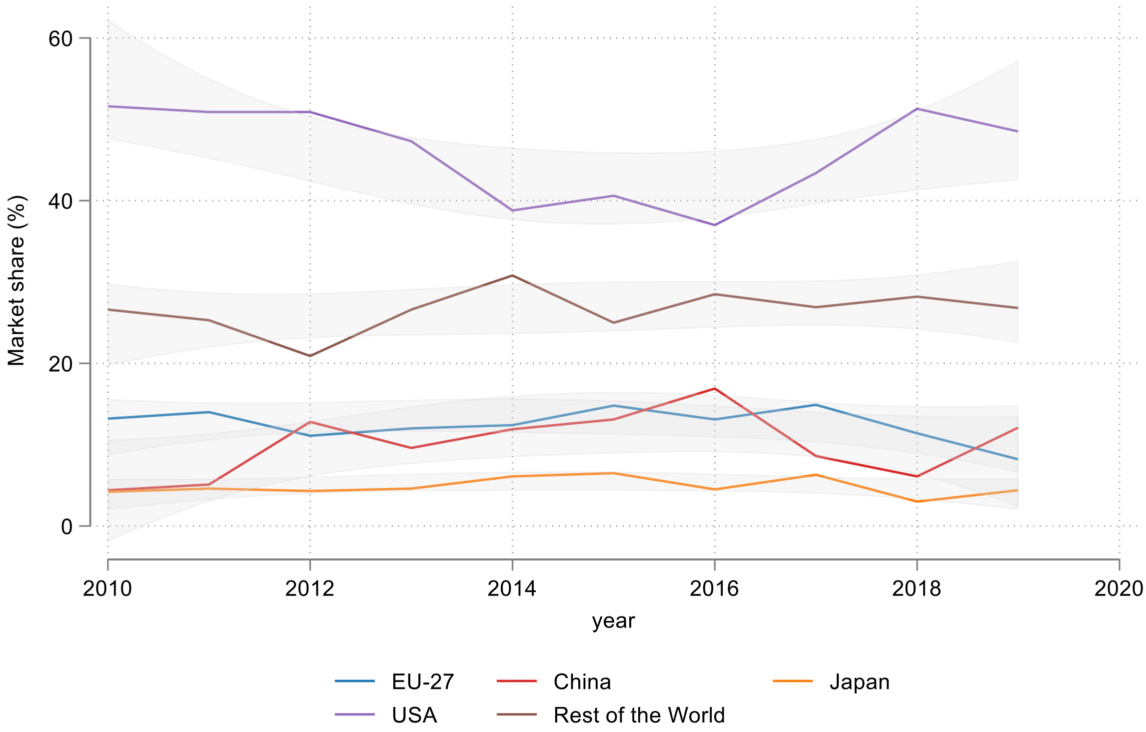
This section looks at the evolution of the global market shares of service robots for personal use in the period 2010-2019. As we did for industrial robotics, we will look at the market shares calculated considering purchases and sales of service robots for personal use, respectively. To start, Figure 4.1 and Table 4.1 show the evolution of the market shares of personal service robots purchases in units of the EU-27 and three major economies, the USA, China and Japan for the period 2010-2019.

[19] See https://www.iso.org/standard/55890.html

[20] More details and comparisons between industrial and service robots, as well as between personal and professional service robots can be found in the methodological report.

[21] For these calculations, we have used the aggregated figures offered by the IFR (2021), even if the new classification does not allow for a comparison by application.

Figure 4.1: Evolution of the global market shares of purchases of robots for personal use, 2010-2019



Source: Table 4.1.

Table 4.1: Evolution of the global market shares of purchases of robots for personal use, 2010-2019

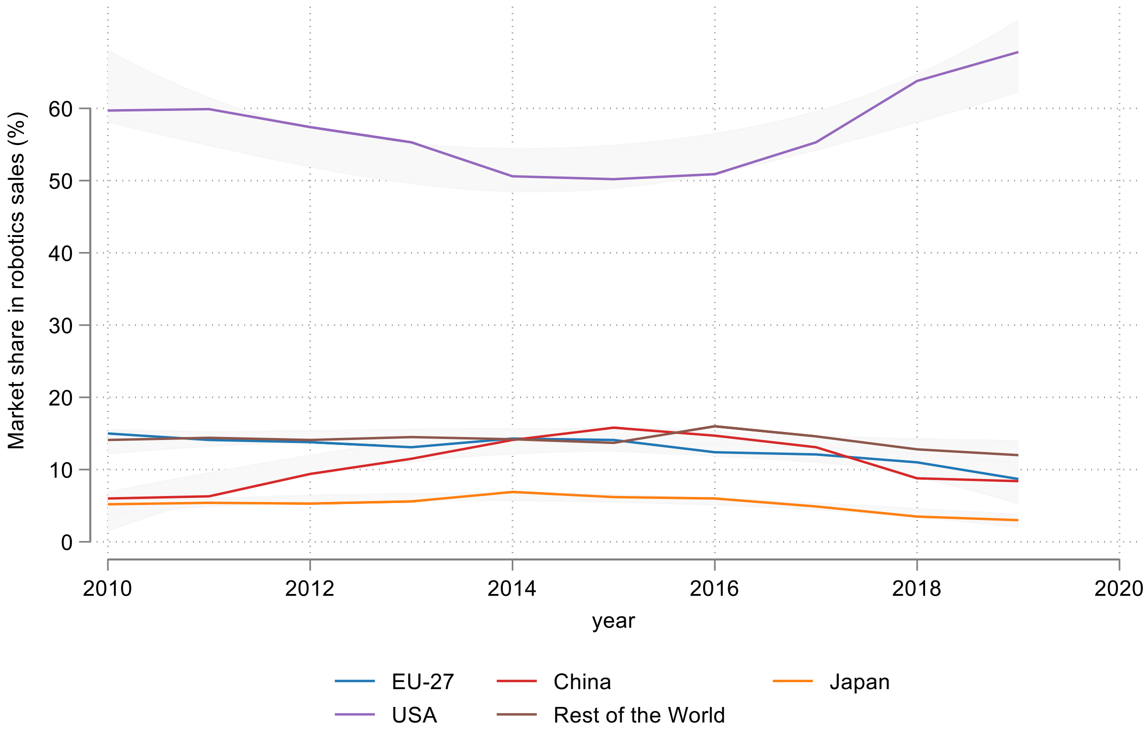
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
China	4.4	5.1	12.8	9.6	11.9	13.1	16.9	8.6	6.1	12.1
EU-27	13.2	14.0	11.1	12.0	12.4	14.8	13.1	14.9	11.4	8.2
Japan	4.2	4.6	4.3	4.6	6.1	6.5	4.5	6.3	3.0	4.4
USA	51.6	50.9	50.9	47.3	38.8	40.6	37.0	43.4	51.3	48.5
Rest of the World	26.6	25.3	20.9	26.6	30.8	25.0	28.5	26.9	28.2	26.8

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

As shown in the figure, the United States has consistently been the world's largest purchaser of service robots for personal use in the period 2010-2019 while the EU-27, Japan and China have shown smaller, although similar, market shares. With the exception of China that shows more volatility, the market shares of the EU-27 and Japan are surprisingly stable over the period under study. Japan's market share oscillates between 4% and 5% during the entire period. The EU-27 market share moves from 13% in 2010 to 15% in 2017, before going down to 8% in 2019. On the other hand, China jumps from a market share of 4% in 2010 to a maximum of 17% in 2016, and ends in 2019 with a market share of 12%. Despite the evident dominance of this market, the US follows a decreasing trend up to 2016, when its share was 37%, and an increasing trend from then onwards. Collectively, these four economies represent a relatively stable market share of around 73% of the world's purchases of service robots for personal use over all the years considered.

Figure and Table 4.2 show the market shares of service robots for personal use sales for the EU-27 and other major economies from 2010 to 2019.

Figure 4.2: Evolution of the global market shares of sales of robots for personal use, 2010-2019



Source: Table 4.2.

Table 4.2: Evolution of the global market shares of sales of robots for personal use, 2010-2019

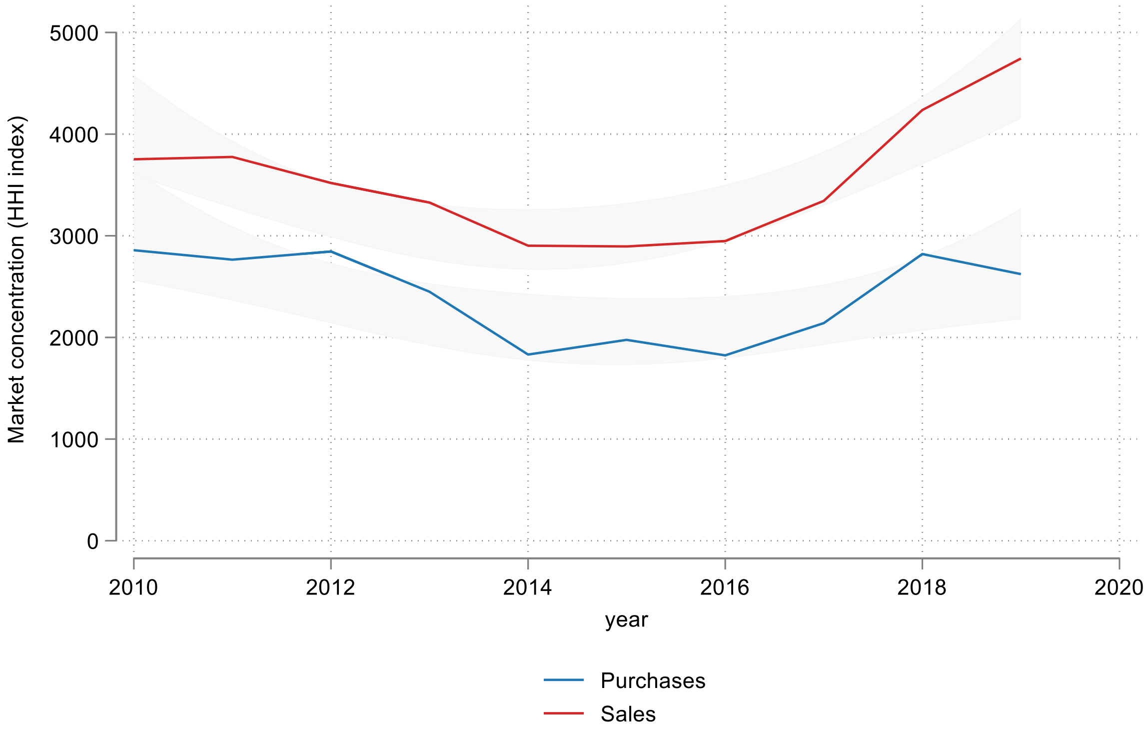
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
China	6.0	6.3	9.4	11.5	14.1	15.8	14.7	13.1	8.8	8.4
EU-27	15.0	14.1	13.8	13.1	14.3	14.1	12.4	12.1	11.0	8.7
Japan	5.2	5.4	5.3	5.6	6.9	6.2	6.0	4.9	3.5	3.0
USA	59.7	59.9	57.4	55.3	50.6	50.2	50.9	55.3	63.8	67.8
Rest of the World	14.1	14.4	14.1	14.5	14.2	13.7	16.0	14.6	12.8	12.0

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

From Figure 4.2 we learn that the United States clearly dominates the global market of service robots for personal use sales in the period 2010-2019. In contrast, the relative participation of the EU-27, China and Japan is significantly lower. The US holds market shares between approximately 50 and 70% during the period under study. Despite increasing its share from 60% in 2010 to 68% in 2019, the US show a decreasing trend up to 2015, when its share reached 50%. The recuperation in the period 2016-2019 more than compensates the losses and brings the market share close to 70%. The EU-27 starts in 2010 with a share of 15% but shows a declining pattern over the entire period reaching approximately 9% of the global sales in 2019. China shows a market share of 6% at the beginning of the period, which increases to reach 16% in 2015 and then goes down to 8% in 2019. Japan shows a more stable evolution, moving from 5% in 2019 to 3% in 2019. Collectively, the four economies considered represented 86% of sales in the market of service robots for personal use in 2010, but 88% in 2019 increasing their participation in this industry. Different from the case of purchases, where the rest of the world holds a market share of 27% over the entire period, in the case of sales these countries moved from concentrating 14% in 2010 to a participation of only 12% in 2019.

These trends are pictured in Figure 4.3 and Table 4.3 that show the indexes of market concentration in this industry using information on both purchases and sales.

Figure 4.3: Evolution of the global market concentration of service robots for personal use, 2010-2019



Source: Table 4.3.

Table 4.3: Evolution of the global market concentration of service robots for personal use, 2010-2019

Variable	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purchases	2858	2765	2845	2449	1832	1976	1824	2141	2820	2623
Sales	3752	3776	3519	3326	2902	2895	2948	3344	4237	4744

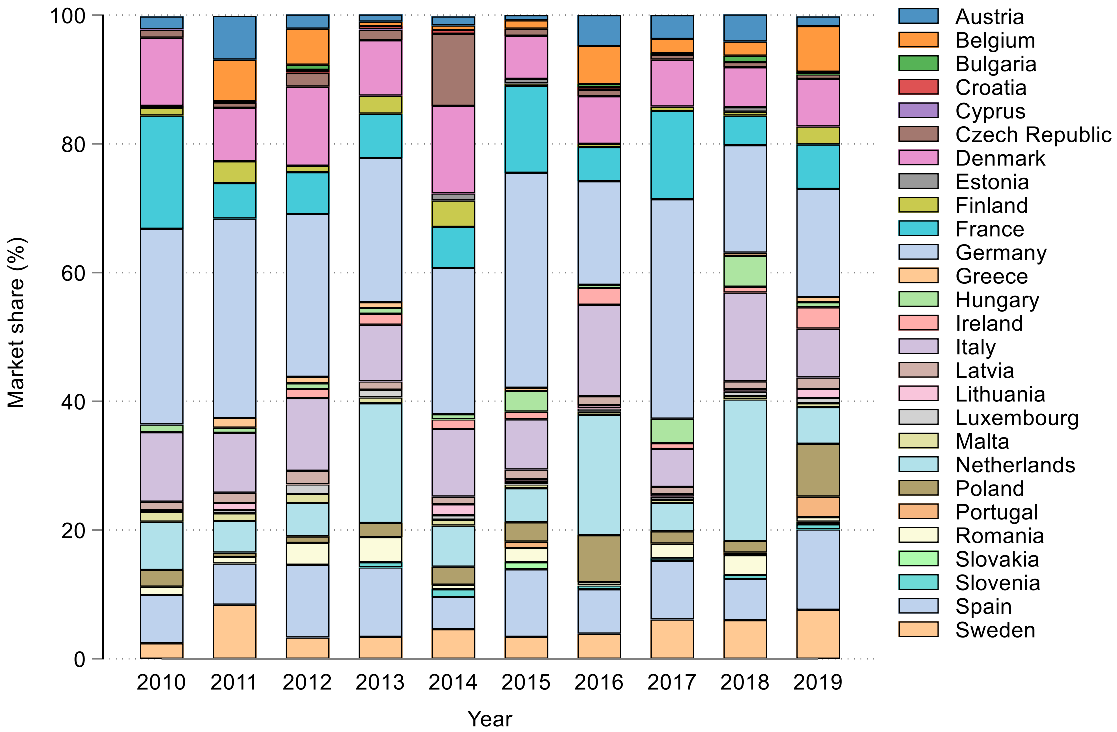
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure 4.3 and Table 4.3 show a high concentration in this market according to the HHI index, which is consistent with the dominant position of the United States in this activity. In the last decade, the global market for personal service robots purchases experienced fluctuations, but it remained overall highly concentrated (i.e. an HHI of 2,500 or greater). Despite the evolution in recent years in terms of market penetration and the proliferation of service robots for personal use, this segment seems to be still dominated by personal and/or household preferences over technology, as well as income, since normally these types of products tend to be more expensive than alternative non-robotic solutions. On average during the period, half of the service robots for personal use were purchased in the United States. Similarly, the figure also shows an increasing concentration in the latest years in the sales of service robots for personal use, which is consistent with the growing role of the US in this market. This trend indicates that sales of service robots for personal use are becoming increasingly monopolised, which may have consequences in terms of quantities sold and, more importantly, prices.

4.1.2 The EU-27 landscape

The previous section showed that the relative role of the EU-27 in the global market for service robots for personal use is rather modest. Both in terms of purchases and sales, the participation of the EU-27 is below 20% and, as expected, shows a decreasing trend. However, purchases of service robot units for personal use went up from 250,000 in 2010 to 1.6 million in 2019. Given that we are considering a consumer product, all EU MS have on average positive sales over the period. However, in some countries and years, the purchases of these types of robots can be close to zero. On the contrary, only 22 EU MS have been identified as selling service robots for personal use. The EU-27 as a whole sold 300,000 service robots for personal use in 2010 and 1.7 million in 2019. In this section, we will look at the composition of EU-27 purchases and sales of service robots for personal use and analyse which are the most relevant MS in this activity, and how they contribute to the aggregated EU-27 market share. Figure 4.4 shows the evolution of the market shares of purchases of service robots for personal use in the EU-27 MS from 2010 to 2019.

Figure 4.4: Evolution of the EU-27 market shares of purchases of robots for personal use, 2010-2019



Source: Table A.V.3 in Annex V.

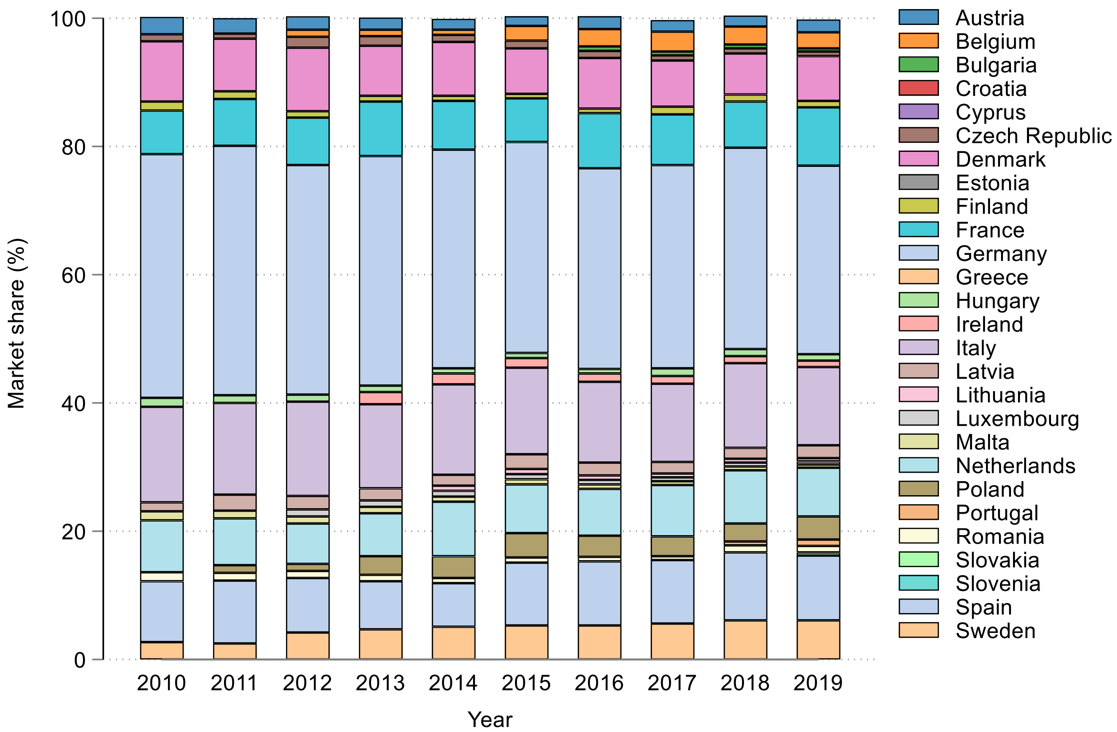
Table 4.4: Evolution of the EU-27 market shares of purchases of robots for personal use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Germany	30.4	31.0	25.3	22.4	22.7	33.4	16.1	34.1	16.7	16.8
Spain	7.5	6.4	11.3	10.8	5.0	10.5	6.9	9.1	6.4	12.5
Poland	2.6	0.7	1.0	2.2	2.8	3.0	7.3	1.9	1.8	8.2
Sweden	2.4	8.4	3.3	3.4	4.6	3.4	3.9	6.1	6.0	7.6
Italy	10.8	9.3	11.3	8.8	10.5	7.8	14.2	5.9	13.8	7.6
Rest of the EU-27	46.2	44.2	47.7	52.4	54.4	41.9	51.6	42.9	55.2	47.1

Source: Table A.V.3 in Annex V. [EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.]

As the figure shows, the evolution of the relative participation in the purchases of service robots for personal use of the different EU-27 MS is quite volatile over the period under study. As with industrial robots, Germany has had a leading position in the purchases of personal service robots in the period 2010-2019, although its share showed a decreasing trend. Germany had a market participation of 30% in 2010, which gradually reduced to reach 17% in 2019. However, the data show two important peaks in Germany's market share in 2015 and 2017, in both cases of around 34%. Spain and Italy follow Germany in the rank of top purchasers of service robots for personal use in this period. They show average market shares in the range of 7.5% to 11% for the entire period, while several point estimates for some years register relevant deviations from these means. Another group of countries composed by Ireland, Latvia, Finland, Hungary, Romania, Czech Republic, Austria, Poland, Belgium and Sweden, present average market shares of between 1% and 5% over the period. Although the variability of the market shares of this group is lower, they show high instability over the years. The last group of countries (Cyprus, Slovakia, Croatia, Estonia, Bulgaria, Slovenia, Portugal, Greece, Lithuania, Luxembourg and Malta) have average market shares over the entire period of below 1% but are also subject to constant important changes from one year to the other. Given the characteristics of this market, defined by 27 segments with different socio-economic conditions and changing consumer expectations, and the features of the products – emerging high-technology and trendy – the rapidly changing market shares indicate an unpredictable market with high demand volatility. Figure 4.5 shows the evolution of the market shares of the sales of service robots for personal use in the EU-27 from 2010 to 2019.

Figure 4.5: Evolution of the EU-27 market shares of sales of robots for personal use, 2010-2019



Source: Table A.V.4 in Annex V.

As explained above, only 22 of the EU-27 MS register a positive market share of sales of service robots for personal use in the period of analysis. The countries that are not active in selling these types of robots are Cyprus, Croatia, Estonia, Slovenia and Greece. However, in 2010 only 15 of EU-27 MS registered non-zero market shares. The countries that have managed to enter this market in the period under study are Slovakia, Portugal, Bulgaria, Lithuania, Luxembourg, Ireland and Belgium. On average over the period, these countries represented 4% of sales of service robots for personal use. The leading MS is again Germany and once more showing a decreasing trend. Germany starts the period with a market share of 38% which gradually declines down to 29% in 2019. Similarly, other countries in the top 6 that also register decreases in their market participation are Italy and the Netherlands. These two countries start the period with market shares of 15%

and 8%, respectively, and register losses of 3.5 percentage points at the end of the period with respect to their initial values. The only two countries of the top 6 that managed to increase their relative participations were Spain, moving from 9% in 2010 to 10% in 2019, and France, increasing two percentage points in the period 2010-2019 from 7% to 9%. With the exception of Sweden, that has a relative position in this activity of around 5% over the entire period, all the other EU MS register very low market shares, if at all positive as was already highlighted before.

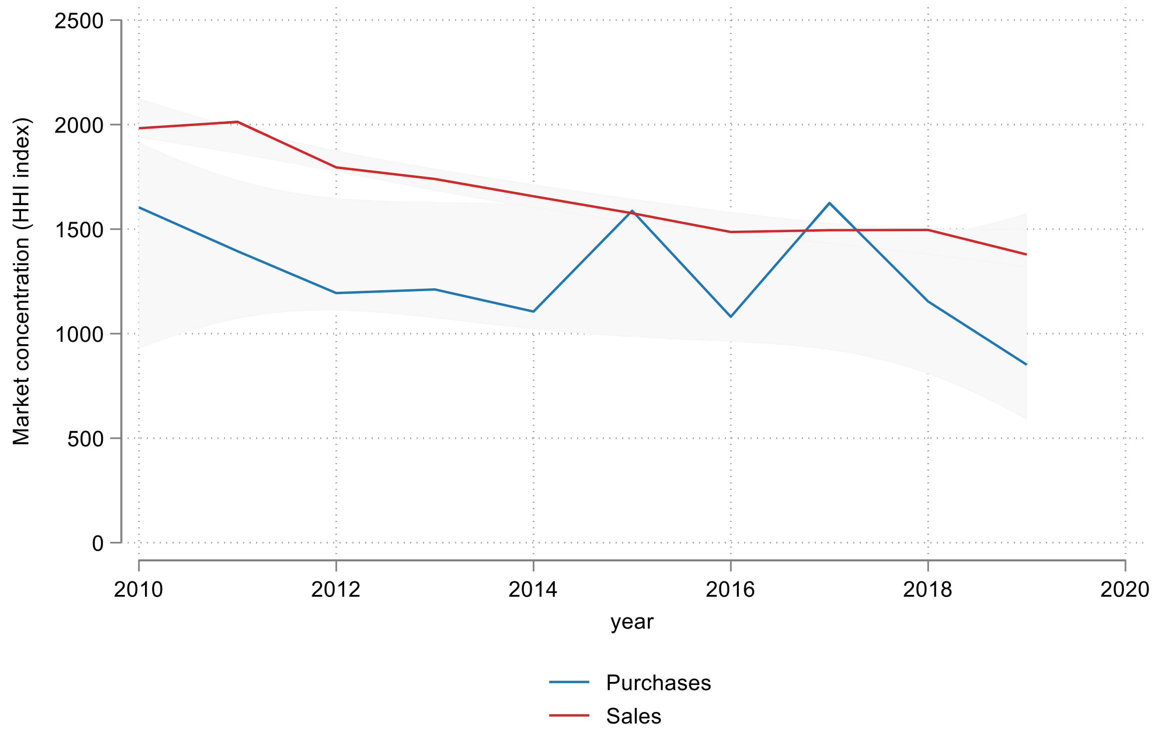
Table 4.5: Evolution of the EU-27 market shares of sales of robots for personal use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Germany	38.0	38.9	35.8	35.8	34.1	32.9	31.3	31.7	31.4	29.4
Italy	14.9	14.3	14.7	13.1	14.1	13.5	12.6	12.2	13.2	12.2
Spain	9.5	9.8	8.5	7.5	6.8	9.8	10.0	9.9	10.6	10.1
France	6.8	7.3	7.4	8.5	7.6	6.8	8.6	7.9	7.2	9.1
Netherlands	8.1	7.3	6.3	6.7	8.5	7.6	7.3	8.0	8.3	7.6
Rest of the EU-27	22.6	22.5	27.4	28.4	29.0	29.4	30.2	30.2	29.4	31.5

Source: Table A.V.4 in Annex V. [EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.]

These trends in the evolution of the EU-27 MS market shares in service robots for personal use in the period 2010-2019 are summarised by the corresponding market concentration indexes shown in Figure and Table 4.6.

Figure 4.6: Evolution of the EU-27 market concentration of robots for personal use, 2010-2019



Source: Table 4.6.

Table 4.6: Evolution of the EU-27 market concentration of robots for personal use, 2010-2019

Variable	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purchases	1604	1394	1194	1211	1106	1588	1081	1625	1154	851.1
Sales	1983	2013	1795	1740	1657	1576	1486	1495	1496	1379

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

As the figure shows, both indicators show a decreasing trend, consistent with the fact that the top purchasers and sellers of service robots for personal use in the EU-27 have registered falling market shares in the two areas, while other MS have successfully entered the market or increased their participation in this activity. The figure shows that, as expected, sales tend to be more concentrated than purchases since the production and distribution capacities supporting this economic activity cannot be enlarged instantaneously, but require a relatively long period of investment and commercialisation. On the other hand, as mentioned above, purchases depend more on income and preferences and, provided there are appropriate distribution channels, automated household appliances can be available for purchase anywhere. Looking at the specific values of the indexes, in the last decade, the EU market for service robots for personal use went from being moderately concentrated (i.e. HHI of 1,500 to 2,500) to competitive (i.e. HHI less than 1,500) when looking both at purchases and sales.

4.2 Service robots for professional use

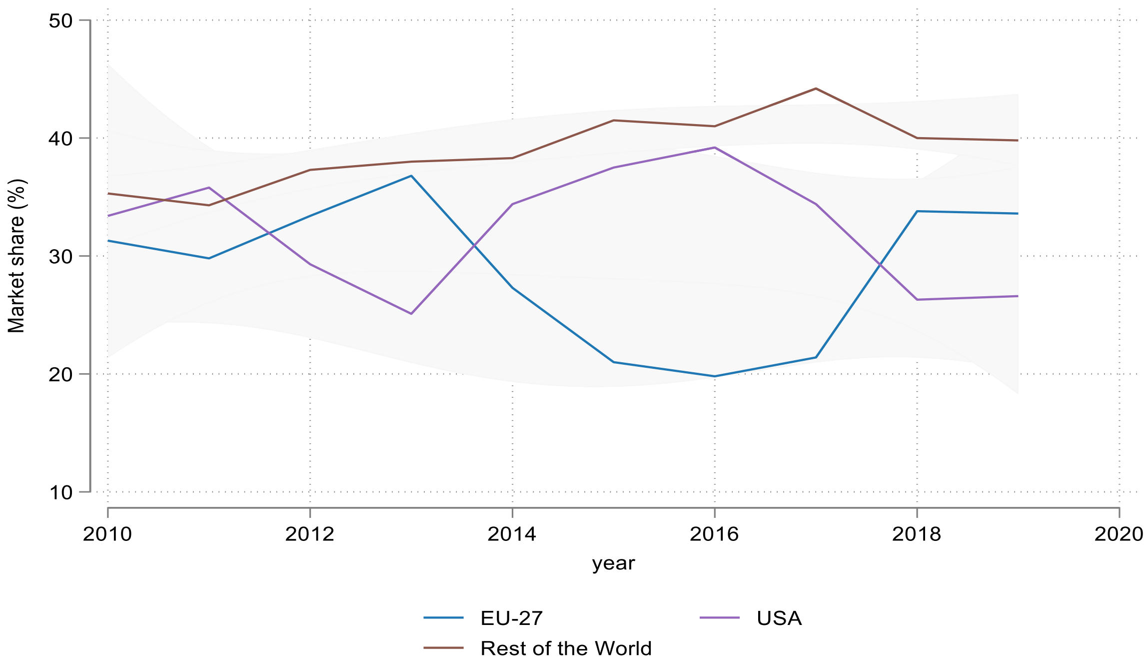
In contrast with personal service robots, professional service robots require a professionally trained operator. Examples are cleaning robots for public places, delivery robots, fire-fighting robots, rehabilitation robots and surgery robots in hospitals. Until 2020 (with data referred to 2019), the geographic disaggregation offered by the IFR covered nine different application areas.[22] In the 2021 edition of the World Robotics report, the IFR has introduced a new classification for service robots in which there are still nine sectors, but the new scheme distinguishes service robots along two dimensions: the robot application and the type of movement. In what follows, we will look at service robots for professional use as a single category first, and then we will look in more detail into four categories that collectively represent more than 80% of professional robots sold. Looking at the aggregated category of professional robots, there is an annual average growth rate of 24%, moving from 15,000 professional robots sold worldwide in 2010 to 132,000 in 2020. This segment of the service robotics industry is not the largest in terms of the units sold, but it is in terms of value, reaching USD 7 billion in sales compared to USD 4 billion from personal robots in 2020, and up from USD 3 billion sales in 2010. As was done in previous sections, the analysis of the evolution of the global landscape is presented first, followed by the description of the main changes registered at the EU-27 level.

4.2.1 The global landscape

The results obtained by applying the methodology described in Section 2 indicate that no geographical unit, with the exceptions of the USA and the EU-27, register shares greater than 5% for both purchases and sales. Hence, in this section all the other countries will be grouped in a category called Rest of the World (hereinafter "ROW") for the comparison of the market share trends. When relevant, we will highlight the specific shares of countries grouped within this category. Starting with the market shares of purchases of professional service robots, Figure 4.7 shows the evolution of the market shares of the three areas considered for the period 2010 to 2019.

[22] These are: (1) field robotics; (2) professional cleaning, inspection and maintenance, construction and demolition; (3) logistic systems; (4) medical robotics; (5) defense; (6) autonomous ships, underwater vehicles and mobile platforms (civil/general use); (7) powered human exoskeletons; (8) robots for public environments; and (9) other professional service robots.

Figure 4.7: Evolution of the global market shares of purchases of robots for professional use, 2010-2019



Source: Table 4.7.

Table 4.7: Evolution of the global market shares of purchases of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27	33.7	33.7	39.1	45.3	28.7	20.3	25.7	29.8	42.1	38.6
USA	39.8	41.3	37.1	29.1	41.0	44.4	41.7	34.6	31.8	26.8
Rest of the World	26.5	25.1	23.8	25.6	30.3	35.3	32.6	35.6	26.1	34.6

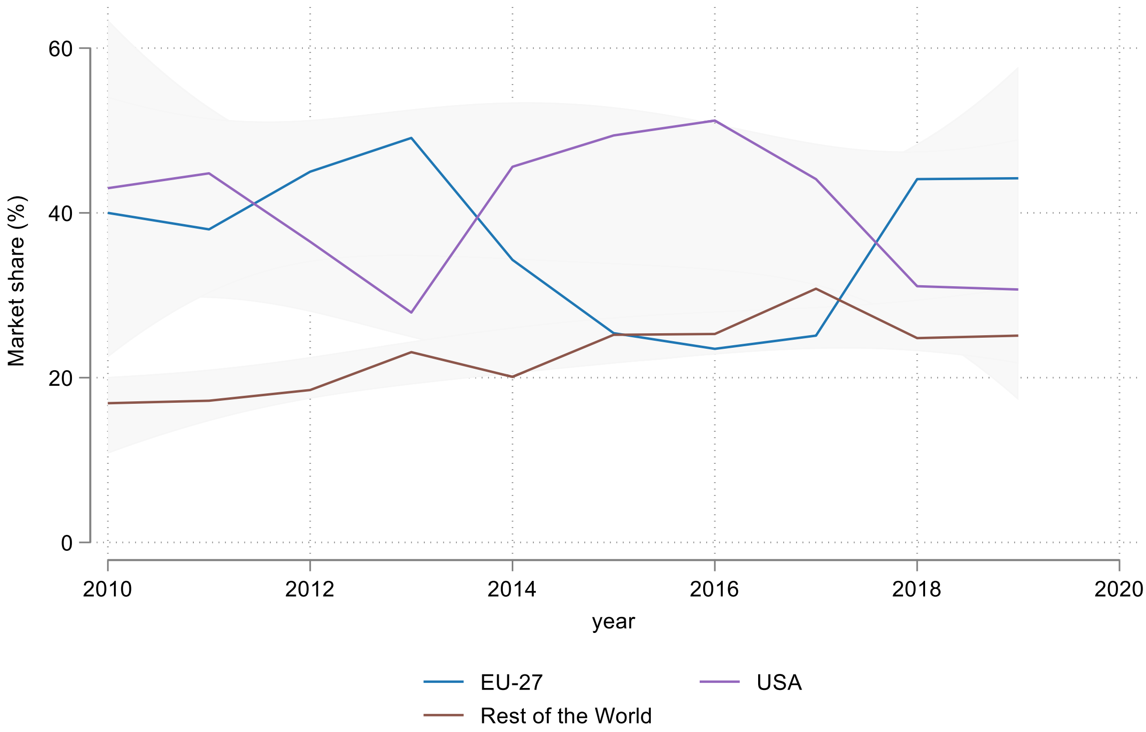
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

This figure shows that, starting roughly at the same level in 2010, the market share of the ROW increases steadily over the period while there is an alternation between the United States and the EU-27 as the world's largest purchaser of service robots for professional use. While the market share of the ROW increased from 27% in 2010 to 35% in 2019 – with a peak of 36% in 2017 – this group is composed of many countries with a varying number over the years, as new countries around the world have joined the automation race. However, within this group, the countries with the largest market shares are Canada, with an average market share over the period of 6%, and the UK, with a corresponding average market share of 5%. On the other hand, the US and the EU-27 dispute the market leader role in this industry, showing high volatility in their market shares.[23] At the beginning of the period, in 2010, the US had a market share of 40% while the corresponding share of the EU-27 was 34%. In the first part of the period under analysis, the EU-27 market share increases while that of the US declines and the leadership is reversed by 2013, where the EU-27 represents 45% of the industry, and the US only 29%. In the period 2013-2016 the trends are reversed and while the US market share increases to reach 44%, the market share of the EU-27 reaches its minimum over the period of 20%. The market share trends are inverted again over the period 2016-2019. In this case, the EU-27 market share increases to 39%, while that of the US declines to 27%. Collectively, the US and the EU-27 represent 65% of this industry in 2010 while their joint participation declines to 60% in 2019. These trends clearly indicate that the service robot

[23] Despite the attempts to link the cross-sectional information provided by IFR over time, we cannot rule out the possibility that the observed oscillations come from data quality issues.

industry, and in particular professional robots, is more diverse and less tangible than the industrial robot industry. These trends correspond to a young and growing industry with a rapidly developing technology in which most purchases would derive from the interest of potential users to test new technology in their operations. From a different perspective, Figure 4.8 shows the global market shares of professional service robots calculated by sales from 2010 to 2019.

Figure 4.8: Evolution of the global market shares of sales of robots for professional use, 2010-2019



Source: Table 4.8.

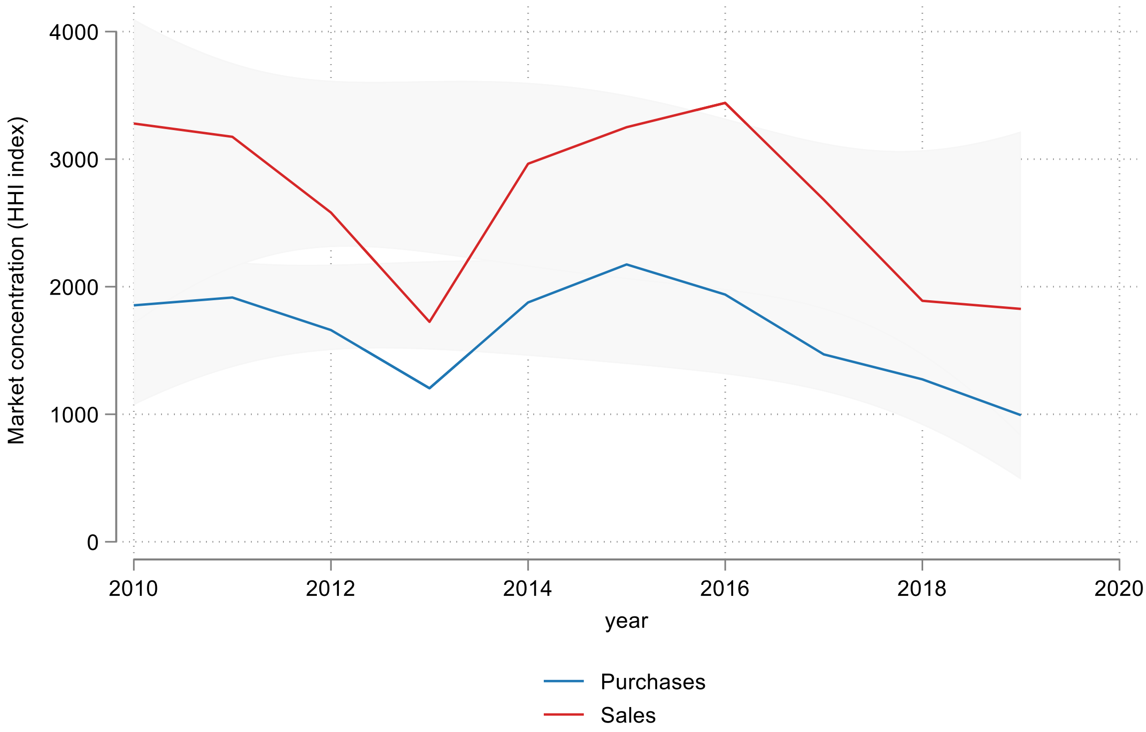
Table 4.8: Evolution of the global market shares of sales of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27	37.1	36.4	45.2	51.9	33.8	24.3	20.6	34.1	47.0	47.8
USA	54.1	53.5	46.6	35.1	52.2	55.2	57.0	49.1	38.7	37.7
Rest of the World	8.8	10.0	8.1	13.0	14.0	20.6	22.4	16.9	14.3	14.5

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

The figure shows an alternation between the United States and the EU-27 as the leaders in the market for professional service robots sales over the past ten years, while the ROW has been gradually increasing its market share. Collectively, the US and the EU-27 represented 83% of total professional robots sales in 2010 but this participation declined over the period to end at 75% in 2019. On the other hand, the ROW share moved from 9% in 2010 to 15% in 2019, with a peak at 22% in 2016. The evolution of the market shares calculated by sales for both the US and the EU-27 follows a similar evolution as that with purchases. According to the data calculated with the proposed methodology, both areas show an irregular trend, with ups and downs depending on the year, but with a clear downwards trend. As explained above, the professional service robot industry is developing quickly. Many start-up companies are created every year, developing innovative applications and improving existing concepts. Similarly, many of these companies disappear quickly, being acquired by incumbents or by companies from other industries that want to expand into service robotics. In addition, others just get out of the business completely because they fail to develop a marketable product or there is insufficient demand for the specific product. This is an emerging and dynamic industry with a rapidly developing technology, and this lack of maturity is evident from the sudden changes in the global market shares. So far, however, this industry has been dominated by the US and the EU-27. In order to summarise the information included in the previous figures, Figure 4.9 shows the evolution of the global market concentration of professional service robots from 2010 to 2019.

Figure 4.9: Evolution of the global market concentration of robots for professional use, 2010-2019



Source: Table 4.9.

Table 4.9: Evolution of the global market concentration of robots for professional use, 2010-2019

Variable	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purchases	1854	1915	1660	1204	1877	2175	1939	1470	1274	993
Sales	3280	3175	2581	1724	2964	3251	3441	2682	1889	1826

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

The figure shows that market concentration in the market for professional service robots has evolved cyclically, following the progression registered by market shares. In this case, sales concentration is higher than purchases concentration. This is consistent with the fact that in terms of sales, there are two dominant areas, the United States and the EU-27, while in the case of purchases we have noted the progression of the market share corresponding to the ROW, where some countries have been gaining market share over the years in the period under consideration. Despite the fluctuations, in the last decade the global market for professional service robot purchases remained competitive (i.e. HHI less than 1,500) with the exception of the year 2015 in which it was moderately concentrated (i.e. HHI of 1,500 to 2,500). On the other hand, over the same period the global market for professional service robots remained moderately concentrated (i.e. HHI of 1,500 to 2,500), with the exception of a couple of years.

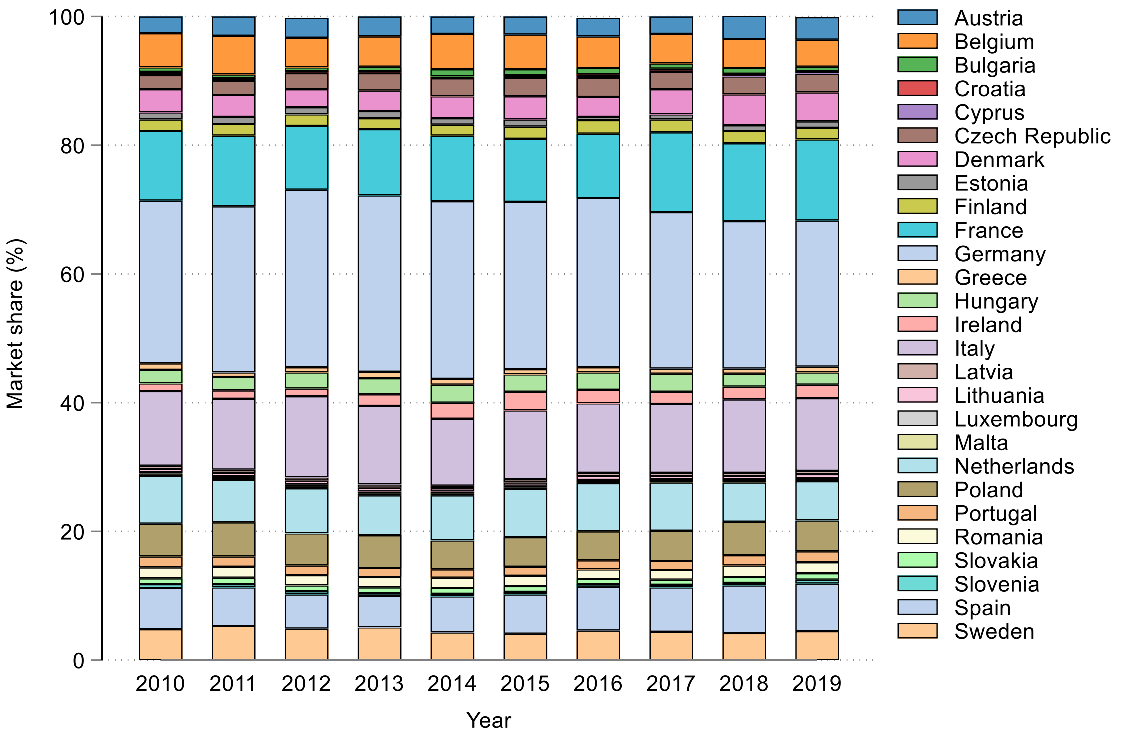
4.2.2 The EU-27 landscape

The previous section shows that the EU-27 is a relevant player in the global professional service robotics industry, alternating with the United States the largest market shares registered over the period 2010-2019. In this section, we will look at the structure of purchases and sales inside the EU-27 by looking in detail at the market shares of the different MS. Figure 4.10 shows the evolution of market shares of purchases of professional service robots of the EU-27 Member States from 2010 to 2019.

According to the data on purchases, several MS register a zero market share over the entire period. These countries are Cyprus, Malta, Croatia, Luxembourg and Slovenia. Other EU MS have very low numbers of purchases of industrial robots, which makes their market shares below 1% on average over the period. These MS are: Latvia, Malta, Croatia, Lithuania, Estonia, Bulgaria, Ireland, Greece and Slovenia. The rest of the MS are actively purchasing professional service robots. Figure 4.10 shows the evolution of the market shares of professional service robots purchases in the EU-27 in the period 2010-2019.

Figure and Table 4.10 indicates that the evolution of the structure of the market shares of purchases of service robots for professional use in the EU-27 was relatively stable in the period under study. The EU-27 MS representing the highest share of purchases of professional service robots over the entire period is Germany, with a participation of 35% in 2010 that went down to 24% in 2019 – still more than double the market share of the second largest EU-27 purchaser. Italy is the second largest EU-27 professional service robots purchaser, with a market share of 11% in 2010 that declines to 9% in 2019. The next MS in the ranking of purchases of professional service robots are the Netherlands, Denmark and Spain. These three countries have shares between 5% and 9% at the beginning of the sample. Over the period, the Netherlands and Spain increase their share from between 2 and 3 percentage points over the period. Denmark, on the other hand, significantly increases its share from 4% in 2010 to around 12% by 2019. From a group perspective, these six countries represented 67% of purchases of service robots for professional use in 2010 and 64% in 2019. In the group of remaining countries only Austria, Ireland and the Czech Republic manage to increase their market shares by around one percentage point each. Collectively, this group (which also includes Latvia, Lithuania, Bulgaria, Greece, Slovakia, Estonia, Portugal, Romania, Finland, Hungary, Sweden and Poland) moves from representing 32% of purchases of professional robots in 2010 to 34% in 2019.

Figure 4.10: Evolution of the EU-27 market shares of purchases of robots for professional use, 2010-2019



Source: Table A.VI.3 in Annex VI.

Table 4.10: Evolution of the EU-27 market shares of purchases of robots for professional use, 2010-2019

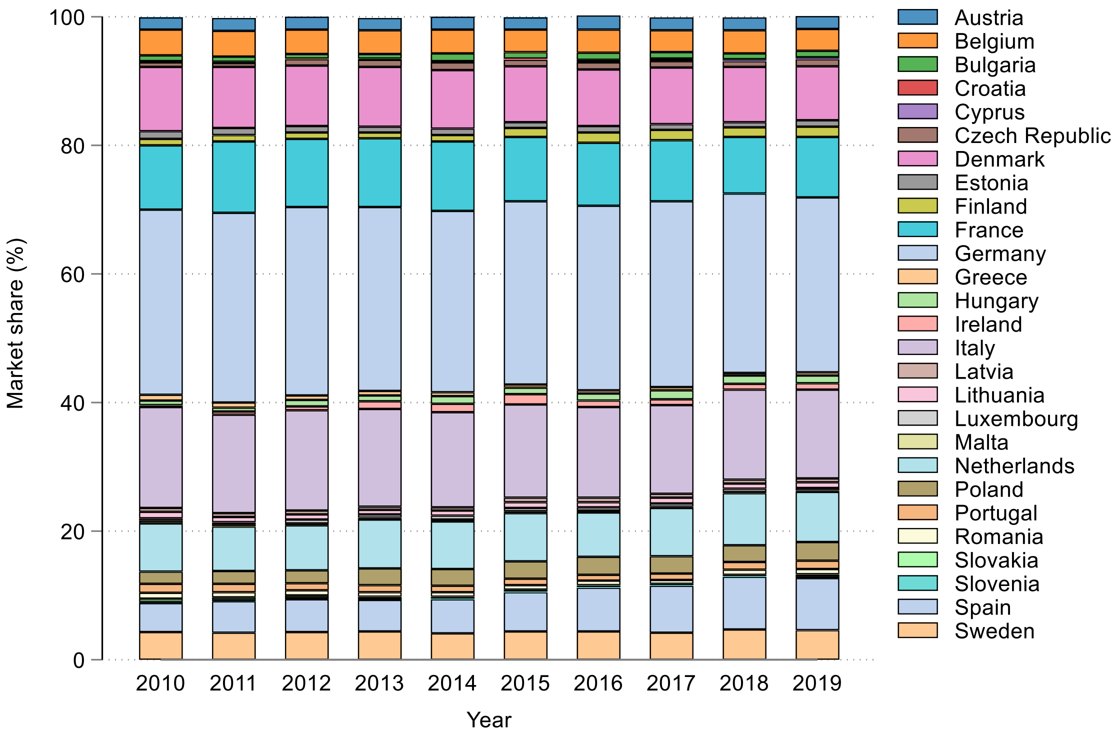
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Germany	35.1	25.4	30.1	27.0	20.4	23.8	30.3	23.5	21.4	23.5
Denmark	4.6	4.0	3.6	5.7	9.3	8.7	7.5	12.7	12.0	12.1
Netherlands	9.1	10.8	9.3	8.3	7.7	9.5	8.2	11.1	9.8	11.4
Spain	6.6	5.9	3.6	4.2	5.2	7.6	7.1	5.5	8.0	10.0
Italy	11.1	9.8	14.8	18.4	13.6	13.3	8.0	10.5	12.3	8.6
Rest of the EU-27	33.5	44.2	38.7	36.5	43.8	37.1	39.0	36.7	36.5	34.4

Source: Table A.VI.3 in Annex VI. [EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.]

In the period 2010-2019, as it can be seen in Figure and Table 4.11, Germany's market share in the sales of professional service robotic was the highest among EU-27 MS starting at 44% by 2010, which decreased until 2014 reaching a low of 29%. After that the share stabilises at around 32% until the end of the period in consideration. Italy is the second largest MS, with a market share of sales of professional service robots of 12% in 2010 that increased over the years until a maximum of 23% in 2013, and then decreased consistently over the years arriving at an 11% by 2019. On the other hand, the trend registered for the evolution of the market shares of Spain and Denmark, which host a growing robotics cluster,[24] is increasing over the period considered. Both countries start with a decrease in their market share until around 2013. After that, their market share consistently increases over time reaching levels of around 9% for both. Italy and the Netherlands are also emerging collaborative robotics clusters.[25] There is a group of followers that registered average market shares of between 1% and 5% over the period comprised by the Czech Republic, Estonia, Hungary, Portugal, Finland, Austria, Poland, Belgium and Sweden. Within this group, the most significant changes correspond to the increase of one percentage point in the market shares of Poland, Finland and Hungary, and the decrease of one percentage point in the participation of Belgium. However, overall this groups increases its collective share by 3 percentage points. On the contrary, the market share of the top 6 declined by two percentage points (from 77% in 2010 to 75% in 2019). The rest of the countries (Cyprus, Slovenia, Croatia, Malta, Slovakia, Luxembourg, Latvia, Greece, Romania, Lithuania, Ireland and Bulgaria) have only a marginal participation in this activity with average market shares below 1% but most close to zero. This is visualised in Figure 4.11.

[24] https://robotics-alliance.dk/wp-content/uploads/2019/12/The-Danish-Robotics-Cluster-in-a-Global-Perspective.-Dec2019.pdf
[25] https://clustercollaboration.eu/cluster-organisations/odense-robotics

Figure 4.11: Evolution of the EU-27 market shares of sales of robots for professional use, 2010-2019



Source: Table A.VI.4 in Annex VI.

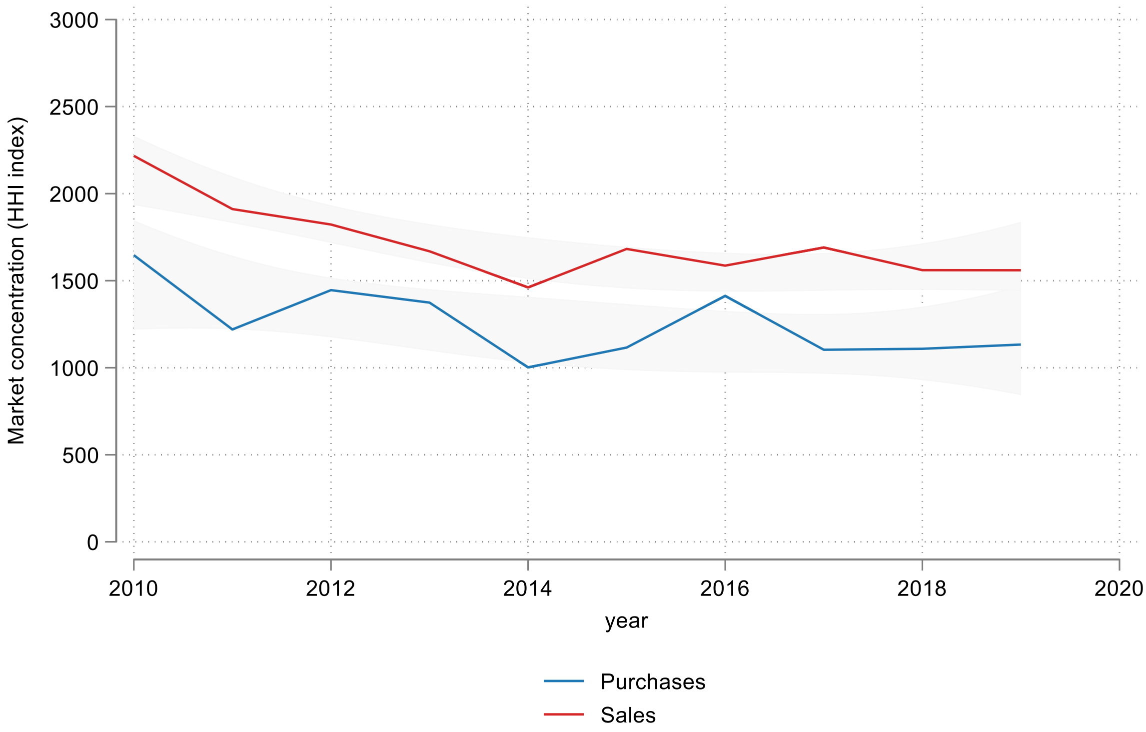
Table 4.11: Evolution of the EU-27 market shares of sales of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Germany	42.0	38.7	35.3	30.4	28.5	33.2	32.3	34.3	32.2	31.8
France	0.0	9.6	8.8	7.6	6.3	6.0	5.3	4.9	6.4	11.3
Italy	11.8	9.6	17.6	22.8	19.1	18.2	16.2	14.7	12.9	11.3
Spain	5.8	4.8	4.3	3.7	6.3	6.0	8.1	7.4	8.6	9.4
Denmark	3.7	2.9	2.6	4.5	7.9	7.3	9.3	10.1	10.1	9.0
Rest of the EU-27	36.7	34.4	31.3	31.1	31.9	29.3	28.9	28.6	29.7	27.3

Source: Table A.VI.4 in Annex VI. [EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.]

Figure 4.12, regarding market concentration of service robots for professional use, illustrates the EU-27 aggregated market share trends. As can be seen there, despite a slight increase in market concentration at the very beginning of the period, the main trends show a decreasing concentration in both purchases and sales. Once more, sales show a greater market concentration than purchases, which indicates that even if some MS cannot establish a capacity to produce and sell robots, trade allows them to purchase and use professional robots. Over the last decade, the EU-27 market for professional service robots remained competitive (i.e. HHI less than 1,500).

Figure 4.12: Evolution of the EU-27 market concentration of robots for professional use (units), 2010-2019



Source: Table 4.12.

Table 4.12: Evolution of the EU-27 market concentration of robots for professional use (units), 2010-2019

Variable	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Purchases	1647	1220	1446	1374	1002	1116	1413	1103	1109	1133
Sales	2217	1911	1823	1669	1461	1682	1587	1691	1561	1560

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

5 The robotics value chain

The previous two sections have offered a detailed description of the evolution of the global and EU-27 market shares in industrial and service robotics industries, respectively, in the past decade. However, in order to contextualise the main insights derived from the analysis, and link them with the main factors that would explain the observed changes, a conceptual framework is needed.[26] Despite the growing attention towards robotics in general and to the deployment of robots in particular, from both the research and policy perspectives, a framework to analyse the entire robotics global value chain is still missing.

Apart from developing a more comprehensive analytical framework – one looking at pre-production, production and post-production stages of the entire robotics value chain – another relevant element that would increase our understanding of the robotics industry is to look at the different types of robots. To date, most studies refer to industrial robots, while the information available for service robots is almost non-existent. However, the service robot segment is the most dynamic, innovative and the one that generates the greatest opportunities for value creation today. In this report, we provide for the first time detailed information about the evolution of the global and EU-27 service robotics industries.

While the previous sections have described the evolution of market shares in detail, in this section we offer a more detailed analysis of the factors that could be behind those trends. However, since a detailed analysis remains outside the scope of this report, we will limit the discussion to highlighting and discussing the factors that we consider to be the most relevant. Hopefully, future research will be able to tackle more of these issues.

5.1 A conceptual framework

Driven by the interest in understanding the impact on employment and productivity, research on robotics has traditionally focused on the installation of industrial robots.[27] However, installing a robot in a factory or deploying medical robots in a hospital require a long sequence of interrelated and synchronised activities, markets and industries sometimes located in different geographic areas. Since most of the literature on robotics has largely neglected the “robotics industry” and “economic geography” perspectives, in this report we aim to bridge this gap. In order to do so, we will rely on the global value chain concept in international and industrial economics to sketch a conceptual framework which we term the Robotics Value Chain (RVC).

As described in the specialised literature, a global value chain is a network of activities that economic actors engage in to bring a product to the market and, as such, not only involves production processes, but also pre-production (design, research and development) and post-production (marketing, distribution). The long-established literature on global value chains (for a review see Inomata, 2017), as well as recent studies that specifically analyse some specific dimensions of the RVC, constitute the basis for the analytical approach employed to study the evolution of robotics market shares. For example, Forge and Blackman (2010) report that large robot-using manufacturers usually have their own in-house robotics integration capabilities or robotics development facilities, and can buy robots directly from robot manufacturers or from specialised intermediaries, such as “integrator” companies that provide specific expertise to install and customise robots. Hence, already in 2010, intermediary robotics companies (system integrators) were becoming important players to bridge some gaps between robot producers and users. Leigh and Kraft (2018) distinguish between “suppliers”, or firms that develop, manufacture, and sell industrial robots, and “robot-using manufacturers”, or organisations that buy, install, and deploy robots throughout multiple production processes. In addition, Cséfalvay and Gkotsis (2020) suggest that the robotics value chain may be separated into three basic elements: (i) robotics developers, or organisations performing robotics technology research and development; (ii) robot manufacturers, i.e. firms whose primary activity is the production of robots; and (iii) robot users, i.e. firms that buy, install and deploy robots.

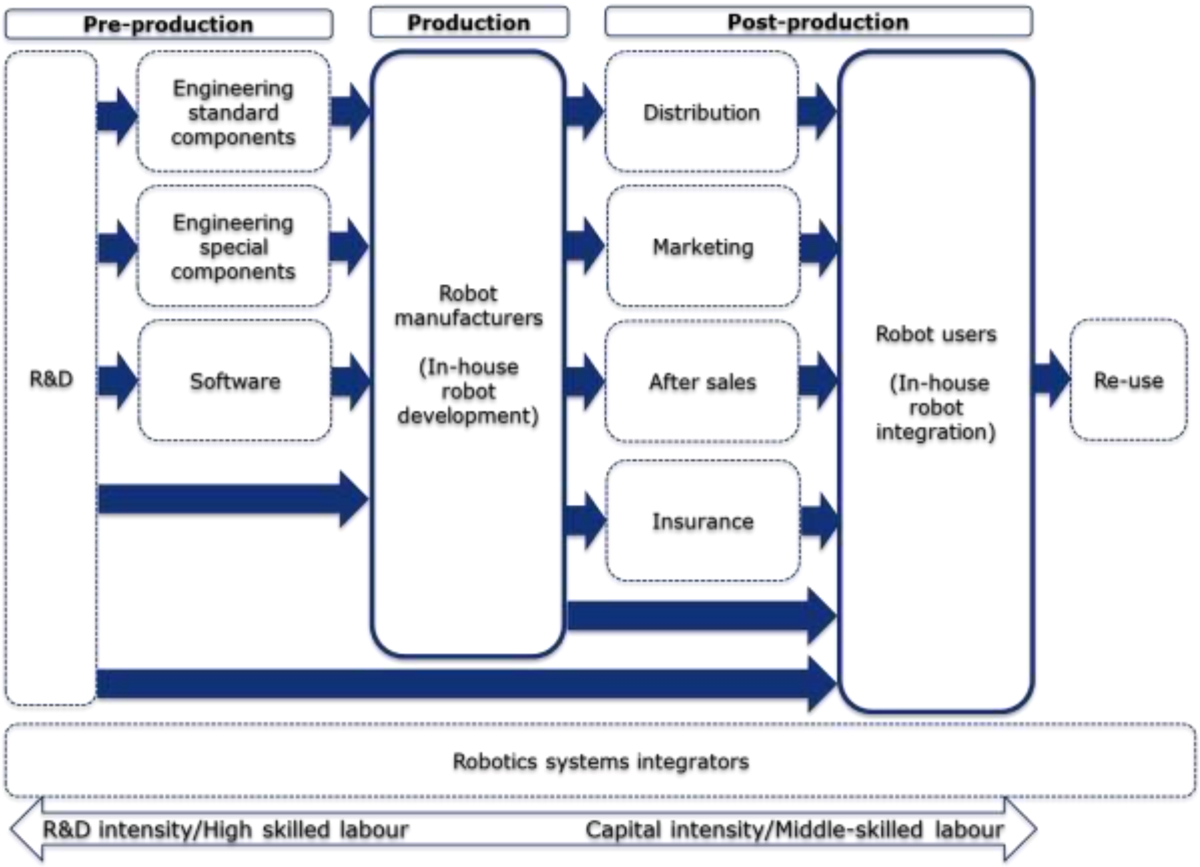
From the above-mentioned sources, an analytical model has been developed (shown in Figure 5.1). According to the diagram, the robotics value chain can be composed of three core stages:

- The pre-production stage aggregates the activities that precede robotics production and includes:
    - Research and development
    - Production of standard and specialised components

[26] While some attempts have been proposed already (see for instance Cséfalvay and Gkotsis, 2020), these remain partial and largely centred on industrial robotics.
[27] Behind this result lies the availability of data and the lack of information about other relevant aspects of the robotics industry.

- Software development
- The production stage, where the manufacture/assembly of robots takes place
- The post-production stage, including a series of complementary activities such as
    - Marketing, distribution, after-sales and insurance, among others
    - Robot deployment/use
    - Re-use

Figure 5.1: The Robotics Value Chain (RVC)



Source: own elaboration.

The figure shows a schematic representation of the main stages of the robotics value chain. These stages are indicative of the main tasks involved but are in no way exhaustive. For instance, as can be seen in the figure, the pre-production stage could be clearly separated into several sub-stages: R&D, engineering and software development. However, due to the existing technical and economic complementarities, we have grouped them together in order to keep the framework as simple as possible. Stages close to each other are assumed to have greater complementarities. Hence, pre-production is more complementary to production than to post-production. However, on some occasions – for instance in the case of vertically integrated firms – the same company could be involved in two or more stages if this is found to be more profitable than specialising in a single stage. Depending on the production technology of each stage, one may either observe very few competitors or a large number of operators. Similarly, depending on the maturity of the technology, a steady flow of new entrants will constantly challenge incumbents in less mature segments or, on the contrary, the market structure may be rather stable and imperfectly competitive in more mature segments. Finally, the pre-production stage is where robots are developed, which requires a high R&D intensity and also highly-skilled workers. On the other hand, the post-production stage is where robots are deployed (i.e., companies installing industrial robots to improve productive efficiency). Traditionally, this stage is composed of businesses requiring large amounts of investment to operate, and thus having a high percentage of fixed assets (such as property, plants, and/or equipment). In this case, medium-skilled workers would suffice to operate the robots. Finally, it is worth noting that firms participating in the different stages, and even companies operating in the same stage, can be located in different geographic areas, according to the relative technological and productive specialisations.

From an economic geography perspective, there may be large benefits for economic agents to locate close to each other. These "economies of agglomeration" emerge by the reduction in transaction, information and transportation costs due to proximity and the gains derived from a denser set of potential interactions in a given area allowing economic opportunities to emerge (Fujita and Thisse, 2013). However, one of the most significant effects of globalisation has been the creation of global value chains[28] distributed among several countries. Nowadays, an ever-increasing proportion of products are the result of assembled components produced in various facilities and countries around the world (OECD, 2016; World Bank, 2017; WTO, 2019). The most important tier of the chain is where added value is generated, not where the actual assembly takes place. However, the uneven geographic distribution of the major factors of production – labour, capital and technology – may have a direct impact on the way technology-oriented global value chains are organised.

In the specific case of the robotics value chain, two relevant issues have been highlighted as playing an important role in the general trends affecting its market and geographic concentration. First, there is a "robotics divide" (López Peláez, 2014). As with other – similar – technological divides, there are profound differences between those countries that have access to robotics and its underlying technologies, and those that do not. This may have economic, social, (geo)political and perhaps even military implications. Given the importance that artificial intelligence and other technologies are acquiring in robotics, in particular in the segment of service robots, the "AI divide" (Bughin et al., 2018) is likely to be relevant as well.[29] Second, geographic imbalances can also originate from industrial linkages or interdependencies across the different stages of the robotics value chain (Ross, 2016). Here, the issue is that countries that are only active in the deployment of robots, but not in the R&D or manufacturing stages, would be placed at the weakest nodes of the RVC, despite the benefits derived from increased automation in productivity and GDP growth.

The existent literature does not adequately explain why there is a significant propensity toward concentration in this industry. From an economic geography perspective, however, it is well known that when new sectors and technologies emerge, there is initially a high level of territorial concentration, which only gradually dissipates over time, resulting in regional convergence. Following the contributions from economic geography, the literature on global value chains acknowledges that the relative importance of different production and location factors varies significantly across production networks. This has a significant impact on the chain's geographic pattern (Kaplinsky, 2000; Kaplinsky and Morris, 2001; Humphrey and Schmitz, 2002; Henderson et al. 2002; Rhodes, Warren, and Carter (Eds.), 2005; Gereffi and Fernandez-Stark, 2016).

While R&D may be considered the most important aspect in the pre-production stage, its contribution falls dramatically in the production and post-production stages. Similarly, for pre-production and to a lesser extent for production, the availability of a highly-qualified and scientific workforce is critical, but post-production largely requires access to middle-skilled individuals capable of working with robots. On the other hand, capital intensity goes in the opposite direction, with post-production having the highest capital intensity and pre-production having the lowest, despite the latter's potentially high investment risk. From an economic standpoint, it is worth noting that robotics users typically deploy robots in conjunction with a larger manufacturing system (e.g. assembly lines, hardware and software support, equipment, and data management). As a result, the cost of purchasing and installing industrial robots is a minor part of the overall capital-intensive investment in a new automated production system (OECD, 2019).

Despite the lack of appropriate data, from the relevant literature, some conjectures about the geographical concentration of the different segments of the RVC can be formulated. First, given the specialised knowledge and experience necessary, pre-production stages may agglomerate in countries with abundant scientific resources and workforce, universities and research organisations, as well as specialised engineering suppliers and manufacturers. Furthermore, as with information technology, research from agglomeration economics

[28] Also known as multinational supply chains and/or value creation networks. See Porter (1985), Dicken (1998) and Rhodes, Warren and Carter (Eds.) (2005).

[29] According to Cséfalvay and Gkotsis (2020), the underlying factors causing the AI divide range from the general trend of increasing capital share in digital and highly automated industries since the turn of the century (Aghion, B. Jones, and C. Jones, 2017), to the unstable balance between innovation and regulation that tends to benefit early adopters and penalises followers (Aghion, Antonin, and Brunel, 2019), to other special factors such as the emergence of "superstar firms" (Autor et al., 2020).

suggests that when innovative regional clusters reach a certain scale and critical mass, they may become self-sustaining and self-reinforcing systems (Saxenian, 1996; Castells, 2000; Fujita and Mori, 2005; Glaeser, 2010; Fujita and Thisse, 2013). As a result, it is reasonable to assume that, in the case of the pre-production stage, the nations and areas with first-mover advantages today may evolve into robotics agglomerations with dominant positions over time.

Second, specific knowledge and advanced manufacturing skills, as well as market size, might both promote and explain territorial concentration in the production stage. Because firms in the automotive and electronics sectors deploy the bulk of global robotics stocks at the current technological level of robotics, nations specialising in these industries may also provide a suitable foundation and market scale for building robotics manufacturing firms. On the other hand, economies with a large service sector will provide ample opportunities for deployment of professional service robots, in an attempt to achieve cost reduction in order to remain competitive, while increasing efficiency and quality in the provision of services.

Third, in the post-production stage, factors such as labour costs, declining workforce due to ageing societies, industrial and employment structures, sectoral and trade specialisation, and countries' positions in both the business cycle and international division of labour interact to determine the geographical concentration of the robotics value chain. This issue has been extensively analysed in the literature concerned with the future of work, which basically compares the skills needed of existing human employment to the (future) talents of robots, based on what is technologically achievable today and what is expected to be possible in the future.[30] Similarly, some recent studies have shown that, as robot prices fall and wages rise, industrial robots are increasingly deployed in industries and countries where wages are high relative to robot prices, implying that these industries and countries benefit from a quick return on capital-intensive investments in robot-based automation. High labour costs may serve as a powerful incentive for firms to install industrial robots. However, the intensity of robot deployment in the majority of European nations is lower than projected, despite their high wages (Atkinson, 2018). Cséfalvay (2019), which further emphasises the strong relationship between high labour costs and extensive robot deployment, arguing that this link not only reflects, but also intensifies, Europe's economic and geographic inequities. Fernández-Macías, et al. (2020) used multivariate and econometric analysis to discover that, between 1995 and 2015, Europe's robot density grew more in industries and countries with higher wages than in sectors with higher routine and manual task content, and in economies with a higher risk of offshoring industrial production.

In addition to these stage-specific factors, there are others of a horizontal nature that can also help to explain the pattern of industrial and geographical concentration of the robotics value chain. A first factor relates to mergers and acquisitions, which may be part of the strategy of new tech companies – such as those in the market of service robots – that want to gain credibility, acquire relevant expertise or change the balance of power in the market in which they are operating. At the same time, the acquirer of a small robotics company may gain new product lines, additional facilities, expertise and intellectual property, as much as entering a new market. A second factor refers to foreign direct investment, with multinational enterprises in general making new technology available and providing access to new markets by improving the training and qualifications of the local workforce and increasing wages and employment. The extent of these positive outcomes depends also on the host country's absorptive capacity. Foreign direct investments entail more than just capital flowing from one country to another. The actual investment package contains new technologies, managerial skills and new markets, with additional support to bear higher risks and to increase profitable opportunities. Foreign direct investments are autonomous transactions of long-term capital movements, motivated by economic interests aiming to profit in the first place. Yet, from an economic point of view, it may be challenging to assign a clear origin to a final product/export in country B when a company from country A has opened a facility in country B to produce this product. A third factor contributing to the pattern of industrial and geographical concentration of the global RVC relates to government programmes in support of specific technologies or grants such as R&D subsidies, as well as taxes and regulation which can create incentives for new technology firms to enter a specific market and change its structure. As an example, tax incentives reduce the amount of tax that a company has to pay to the government, and may help small tech companies to cut their costs rendering an industry more profitable for them. Governments usually do this to induce businesses to create jobs or to invest more in their country. This has clear implications on the market structure for a given industry in a country or geographical area. Obviously, a mix of more of the abovementioned circumstances may have an even larger impact on the market structure. For example, a change in the marketplace due to external events such as new

[30] Some studies predict and assess workers' risks of being displaced by automation (Frey and Osborne, 2013; Chui, Manyika, and Miremadi, 2015; Arntz, Gregory, and Ziehran, 2016; Nedelkoska and Quintini, 2018; Lordan, 2018; Frey, 2019); others calculate that each robot installed in the United States replaces six people (Acemoglu and Restrepo, 2017), whereas each robot installed in Europe replaces between three and four workers (Chiacchio, Petropoulos, and Pichler, 2018).

laws and regulations may create a gap in a firm's critical offerings, which constitutes a major opportunity for a strategic merger. Clearly, in the context of the present analysis, these explanations can only appear as hypotheses, as the statistical investigation carried out in this study only allows us to observe trends and facts, whereas studying causal relationships requires data and econometric tools beyond those currently available.

Because the specific production and location requirements that emerge at various points along the RVC are not universal or easily replicated, countries with these production factors may be able to concentrate large shares of the market across the RVC. While these criteria may have some explanatory power, when it comes to individual nations, further research would be needed to determine the causality of the relationship between specific location factors and the countries' place in the RVC.

5.2 An economic geography perspective of the RVC

An increasing number of studies in the literature focus on a single stage of the robotics chain and pay special attention to the global concentration of the activities of that particular stage. Most studies looking at the pre-production stage focus on R&D, since information about engineering suppliers or specific robotics software is very hard to obtain. In this respect, Keisner et al. (2016), in a study of industrial robotics R&D, discovered that in 2015 ten countries (Japan, the USA, China, Korea, Canada, Germany, Italy, France, the UK and Switzerland) concentrated 80% of firms and institutes in the sector. Similarly, applicants from these nations submitted the great majority of robotics-related patents between 1960 and 2011. Similarly, Cséfalvay and Gkotsis (2020) show that Japan and Korea hold today about half of all global robotics-related patents, followed by the US and Europe. According to these authors, robotics R&D in Europe is also heavily concentrated in a small number of MS. Here, Germany, France and Sweden account for more than 80% of total European robotics patents. Examining global robotics patent activity between 2005 and 2019, Konaev and Abdulla (2021) find that the top four countries are China, accounting for nearly 35% of the global robotics patents over the entire period, Japan, South Korea and the US. Industrial robotics is the most popular category of robotics patent types, followed by medical robotics and transportation. Since the patent system specifically aims at encouraging the formation of new firms based on inventions, we can establish a direct link between start-ups and patents. The data collected for this project show that the top ten countries in terms of robotics start-ups represented 75% of the total in 2010 and an identical share in 2020. The list of countries is identical, with just one small difference, which is the entry of Spain and the exit of Denmark.

In terms of the analysis of the production stage, Leigh and Kraft (2018) point out that only 12 nations are represented among the 28 robot-supplier businesses that contribute data for the IFR. Furthermore, only four nations in the world have three or more industrial robotics manufacturing firms: Denmark and Switzerland each have three, while Germany and Japan each have six. Forge and Blackman (2010) also point out that just eight countries in Europe have large enterprises that specialise in designing and producing industrial robots (Germany, Switzerland, Sweden, Italy, France, the UK, the Netherlands and Austria). However, industrial robotics companies tend to be larger than those operating in the service robotics segment. However, there is lack of data about companies in this activity. The IFR statistics on service robots are taken from a sample that has been evolving over time and that focuses on sales. The IFR started surveying around 200 companies back in 2010 but the sample is currently close to 1,000 service robotics companies. Here again, the bulk of these companies come from countries traditionally involved in robotics in general, although in the last years, according to the data on start-ups, other countries have entered in this industry, albeit with a reduced number of firms. Given that the resources required in the pre-production stage are geographically concentrated and that the linkages between pre-production and production are strong, this stage also shows a high tendency to agglomerate. These linkages create competitive advantages that reinforce the advantageous positions of incumbent geographies.

As with the analysis of pre-production, the information available to study post-production is limited to the information about robot users. To the best of our knowledge, nothing has been written about post-production activities such as marketing, distribution, after sales and other complementary activities to robotics production. Robotics users also tend to be highly geographically concentrated. As Cséfalvay (2019) points out, the vast majority of industrial robots installed in 2015 were used in only five countries: Japan (18%), China (16%), the US (15%), Korea (13%) and Germany (11%). When all other EU-27 MS are added to Germany's share, the EU-27 represented 26% and the top five economies, including Europe, had a combined share of 88% of the world robot stock, demonstrating a huge difference between the few leaders and the rest of the world.

A relevant result in the literature, which is confirmed by the evidence presented here, is that a substantial territorial concentration appears to be the predominant feature at each step of the RVC, with only a few countries dominating the landscape. Most of these studies, however, do not include an analysis of the complete

RVC or of the interplay between different components of the chain. Given the complexity and dynamism of the RVC, particularly when it refers to service robotics, this tendency is not necessarily applicable with the same intensity in all stages of the chain, it does not have the same strength for different segments of the robotics industry, and nor is it likely to be permanent in the long-run.

5.3 The global and EU-27 landscapes revisited

In this section we try to match the results presented in Sections 3 and 4, with the conceptual framework sketched in the previous two sub-sections. The aim is to identify those geographies that have leading positions in the different segments of the robotics industry. As explained above, a leader position would correspond to a situation in which a given country or geographic area has advanced positions in the two stages of the RVC that we can observe with our data: production and use. In what follows, we will cluster the different geographic areas in three groups, depending on the average value of their purchases and sales shares over the period under analysis. These three groups are: (i) high, when the market shares are well above the mean; (ii) medium, when the shares are located around the mean; and (iii) low, which corresponds to a situation in which the corresponding market share is very low or non-existent, for instance if the country does not participate in a specific stage of the RVC. A leader position would thus correspond to a situation in which the country ranks high in both stages. A follower position is defined by the confluence of two medium positions. Those countries or geographic areas that show low values on both stages will be considered as the fringe group.

Table 5.1 presents the results of this exercise. In this case, the EU-27 is the only leader, having above-average market shares in the two RVC stages. Korea, the United States and the United Kingdom would be considered as followers, showing mean values in both stages. China and Japan, on the other hand, show asymmetric behaviour and shared leaderships in different stages with the EU-27. While China is a leader in post-production (installations) but a follower in production (sales), Japan is a leader in production but a follower in post-production. Finally, despite the fact that some countries are entering, sometimes successfully, in the automation and robotisation race, their participations are yet too small to be considered followers. In this case, while many countries are entering the RVC in the post-production stage (i.e., installations of industrial robots), very few have been able to successfully develop a sustainable position in the production stage.

Things are a different when looking at service robots in general, and service robots for personal use in particular. This category of robots is consumer-oriented and the same rules of industrial robotics do not apply. Here, as explained before, disposable income along with preferences over technology and cultural issues regarding household chores would be the most relevant factors to explain purchases. On the other hand, incumbency advantage, brand reputation and technology would explain sales. In this case, as discussed above in Section 4, and summarised in table 5.2, the US is the sole leader of this segment, having marked advantages over all the other countries/areas in this category of robots. The EU-27 and China are followers, while all the other countries would be placed in the fringe group.

Table 5.1: Clusters of countries based on their relative participation in the industrial robotics industry

		Purchases		
		High	Medium	Low
Sales	High	EU-27	Japan	
	Medium	China	Korea, USA, UK	
	Low			Rest of the World

Source: Own elaboration.

Table 5.2: Clusters of countries based on their relative participation in the personal robotics industry

		Purchases		
		High	Medium	Low
Sales	High	USA		
	Medium		EU-27, China	
	Low			Rest of the World

Source: Own elaboration.

Turning the attention to service robots for professional use, as discussed in Section 4 of this report, both the US and the EU-27 have a leadership position. They have been alternating the top purchaser/seller for the entire decade. As followers in the professional robots segment of the RVC we find the UK and Canada. The rest of the countries would be again in the fringe group.

Table 5.3: Clusters of countries based on their relative participation in the professional robotics industry

		Purchases		
		High	Medium	Low
Sales	High	USA, EU-27		
	Medium		UK, Canada	
	Low			Rest of the World

Source: Own elaboration.

A similar exercise can be performed with the EU-27 MS's market shares of industrial robot purchases and sales. The results are presented in Table 5.4 using the average market shares over the period under study as the reference variable. From the results, three big clusters emerge. The first one, comprised of Germany, Italy, France, Spain and the Netherlands, represents the countries heavily involved in both purchasing and selling robots. Given their combined weight in both purchases and sales (77% and 74%, respectively), they constitute the leaders of the EU-27 industrial robotics industry. A second group of countries, where we find Slovakia, Romania, Portugal, Belgium, Hungary and Finland, are followers and present intermediate values of market shares for purchases and sales. Finally, those countries that are not active at all in industrial robotics, or have a share that is close to zero, constitute the third or fringe group. This fringe is composed by Cyprus, Luxembourg, Malta, Latvia, Lithuania, Croatia, Greece, Ireland, Estonia and Bulgaria. Several countries do not follow this symmetric distribution and can somehow represent special cases. For instance, Sweden, Austria and Denmark can be considered over all the period as high sellers, but their level of purchases is intermediate. On the contrary, the Czech Republic and Poland have been purchasing intensively industrial robots over the period, but they only sell moderate amounts. The last case is Slovenia, which managed to sell an intermediate amount of industrial robots, while belonging to the fringe group in terms of purchases.

Despite the differences in terms of technology and market structure, a similar clustering can be obtained when using the results for service robots in the categories of both personal and professional as shown in tables 5.5. and 5.6. As a conclusion, the group of countries that constitutes the basis for the leadership role of the EU-27 in the global landscape is comprised of Germany, Italy, France, the Netherlands and Spain.

Table 5.4: Clusters of EU-27 MS based on their relative participation in the industrial robotics industry

		Purchases: High	Purchases: Medium	Purchases: Low
Sales	High	DE, IT, FR, ES, NL	SE, AT, DK	
Sales	Medium	CZ, PL	SK, RO, PT, BE, HU, FI	SI
Sales	Low			CY, LU, MT, LV, LT, HR, GR, IE, EE, BG

Source: Own elaboration.

Table 5.5: Clusters of EU-27 MS based on their relative participation in the personal robotics industry

		Purchases: High	Purchases: Medium	Purchases: Low
Sales	High	DE, IT, FR, ES, NL, DK		
Sales	Medium		SE, PL, AT	
Sales	Low		CZ, RO, HU, BE	FI, LV, IE, MT, LU, LT, GR, PT, SI, BU, EE, HR, SK, CY

Source: Own elaboration.

Table 5.6: Clusters of EU-27 MS based on their relative participation in the professional robotics industry

		Purchases: High	Purchases: Medium	Purchases: Low
Sales	High	DE, IT, FR, NL, ES	DK	
Sales	Medium		SE, BE, PL	
Sales	Low		AT, CZ, HU, IE	FI, LV, MT, LU, LT, GR, PT, SI, BU, EE, HR, SK, CY, RO

Source: Own elaboration.

6 Conclusions

This report proceeds along three main dimensions. First, departing from previous work that identified the main sources of statistical information about robotics, as well as the main challenges in working with these data, we have built a dataset including the market shares of robots. A methodology was designed and applied to compute the market shares of different types of robots (industrial, service robots for personal and professional uses) over the course of a decade (2010-2020). Second, the evolution of the market shares has been detailed by giving an in-depth account of the most significant changes in the relative participation of different economies in the robotics industry. The analysis covers not only the global landscape, but also the main changes registered within the EU-27 in the same period. Third, in order to contextualise the insights from the previous two tasks, a conceptual framework was developed to provide a more structured and informed analysis of the recent trends in these activities. This conceptual framework, which we have termed the Robotics Value Chain (RVC), should serve to identify relevant areas of the robotics industry where knowledge and data are limited, and to understand the industrial organisation of the robotics industry and its main segments.

By combining different sources of statistical information, it was possible to reconstruct the necessary data to compute the EU market shares of robotics. Working with incomplete data sets requires the use of imputation techniques, as well as assumptions regarding the behaviour of some segments of the industry. Unavoidably, this introduces some uncertainty about the results. However, the final indicators are in line with the main trends identified in the literature on the robotics industry. Nonetheless, the usefulness of these data and associated methodology to enlarge our knowledge of the robotics industry will have to be assessed by confrontation with the evolving reality, as well new case studies and market reports which may use more specific and targeted data as they become available.

For the second issue, this report provides a detailed description of the evolution of the market shares from different perspectives. First, we look at the global and EU-27 landscape. Second, we analyse market shares using data on purchases and sales, so we can compare two different stages of the RVC. Third, by applying the designed methodology, we can look at the market shares of industrial robots and two categories of service robots (for personal and professional use). The latter results are a relative novelty in the literature since little has been written about this particular segment of the industry. After taking all possible precautions with respect to the representativeness of the data produced, we are confident that our results provide insight on the main trends with respect to the relative participation of different countries in these two segments of the robotics market.

Overall results show that regarding industrial robots, the purchases market is concentrated in China, which showed a particularly intense increase from 2010 until 2017 (from 12% of the market share up to 38%), followed by the EU-27, which dropped its share from 23% in 2010 to 14% in 2020. The sales market, even though it shows a significant increase in the Chinese participation in the market (from 1% to 17% by the end of the period), is still dominated by Japan and the EU-27 (holding 35% and 32% of the market respectively in 2020). As for the European landscape, main results from purchases and sales show a dominance of Germany as the top country in the industry, but a significant decrease of its share over the years. This trend also applies for service robots (both for personal and professional use). Italy, Spain and France followed in the purchases market, while from the sales perspective, Italy and Denmark showed significant increases in their shares.

When considering the service robots, the United States dominates both the purchases and sales market of service robots for personal use. When compared to the market shares of Japan and the EU-27, China's behaviour has been erratic up until 2017, but all have roughly similar market shares by the end of the period. The EU-27 shows a significant drop both for the purchases and sales markets after 2017, going from shares of around 15% and 12% respectively, to almost 8% by 2019. This market is again lead by Germany, which also shows a significant decrease on the share after 2017, followed by Spain, France, Denmark, the Netherlands and Italy with a steady share over the time period.

As for service robots for professional use, market leadership is disputed between the US and the EU-27 (with high volatility in the purchases market). The Rest of the World category exhibits a significant increase in the share over the years, led by Canada for the purchases market, which holds 6% of the total and followed by the UK. When looking specifically at the European landscape, Germany is again leading, followed not closely by Italy and France.

The main conclusions from the data relate to the concentration of robotics activities in a handful of economies. Despite the entry of new participants in this activity, which happens mostly on the demand side accounting for only modest reductions in market concentration over the period, the bulk of robotics resources are concentrated in a small number of regions. The EU-27 is one of them. It holds leadership positions in industrial and professional service robots, while it can be considered to be a follower in the segment of service robots for personal use.

After a careful consideration of the main trends from the analysis of the market shares, along with the conceptual framework developed, four significant patterns emerge from the data:

- A small group of countries, representing an exceptionally high concentration across the whole robotics value chain, dominate the markets for automation and robotisation processes. This happens at the global scale and can be seen within the EU-27 as well.
- Among the leading countries, the magnitude and scope of each economy's participation in the robotics value chain varies greatly, and no single country shows equally strong positions in all the different segments of the aggregated robotics industry. Within the EU-27, however, the same core group of countries leads all three segments of the European robotics industry.
- Some small developed economies, although relatively less involved in the robotics industry, have succeeded in specialising in specific stages of the robotics value chain. This is mostly happening in the service robotics segments and seems to be a mostly European phenomenon. (e.g., Poland for service robots for personal use).
- Despite the strong concentration in all robotics segments, latecomers can enter the robotics value chain, mostly at the post-production stage (i.e., robot deployment). However, working their way up the robotics value chain and entering the production or pre-production stages is a more complex issue.

These trends describe the current state of the global industrial organisation of the robotics industry, or robotics value chain (RVC) as we have called it. However, due to the emerging relevance of service robotics and its more decentralised organisational structure, the existing market structure may be altered, perhaps dramatically, in the coming years.

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Annex I Methodology: Industrial robots

To proceed with the methodology for industrial robots, the starting point is the following identity:

$$I_{c,t} = D_{c,t} + \sum_{c=1}^{W} M_{c,t} - \sum_{c=1}^{W} X_{c,t} \quad \text{(I.1)}$$

Where,

$I_{c,t}$ is the number of newly installed industrial robots in country *c* in year *t*,

$D_{c,t}$ is the number of industrial robots purchased from domestic sources that are installed in country *c* in year *t*,

$\sum_{c=1}^{W} M_{c,t}$ is the sum of imported industrial robot units by country *c* in year *t* from all countries of the world (*c*=*1*,...*W*),

$\sum_{c=1}^{W} X_{c,t}$ is the number of exported industrial robots units by country c in year t to all countries of the world (*c*=*1*,...*W*).

This identity assumes that all robots produced are installed, which means that there is no inventory.

Installed industrial robots from domestic suppliers

As we have available data on the number of installations (I, provided by IFR) and the imported and exported units of robots (M and X, from Comtrade), the only unknown in equation 1 can be easily found by:

$$D_{c,t} = I_{c,t} + \sum_{c=1}^{W} X_{c,t,r} - \sum_{c=1}^{W} M_{c,t} \quad \text{(I.2)}$$

Total sales of robots by country and year

Total sales (S) of industrial robots in country *c* in year *t* can then be calculated by summing the number of installed robots purchased from domestic suppliers (D) and the exports of industrial robots to each partner country (X). This can be represented by the following equation:

$$S_{c,t} = D_{c,t} + \sum_{c=1}^{W} X_{c,t} \quad \text{(I.3)}$$

In this equation we assume that all robots that are exported from country *c* are produced in country *c*.[31]

[31] This assumption may not hold in the case of re-exports, i.e. when countries export imported goods. However, due to the limited availability of data on re-exports in the Comtrade database we cannot control for this possibility.

Annex II Methodology: Service robots

To proceed with the methodology for service robots, the first step is to disaggregate to the country level the data provided by the IFR at the continent level. For that purpose, the information provided by Dealroom about the number of robotics companies operating in each country is used, along with the following disaggregation equation:

$$\hat{S}^{i}_{c,t} = s^{i}_{c,t} * \mathrm{SR}^{i}_{C,t} \quad \text{(II.1)}$$

Where,

$\hat{S}^{i}_{c,t}$ is the estimated volume of sales of service robots of type *i* (*i*=personal, professional) in country *c* in year *t*,

$s^{i}_{c,t}$ is the share of service robot companies of type *i* in country *c* in year *t*,

$\mathrm{SR}^{i}_{C,t}$ is the volume of sales of service robots of type *i* in continent *C* (C=Europe, Americas, Asia/Australia) in year *t*.

This formula gives the sales of service robots by country and year. By summing over the EU-27 and also over all the countries to obtain the world total, the calculation of the market shares of sales is straightforward.

To proceed to the calculation of purchases of service robots by country and year, the first thing is to separate the sales that go to the domestic market from the sales that go to foreign markets (i.e., exports) in each country and year. Since there is no data available from either the IFR or Comtrade, information from the UNIDO Industrial Demand-Supply Balance Database about domestic production and exports has been used to calculate the following equation:

$$\hat{S}^{i}_{c,t} = \widehat{D}^{i}_{c,t} + \hat{X}^{i}_{c,t} \quad \text{(II.2)}$$

Where

$\widehat{D}^{i}_{c,t}$ is the estimated volume of service robots of type *i* sold in the domestic market in country c in year t,

$\hat{X}^{i}_{c,t}$ is the estimated volume of exported service robots of type *i* by country *c* in year *t* to all countries of the world (*c*=*1*,...*W*),

In this case $\widehat{D}^{i}_{c,t} = \alpha^{i}_{c,t}\hat{S}^{i}_{c,t}$ and $\hat{X}^{i}_{c,t} = (1 - \alpha^{i}_{c,t})\hat{S}^{i}_{c,t}$, where $\alpha^{i}_{c,t}$ is the proportion of domestic sales of service robot type *i*, calculated as the (weighted) average of the information obtained from the ISIC sectors chosen – as explained in the main text – to approximate both service robots for personal use and professional use. The next step is to disaggregate the total volume of exports into the origin-destination pairs using Comtrade data:

$$\hat{X}^{i}_{c,d,t} = \sum_{c=1}^{W} \chi^{i}_{c,d,t} \quad \text{(II.3)}$$

Finally, total service robots purchases of type *i* in country *c* in time *t* can be calculated by the sum of service robots type *i* purchases originating in country *c* domestic market in time *t*, plus the imports of service robots type *i* of destination country *c* from origin country *d* in time *t*:

$$P^{i}_{c,t} = \widehat{D}^{i}_{c,t} + \sum_{c=1}^{W} M^{i}_{c,d,t} \quad \text{(II.4)}$$

Annex III Indicators

Market shares

Market shares are the main objective of this report. They can be calculated for the two main variables (*V*=purchases and sales), for different types of robots (*i*=industrial, service for personal use and service for professional use), and for different geographic areas (*c*=EU-27, USA, China and other relevant countries in these industries), based on the dataset built for the purpose as explained in the methodology section and in annexes I and II. The market share of country *c* for the robotics type *i* in year *t* can be defined as:

$$\mathrm{MS}^{i}_{c,t,V} = V^{i}_{c,t} \,/\, \sum_{\mathrm{c}=1}^{W} V^{i}_{c,t} \qquad \text{(III.1)}$$

Where,

$\mathrm{MS}^{i}_{c,t,V}$ is the market share of robot type *i* in country *c* in year *t* calculated with variable *V*,

$V^{i}_{c,t}$ is the number of robots of type *i* in country *c* in year *t* calculated with variable *V*,

$\sum_{\mathrm{c}=1}^{W} V^{i}_{c,t}$ is the number of robots of type *i* for all the countries in the world (i.e. countries *c=1,...W*) in year *t*, calculated with variable *V*.

Market concentration

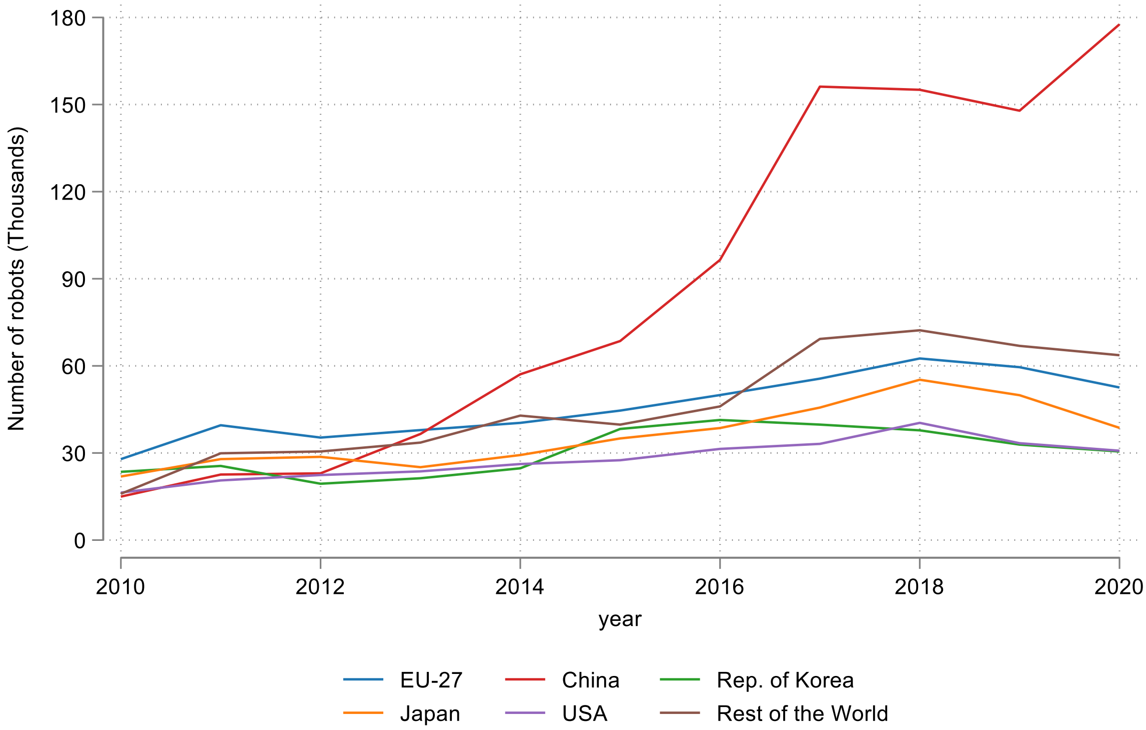
The Hirschman-Herfindahl Index, known also by its acronym HHI, (Herfindahl 1950; Hirschman 1964) is the selected market concentration measure used in this report. This indicator is widely used in empirical industrial economics studies (Scherer and Ross, 1990). It is a versatile indicator that can provide useful information to study competition and market structure (Hannah and Kay, 1977; Clarke et al., 1984; Tirole, 1988), and can also be used to analyse economic diversity (Tauer, 1992) or macroeconomic or trade specialisation (Storper et al., 2002).

The HHI for year *t* is defined as the sum of the squares of the market shares (*s*) of all the countries (*c=1,...W*) for the robot type *i* and variable *V*. The formula is as follows:

$$HHI^{i}_{t,V} = \sum_{c=1}^{W} s_c^2 \qquad \text{(III.2)}$$

Annex IV Support material for industrial robots

Figure A.IV.1: Evolution of the global volumes of industrial robots purchases, 2010-2020.



Source: Table A.IV.1.

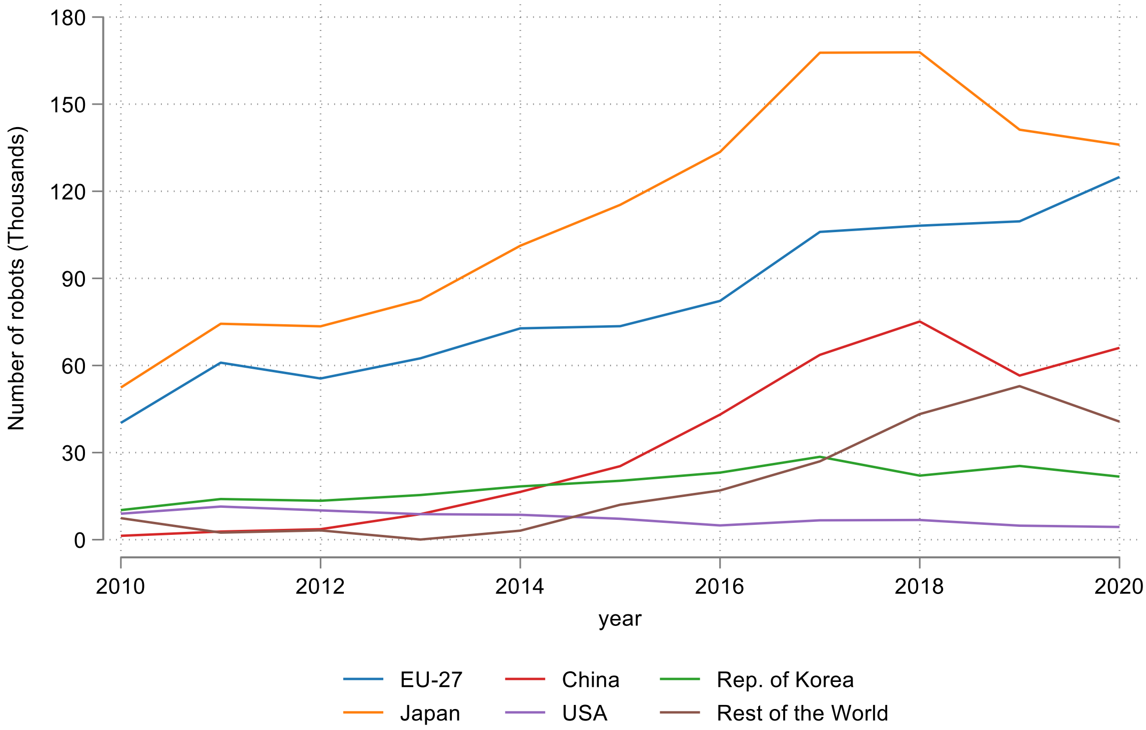
Table A.IV.7: Evolution of the global volumes* of industrial robots purchases, 2010-2020.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	15.0	22.6	23.0	36.6	57.1	68.6	96.5	156.2	155.1	147.9	177.6
EU-27	27.9	39.6	35.3	37.9	40.4	44.6	50.0	55.6	62.6	59.5	52.6
Japan	21.9	27.9	28.7	25.1	29.3	35.0	38.6	45.6	55.2	49.9	38.7
Rep. of Korea	23.5	25.5	19.4	21.3	24.7	38.3	41.4	39.8	37.8	32.9	30.5
USA	16.4	20.6	22.4	23.7	26.2	27.5	31.4	33.1	40.4	33.4	30.8
Rest of the World	16.0	29.9	30.5	33.6	42.9	39.8	46.0	69.3	72.3	66.9	63.7

* In thousand units

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.IV.2: Evolution of the global volumes of industrial robots sales, 2010-2020.



Source: Table A.IV.2.

Table A.IV.2: Evolution of the global volumes* of industrial robots sales, 2010-2020.

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
China	1.3	2.8	3.6	8.8	16.5	25.3	43.1	63.7	75.2	56.5	66.1
EU-27	40.2	61.0	55.5	62.5	72.8	73.5	82.2	106.0	108.1	109.6	124.9
Japan	52.4	74.4	73.5	82.6	101.2	115.3	133.5	167.7	167.9	141.2	136.0
Rep. of Korea	10.2	14.0	13.4	15.4	18.4	20.3	23.1	28.6	22.1	25.4	21.7
USA	9.0	11.4	10.1	8.8	8.6	7.2	4.9	6.7	6.8	4.8	4.4
Rest of the World	7.4	2.4	3.2	0.1	3.1	12.0	17.0	27.0	43.3	52.9	40.7

* In thousand units

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.IV.3: Evolution of the EU-27 volumes* of industrial robots purchases, 2010-2020

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	496	628	835	720	898	987	1686	1641	1504	1475	1229
Belgium	451	737	1077	1518	484	491	871	1154	1035	1058	836
Bulgaria	13	15	37	27	0	0	0	0	0	0	0
Croatia	1	16	16	14	0	0	0	0	0	0	0
Cyprus	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	402	1618	1040	1337	1533	2193	1974	2893	2725	2622	1975
Denmark	373	436	503	477	608	628	752	800	673	772	690
Estonia	4	11	4	15	0	0	0	0	0	0	0
Finland	270	297	330	365	286	333	699	476	532	533	430
France	2049	3058	2956	2161	2944	3045	4232	5014	5829	6711	5368
Germany	14061	19533	17528	18297	20051	19945	20074	21267	26723	22298	22354
Greece	44	9	31	43	0	0	0	0	0	0	0
Hungary	202	961	974	555	534	517	717	2470	912	926	1116
Ireland	41	48	63	83	0	0	0	0	0	0	0
Italy	4517	5091	4402	4701	6215	6657	6465	7760	9847	11067	8525
Latvia	0	0	4	4	0	0	0	0	0	0	0
Lithuania	3	17	1	5	0	0	0	0	0	0	0
Luxembourg	0	0	0	0	0	0	0	0	0	0	0
Malta	0	0	5	1	0	0	0	0	0	0	0
Netherlands	508	1015	810	895	1234	1487	1778	1814	1658	1785	1746
Poland	569	686	725	692	1267	1795	1632	1891	2651	2633	2147
Portugal	251	212	276	262	342	425	993	824	696	862	592
Romania	70	469	153	171	251	350	784	634	495	552	377
Slovakia	832	415	174	1313	343	488	1732	1203	749	636	462
Slovenia	149	187	345	267	0	0	0	0	0	0	0
Spain	1897	3091	2005	2764	2312	3766	3919	4250	5266	3992	3387
Sweden	682	1016	1016	1199	1073	1501	1647	1517	1263	1623	1323
EU-27 total	27885	39566	35310	37886	40375	44608	49955	55608	62558	59545	52557

* In units of robots.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.IV.4: Evolution of the EU-27 volumes* of industrial robots sales, 2010-2020

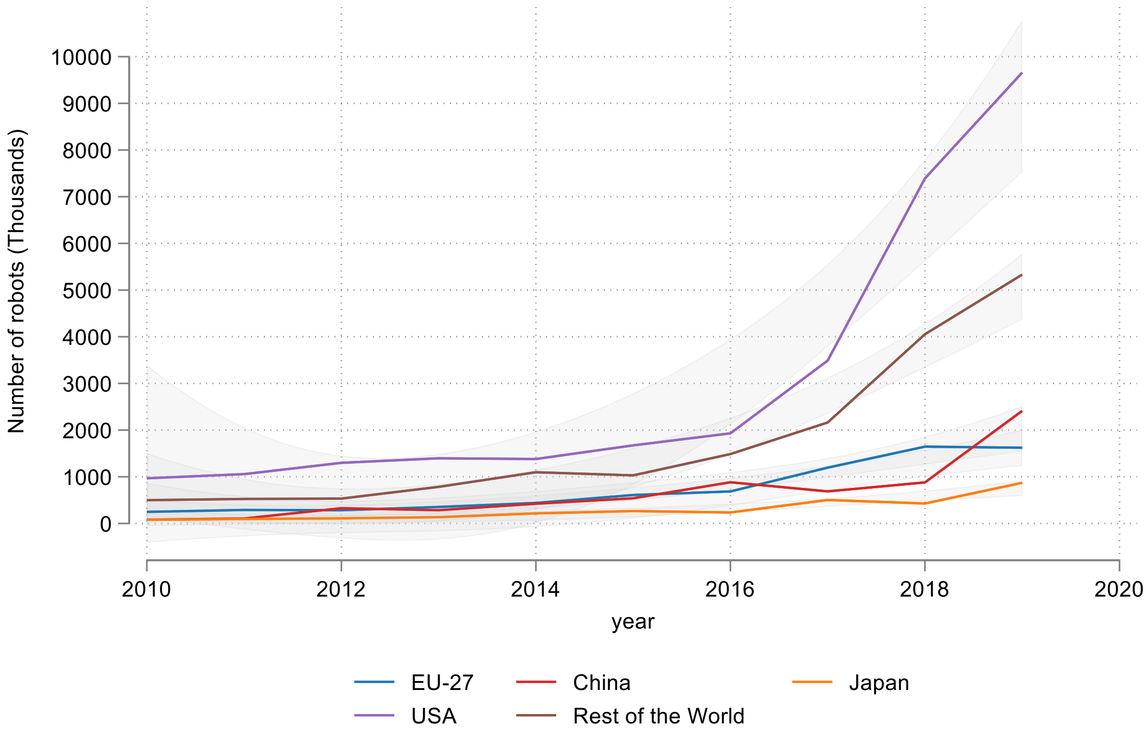
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	2599	4145	4065	4688	5399	5527	5894	7187	7094	7561	7474
Belgium	383	600	613	824	958	955	1140	1689	2301	2902	3382
Bulgaria	19	27	21	24	30	49	94	146	209	173	285
Croatia	4	10	9	8	26	71	154	375	498	677	510
Cyprus	0	0	0	0	0	0	0	0	0	0	0
Czech Republic	268	331	292	272	396	408	382	452	299	208	553
Denmark	632	968	919	1025	1962	2805	4453	8060	10303	10779	13922
Estonia	7	11	13	15	18	16	15	43	58	101	90
Finland	756	993	916	1009	1246	1503	1566	2054	1776	1723	1795
France	4448	6238	5604	5865	7916	9076	10683	15304	14124	14517	15080
Germany	18722	28693	25593	28337	30140	27907	29955	35804	35514	33864	40023
Greece	7	0	0	0	0	7	5	6	5	4	1
Hungary	746	1007	748	604	481	497	499	658	732	493	955
Ireland	10	16	55	110	141	175	125	71	77	77	82
Italy	4681	7617	7646	10000	12574	13152	14626	18558	20124	21971	24436
Latvia	2	2	2	1	2	2	3	3	2	2	1
Lithuania	14	26	22	23	30	27	35	58	70	58	115
Luxembourg	0	0	0	0	0	0	0	0	0	0	0
Malta	0	1	0	0	0	1	25	34	41	6	19
Netherlands	802	1176	1006	1192	1660	2104	2735	4056	4521	4478	4730
Poland	35	59	58	81	102	106	118	161	235	307	428
Portugal	242	288	175	193	255	270	375	385	392	319	504
Romania	176	282	224	204	202	173	168	234	251	225	274
Slovakia	140	298	224	242	438	334	358	489	205	233	420
Slovenia	31	45	51	56	72	83	88	158	336	275	821
Spain	1288	2005	1919	1910	2441	2287	2617	3430	2946	2774	2692
Sweden	4227	6137	5350	5797	6308	6013	6125	6601	6031	5914	6315
EU-27 total	40239	60975	55525	62480	72797	73548	82238	106016	108144	109641	124907

* In units of robots.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Annex V Support material for personal robots

Figure A.V.1: Evolution of the global volumes of purchases of robots for personal use, 2010-2019



Source: Table A.V.1.

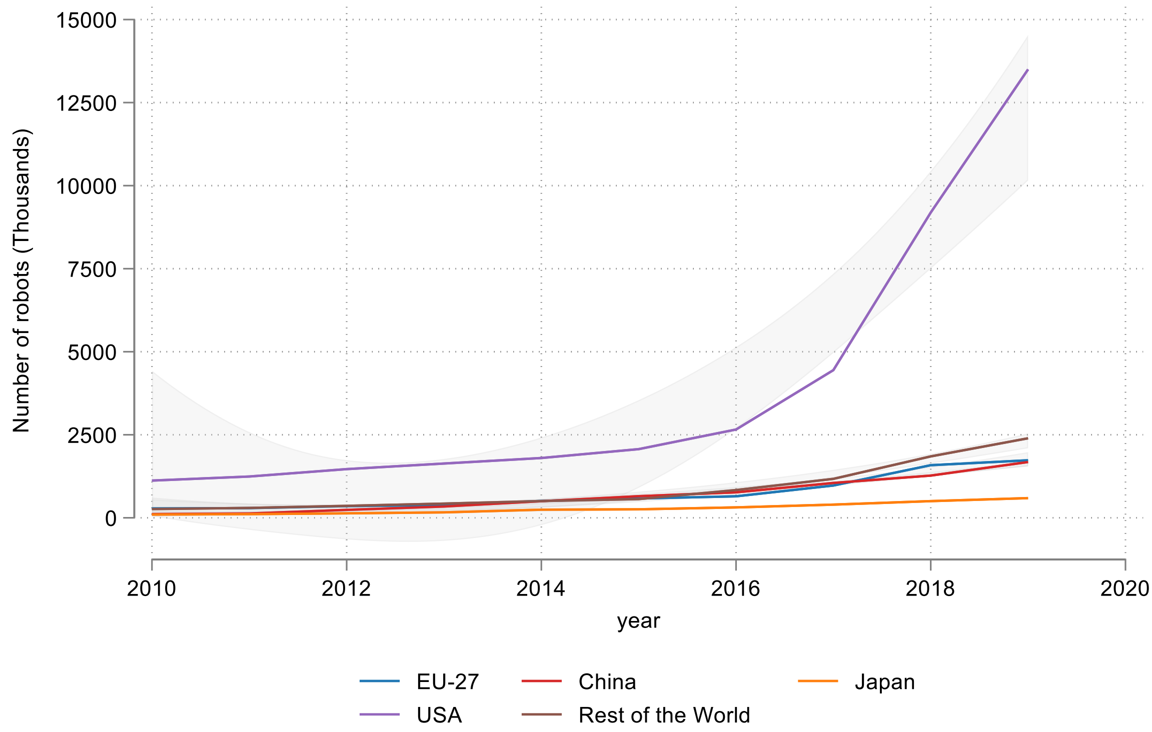
Table A.V.1: Evolution of the global volumes* of purchases of robots for personal use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
China	82.1	106.9	327.4	284.5	423.3	540.1	883.3	687.9	879.5	2413.0
EU-27	248.7	290.6	284.3	353.9	440.5	610.3	686.9	1196.2	1646.3	1623.4
Japan	79.3	96.4	110.0	136.0	217.4	266.0	236.5	504.1	428.0	871.9
USA	968.6	1058.2	1299.6	1397.0	1381.5	1673.8	1931.1	3489.8	7392.2	9660.0
Rest of the World	499.7	525.6	533.3	784.9	1097.7	1030.9	1488.1	2163.2	4054.0	5331.7

* In thousand units.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.V.2: Evolution of the global volumes of sales of robots for personal use, 2010-2019



Source: Table A.V.2.

Table A.V.2: Evolution of the global volumes of sales of robots for personal use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
China	111.8	131.1	239.6	341.3	500.3	650.8	767.3	1050.7	1272.1	1679.7
EU-27	282.4	292.9	352.2	385.9	508.8	581.9	647.7	973.7	1584.6	1732.1
Japan	97.9	111.5	135.2	165.4	244.9	256.0	314.0	397.4	502.6	592.9
USA	1121.6	1244.1	1466.9	1635.3	1801.3	2068.4	2659.8	4446.0	9190.8	13500.0
Rest of the World	264.8	298.2	360.7	428.2	505.0	564.0	837.1	1173.3	1849.9	2395.3

* In thousand units.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.V.3: Evolution of the EU-27 volumes* of purchases of robots for personal use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	5090	19709	6176	4032	6275	4987	33224	44420	68659	23793
Belgium		18944	15863	2573	2968	7758	40668	25719	36014	115519
Bulgaria			2245				3102	4139	16040	6563
Croatia			1021	1601	2832		2542			
Cyprus	238	561	226	480				497		
Czech Republic	3032	2371	5936	5723	49257	6820	6892	8203	12365	11896
Denmark	26434	24067	34826	30292	60062	41193	50940	87256	101411	120719
Estonia	664				4980	4063			11094	
Finland	3101	9873	2797	9773	17957	2485	3333	8877	9533	45489
France	43728	15966	18610	24358	28224	82436	36502	164216	75901	111810
Germany	75685	90171	71988	79103	100119	203687	110540	408098	274710	272752
Greece		4495	2932	3047		3230			8986	12569
Hungary	3024	2393	2469	3234	3587	19574	3671	45925	78527	13706
Ireland			4111	6152	6638	7058	17998	10780	14564	53684
Italy	26813	27111	32105	31274	46382	47867	97640	70507	227323	123701
Latvia	3250	4740	5934	4704	5461	9239	9333	13158	20293	29753
Lithuania	776	3251			7666	2454	3312	4603	6927	22701
Luxembourg		1401	4294	4106	3198	2467	3154	5419	11447	13203
Malta	3764	3408	4038	3149	3920	3507	3671	5479	7630	9090
Netherlands	18604	14303	14653	65656	28266	32044	128530	52334	362055	93307
Poland	6528	2156	2853	7865	12515	18526	50213	22895	29887	133828
Portugal						6079			6651	51527
Romania	3170	2841	9594	13969	3133	13351	3265	27673	51460	10965
Slovakia						6807				6695
Slovenia				2768	5094		4161	4934	9649	12347
Spain	18754	18477	32165	38060	21832	64141	47117	108651	105947	203670
Sweden	6094	24383	9460	12000	20101	20508	27082	72380	99209	124099
EU-27 total	75685	90171	71988	79103	100119	203687	128530	408098	362055	272752

* In units of robots.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.V.4: Evolution of the EU-27 volumes* of sales of robots for personal use, 2010-2019

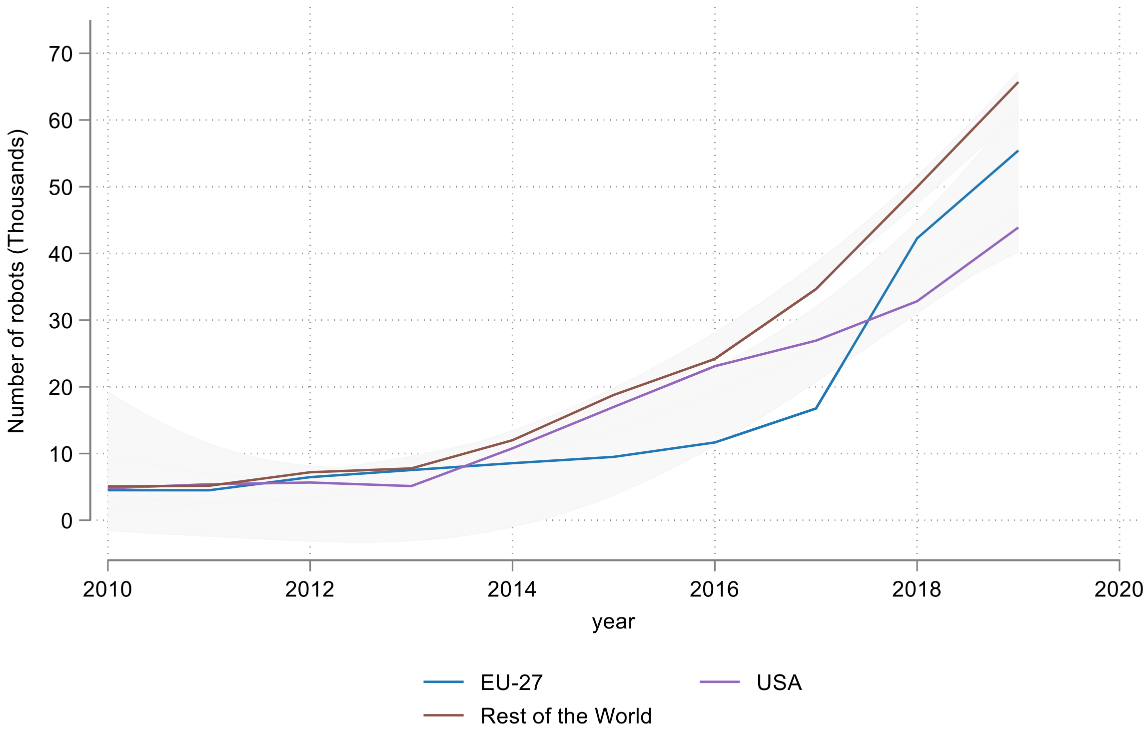
Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	7666	7118	7473	7345	8596	8796	12926	17976	26417	35146
Belgium			3714	3683	4306	13194	17204	30007	44014	43931
Bulgaria							4276	5951	8897	8782
Croatia										
Cyprus										
Czech Republic	3032	2371	5936	5723	5712	6820	6892	8203	12365	11896
Denmark	26434	24067	34826	30292	42622	41193	50940	70395	101411	120719
Estonia										
Finland	3833	3553	3690	3590	4266	4356	4281	11957	17326	17573
France	19154	21270	25930	32893	38462	39417	55967	77407	113540	158136
Germany	107346	113984	125969	138254	173354	191316	202436	308597	497170	509792
Greece										
Hungary	3831	3570	3717	3688	4312	4401	4278	12037	17557	17574
Ireland				7372	8620	8795	8646	12045	17536	17567
Italy	42135	41791	51609	50663	71738	78673	81835	119142	208718	211059
Latvia	3833	7215	7469	7375	8653	13205	12927	17970	26475	35146
Lithuania					4325	4400	4279	5952	8900	8790
Luxembourg			3722	3690	4328	4404	4280	5954	8904	8786
Malta	3832	3579	3717	3673	4267	4368	4278	5948	8864	8787
Netherlands	22993	21440	22297	25706	43161	44024	47334	77957	131935	131796
Poland		3572	3717	11038	17295	22013	21573	30018	43994	61511
Portugal									8890	17576
Romania	3832	3584	3699	3692	4302	4404	4280	5950	17571	17572
Slovakia										8787
Slovenia										
Spain	26818	28613	29819	28890	34567	57306	64639	96144	167358	175717
Sweden	7664	7193	14890	18318	25963	30779	34414	54087	96804	105430
EU-27 total	107346	113984	125969	138254	173354	191316	202436	308597	497170	509792

* In units of robots.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Annex VI Support material for professional robots

Figure A.VI.1: Evolution of the global volumes of purchases of robots for professional use, 2010-2019



Source: Table A.VI.1.

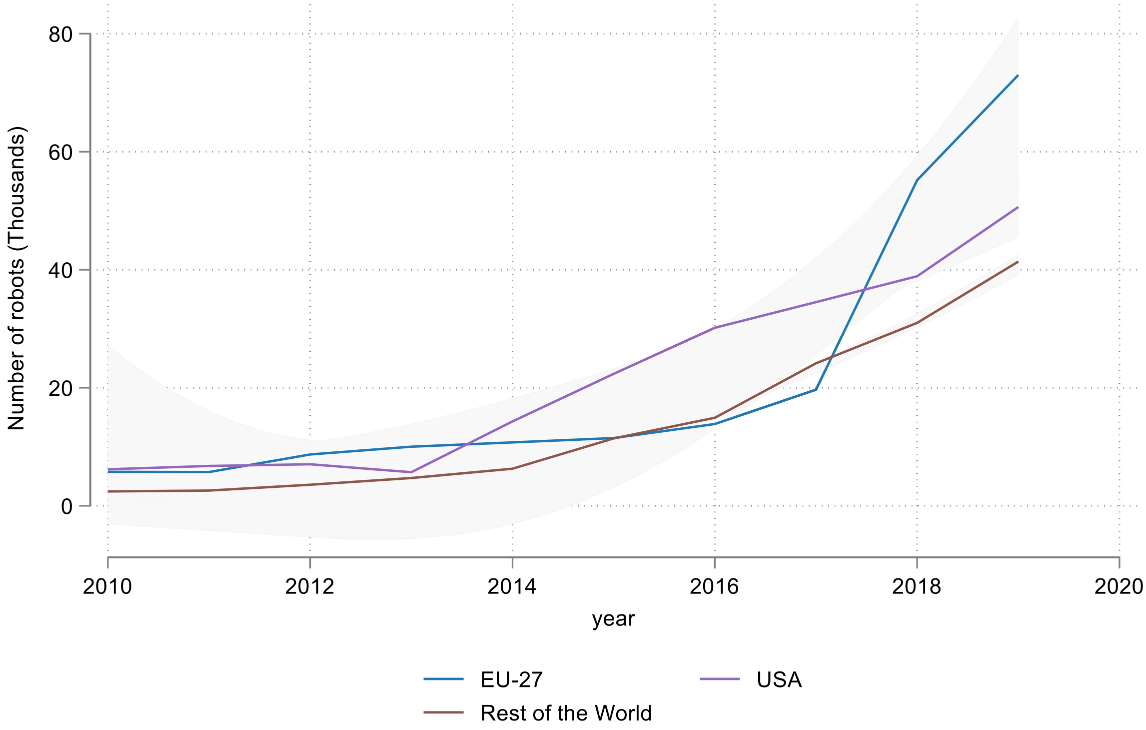
Table A.VI.1: Evolution of the global volumes* of purchases of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27	3.5	3.9	5.6	6.7	7.3	7.6	12.0	38.7	39.2	48.4
USA	4.2	4.8	5.3	4.3	10.4	16.7	19.4	45.0	29.6	33.7
Rest of the World	2.8	2.9	3.4	3.8	7.7	13.3	15.2	46.2	24.3	43.3

* In thousand units.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VI.2: Evolution of the global volumes of sales of robots for professional use, 2010-2019



Source: Table A.VI.2.

Table A.VI.2: Evolution of the global volumes of sales of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
EU-27	3.9	4.2	6.4	7.7	8.6	9.1	9.6	44.3	43.8	59.9
USA	5.7	6.2	6.6	5.2	13.2	20.8	26.6	63.8	36.0	47.3
Rest of the World	0.9	1.2	1.2	1.9	3.6	7.7	10.5	21.9	13.3	18.1

* In thousand units.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VI.3: Evolution of the EU-27 volumes* of purchases of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	119	135	203	237	227	268	344	457	1503	1932
Belgium	240	272	294	357	468	518	574	778	1898	2321
Bulgaria	33	26	41	52	93	86	116	136	371	409
Croatia	12	11	16	18	19	22	37	51	131	165
Cyprus	8	7	9	9	9	17	25	39	49	75
Czech Republic	98	100	160	200	239	280	347	451	1201	1587
Denmark	162	153	178	238	290	342	360	661	2018	2519
Estonia	50	49	73	84	84	103	55	139	364	558
Finland	80	81	116	131	142	176	248	336	785	997
France	489	496	639	776	877	933	1167	2078	5123	6999
Germany	1140	1160	1786	2066	2360	2468	3069	4074	9681	12570
Greece	44	33	53	72	80	79	93	128	343	515
Hungary	94	93	163	185	239	256	314	466	831	1058
Ireland	54	60	78	134	217	273	250	316	848	1149
Italy	525	495	812	916	891	1018	1266	1793	4826	6273
Latvia	23	23	34	36	38	51	61	76	207	293
Lithuania	21	22	36	43	46	52	70	89	221	310
Luxembourg	11	12	19	23	27	32	37	55	140	171
Malta	17	14	20	24	23	16	19	28	72	89
Netherlands	333	299	455	463	598	714	875	1249	2587	3386
Poland	231	237	324	384	389	440	527	790	2193	2679
Portugal	78	70	95	106	113	129	158	228	696	925
Romania	76	78	106	119	133	153	178	250	749	959
Slovakia	41	43	61	71	77	83	98	128	365	556
Slovenia	25	21	30	31	36	36	48	70	174	350
Spain	289	270	343	369	479	576	796	1154	3128	4078
Sweden	217	238	316	383	365	385	537	740	1767	2505
EU-27 total	4510	4498	6460	7527	8559	9506	11669	16760	42271	55428

* In units of robots.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VI.4: Evolution of the EU-27 volumes* of sales of robots for professional use, 2010-2019

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Austria	109	114	176	188	219	222	308	403	1105	1437
Belgium	230	229	329	375	399	400	497	673	2002	2475
Bulgaria	53	46	65	71	126	118	150	194	518	710
Croatia	10	9	12	17	18	15	34	45	128	160
Cyprus	1	1	1	3	4	17	24	45	28	41
Czech Republic	40	37	84	108	124	116	151	197	514	794
Denmark	577	543	821	934	982	1000	1216	1736	4738	6145
Estonia	68	63	85	94	109	101	132	177	446	715
Finland	60	58	86	92	105	156	227	320	840	1197
France	575	635	922	1074	1158	1145	1364	1871	4858	6879
Germany	1660	1690	2549	2865	3032	3273	3972	5685	15381	19843
Greece	51	44	63	70	66	62	66	93	246	389
Hungary	39	37	88	95	128	120	151	274	703	873
Ireland	16	29	49	120	138	179	132	175	513	711
Italy	907	878	1357	1519	1593	1665	1957	2713	7715	10072
Latvia	37	34	49	55	51	85	94	121	315	469
Lithuania	56	47	67	75	88	102	111	171	447	632
Luxembourg	25	20	50	49	62	60	67	100	250	307
Malta	25	22	29	33	32	30	36	45	128	161
Netherlands	433	396	608	763	800	857	959	1469	4475	5674
Poland	111	117	176	260	276	314	383	529	1423	2084
Portugal	78	73	100	108	105	114	131	191	649	945
Romania	52	47	68	74	70	84	92	121	447	559
Slovakia	27	22	32	34	34	31	36	47	125	237
Slovenia	12	10	16	16	16	14	16	22	63	234
Spain	262	282	447	493	572	700	944	1441	4536	5911
Sweden	247	243	372	439	441	510	612	827	2589	3347
EU-27 total	5761	5726	8701	10024	10748	11490	13862	19685	55182	73001

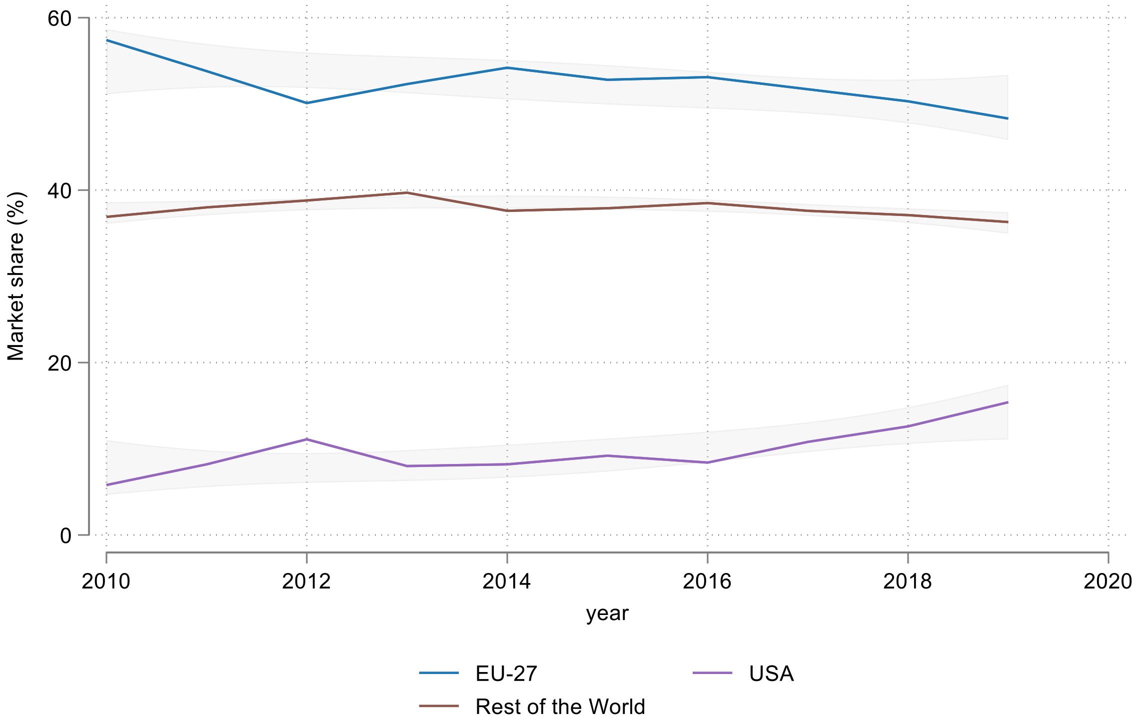
* In units of robots.

Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Annex VII Support material for sub-categories of professional robots[32]

Field robotics - Global landscape

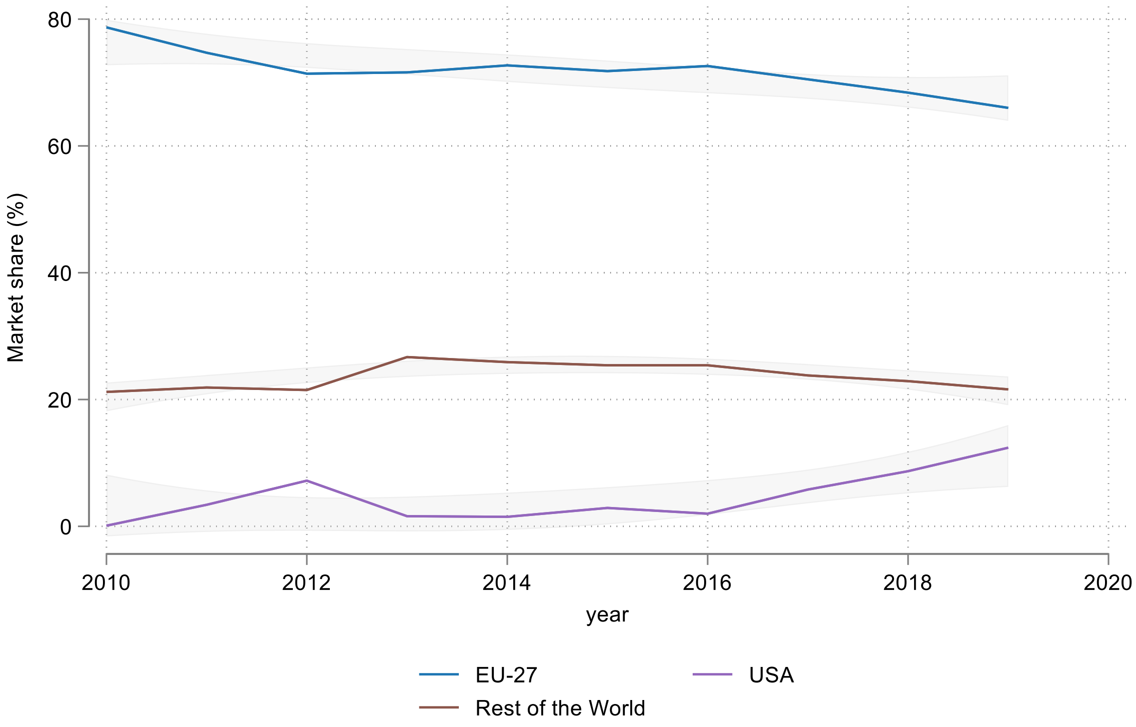
Figure A.VII.1: Evolution of the global market shares of field robots purchases, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

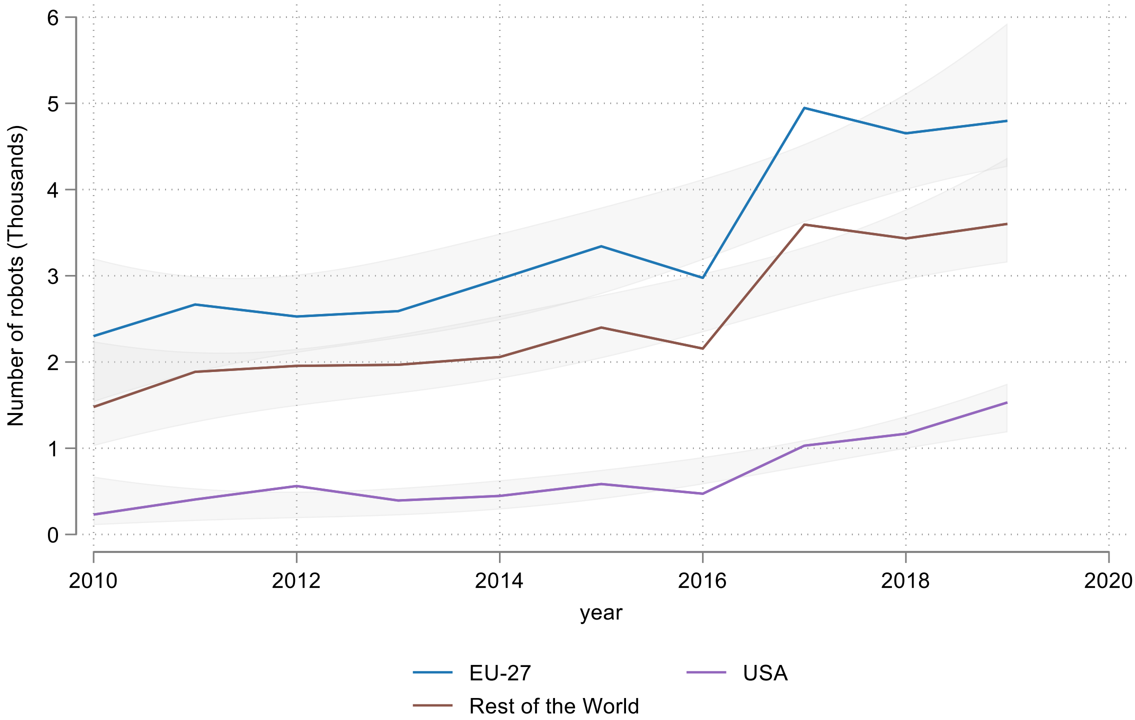
[32] These sub-categories are those for which the IFR provides disaggregated geographic data.

Figure A.VII.2: Evolution of the global market shares of field robots sales, 2010-2019



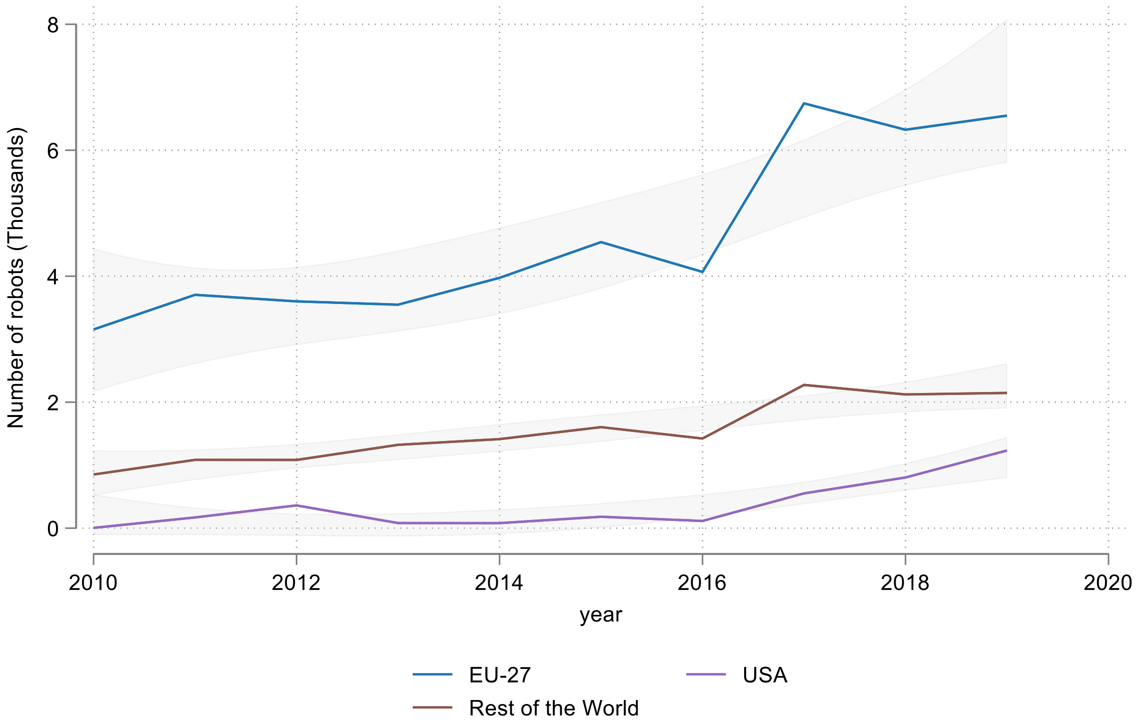
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.3: Evolution of the global volumes of field robots purchases, 2010-2019



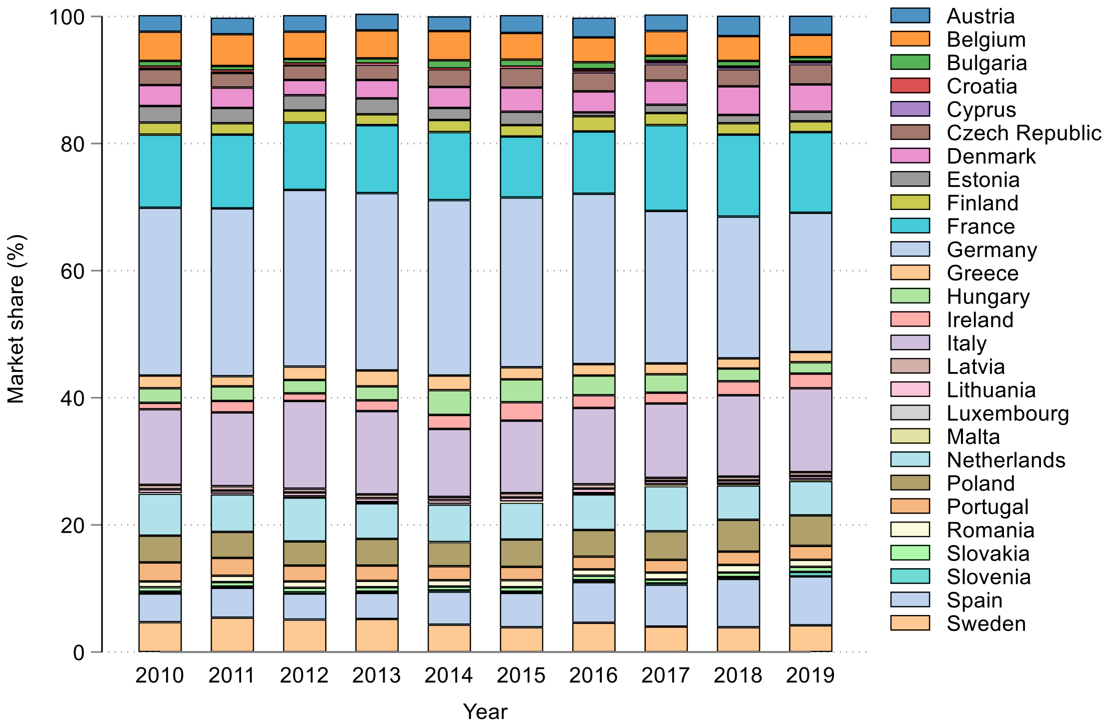
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.4: Evolution of the global volumes of field robots sales, 2010-2019



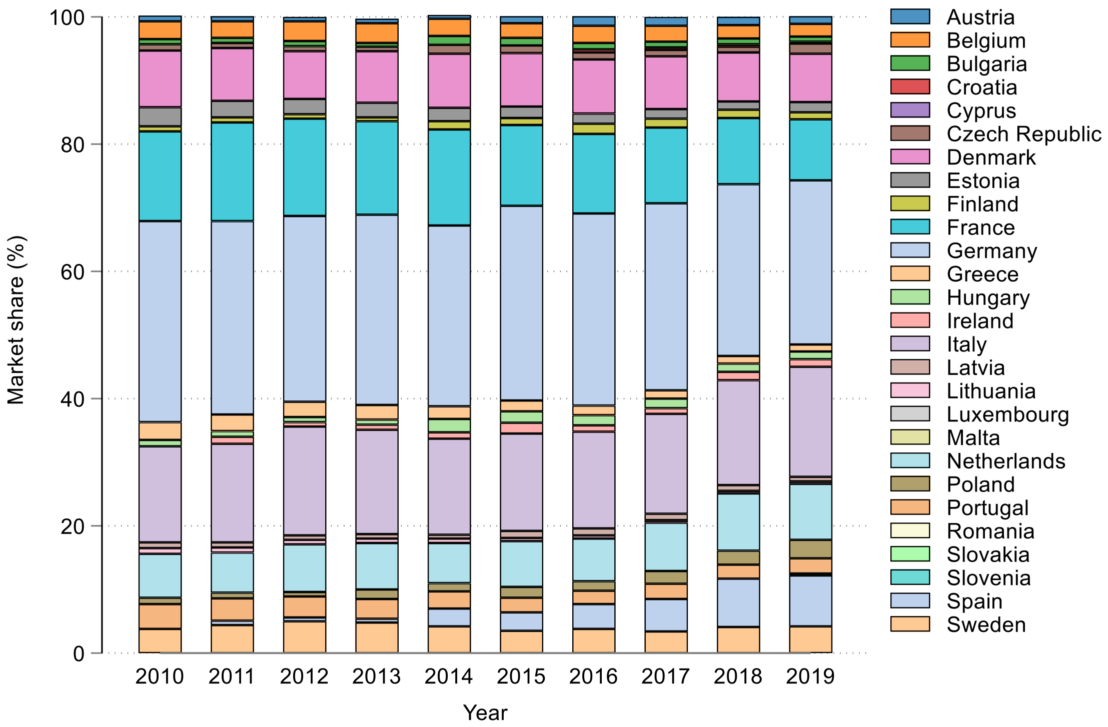
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.5: Evolution of the EU-27 market shares of field robots purchases, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

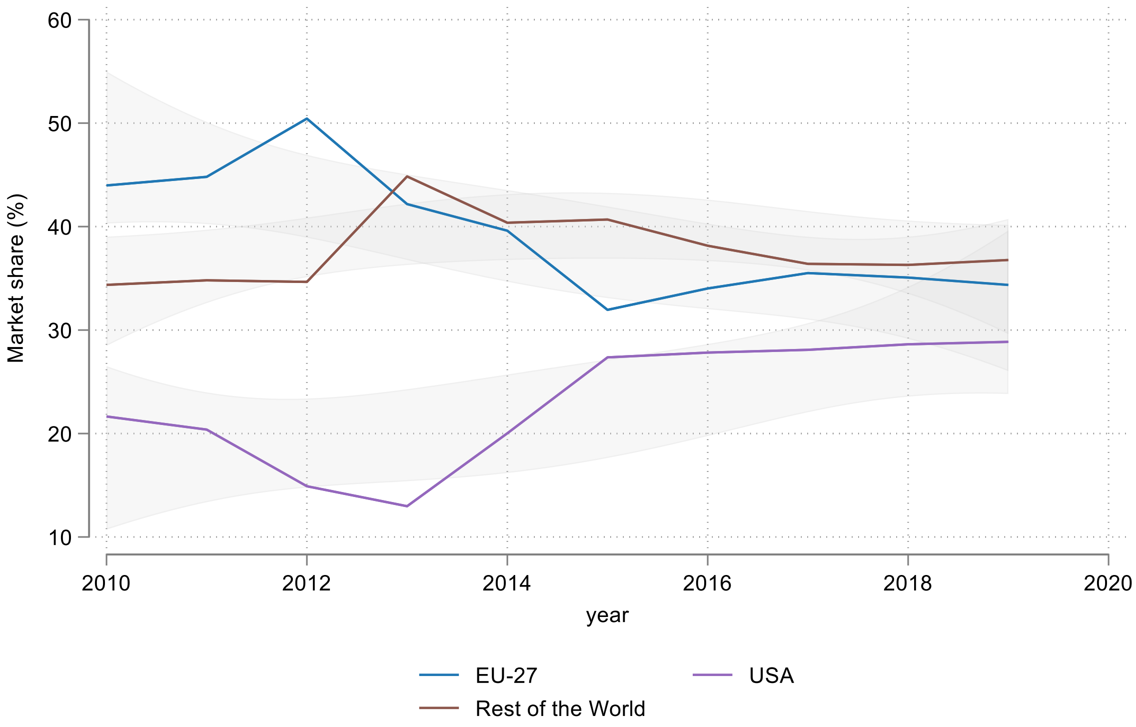
Figure A.VII.6: Evolution of the EU-27 market shares of field robots sales, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

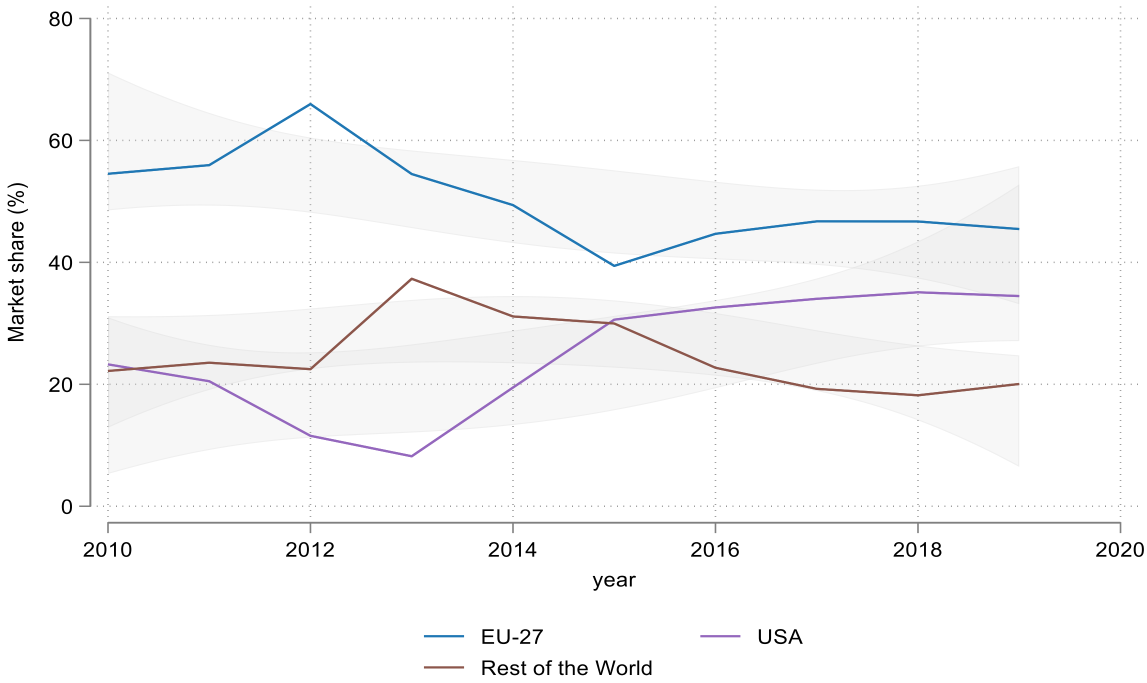
Professional cleaning, inspection and maintenance, construction and demolition robots – Global landscape

Figure A.VII.7: Evolution of the global market shares of cleaning, inspection and maintenance, construction and demolition robots purchases, 2010-2019



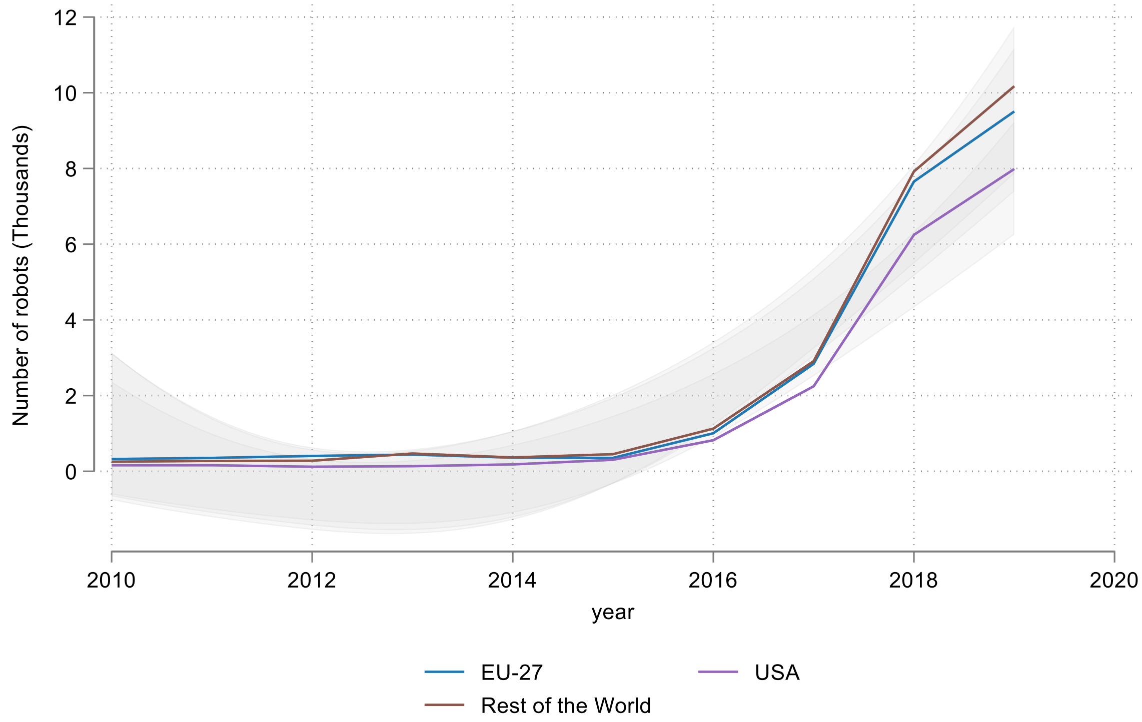
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.8: Evolution of the global market shares of cleaning, inspection and maintenance, construction and demolition robots sales, 2010-2019



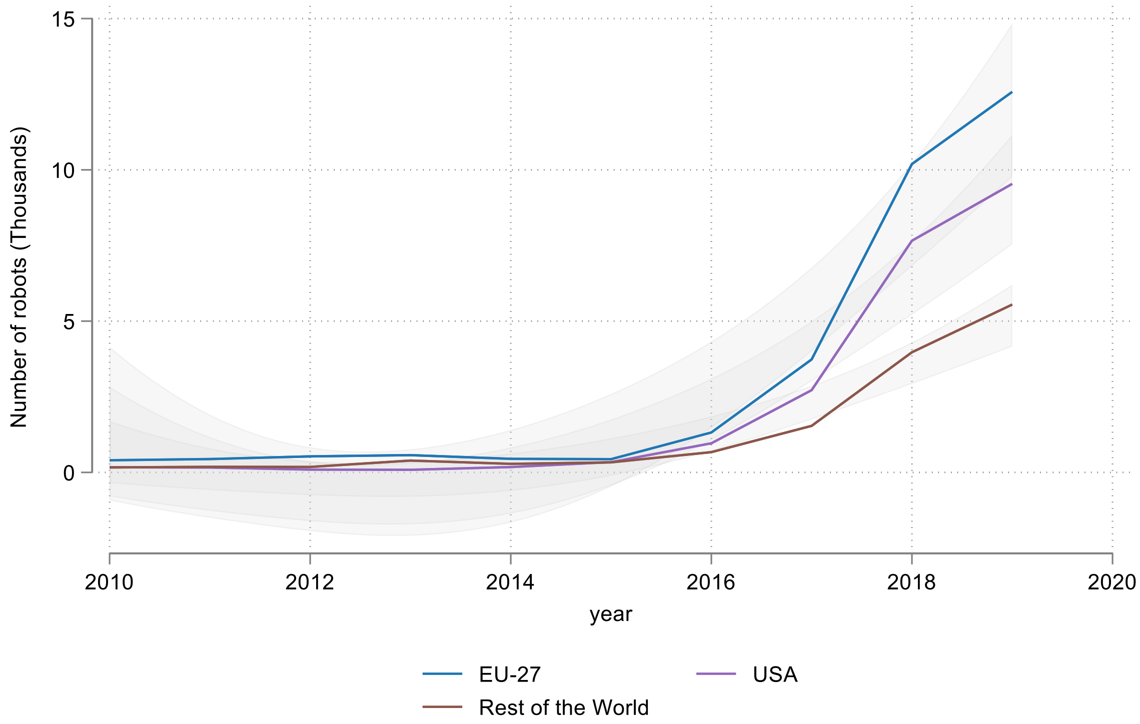
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.9: Evolution of the global volumes of cleaning, inspection and maintenance, construction and demolition robots purchases, 2010-2019



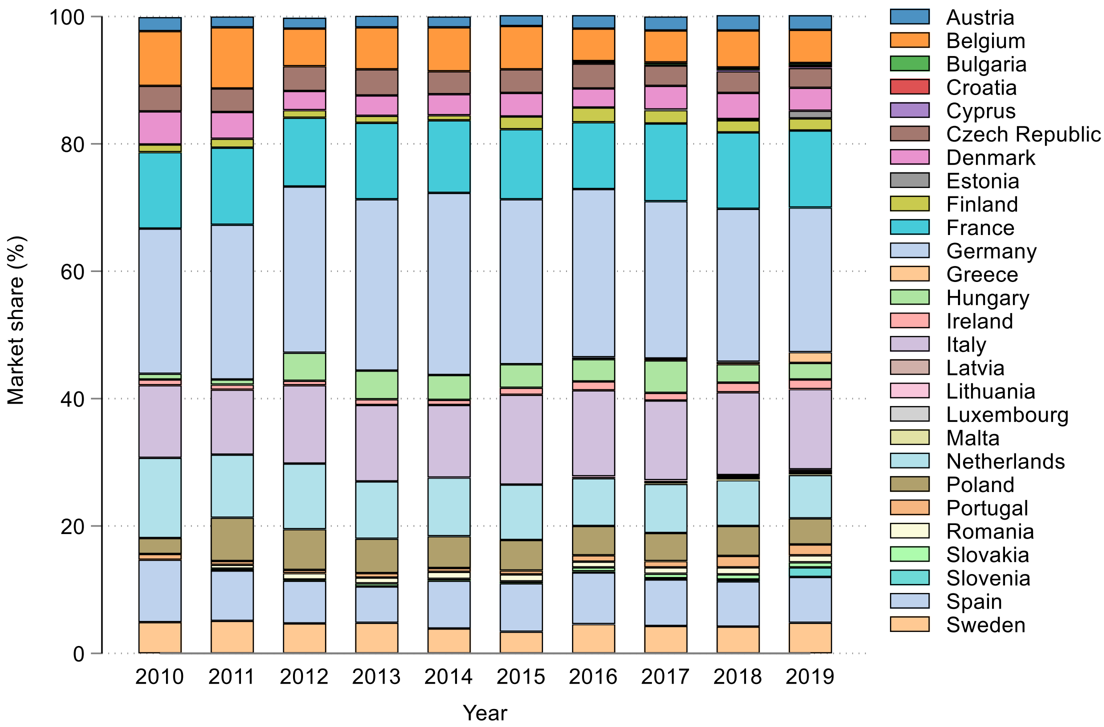
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.10: Evolution of the global volumes of cleaning, inspection and maintenance, construction and demolition robots sales, 2010-2019



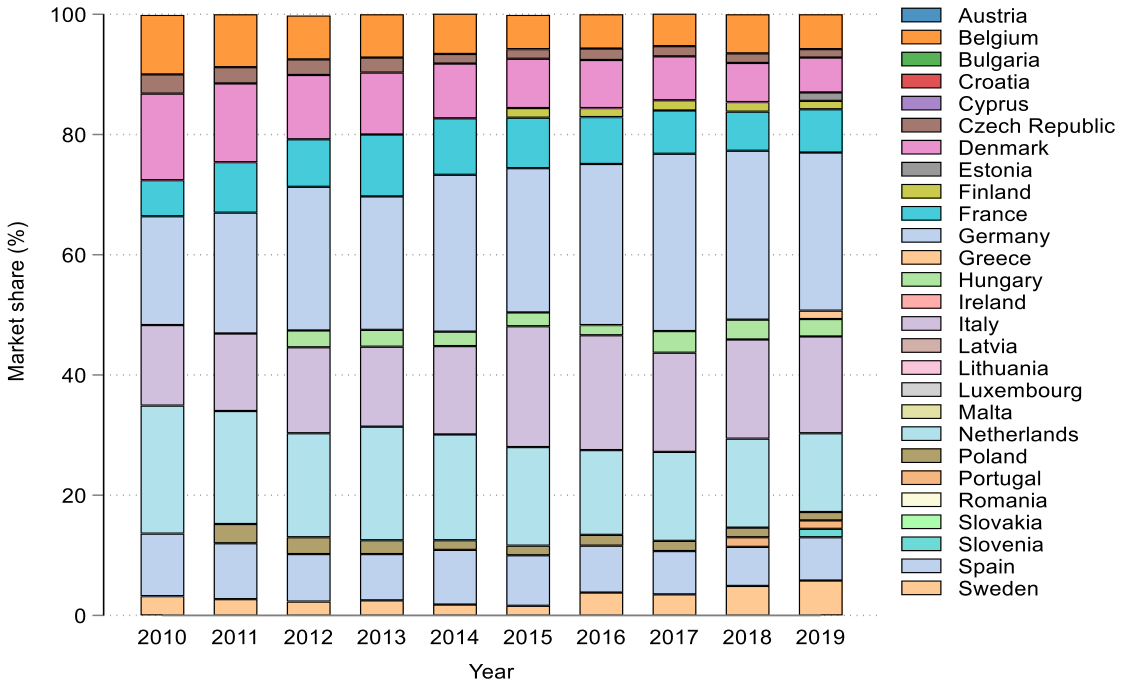
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.11: Evolution of the EU-27 market shares of cleaning, inspection and maintenance, construction and demolition robots purchases, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

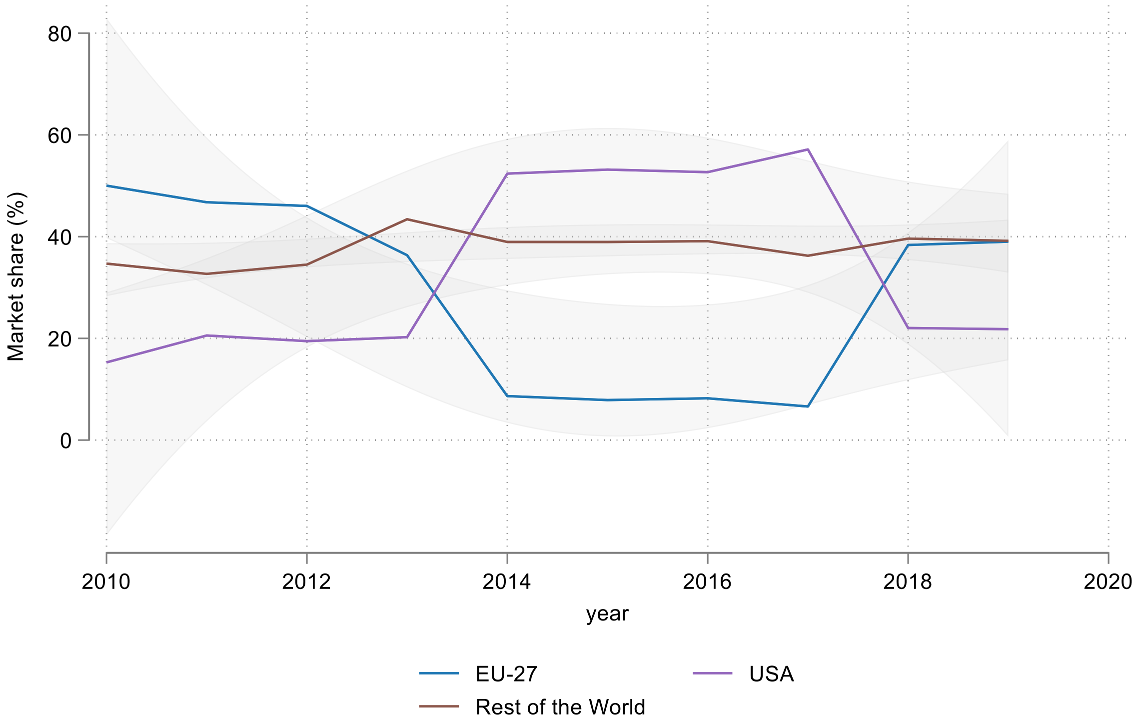
Figure A.VII.12: Evolution of the EU-27 market shares of cleaning, inspection and maintenance, construction and demolition robots sales, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

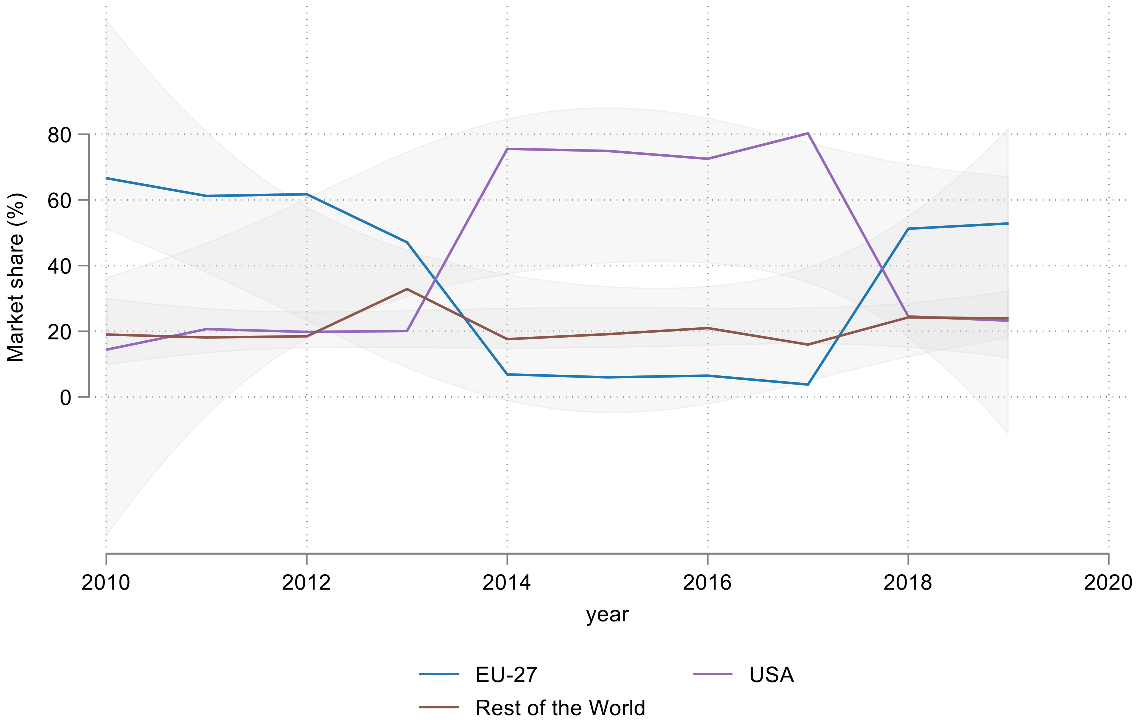
Logistic systems robots – Global landscape

Figure A.VII.13: Evolution of the global market shares of logistic systems robots purchases, 2010-2019



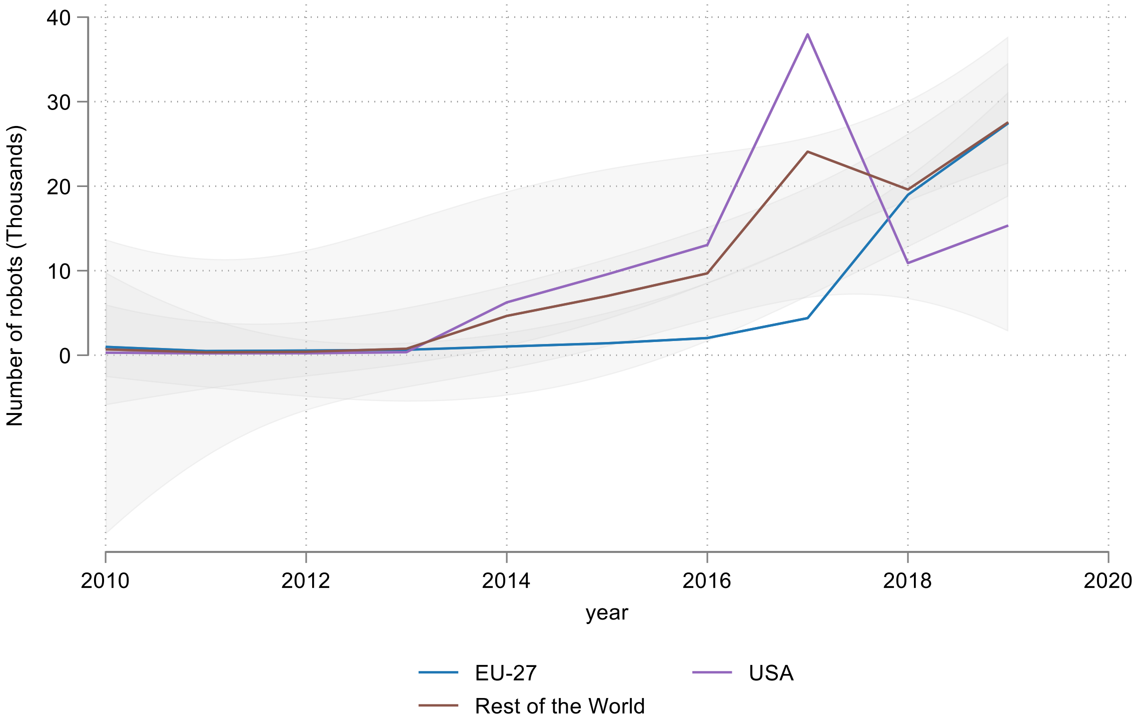
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.14: Evolution of the global market shares of logistic systems robots sales, 2010-2019



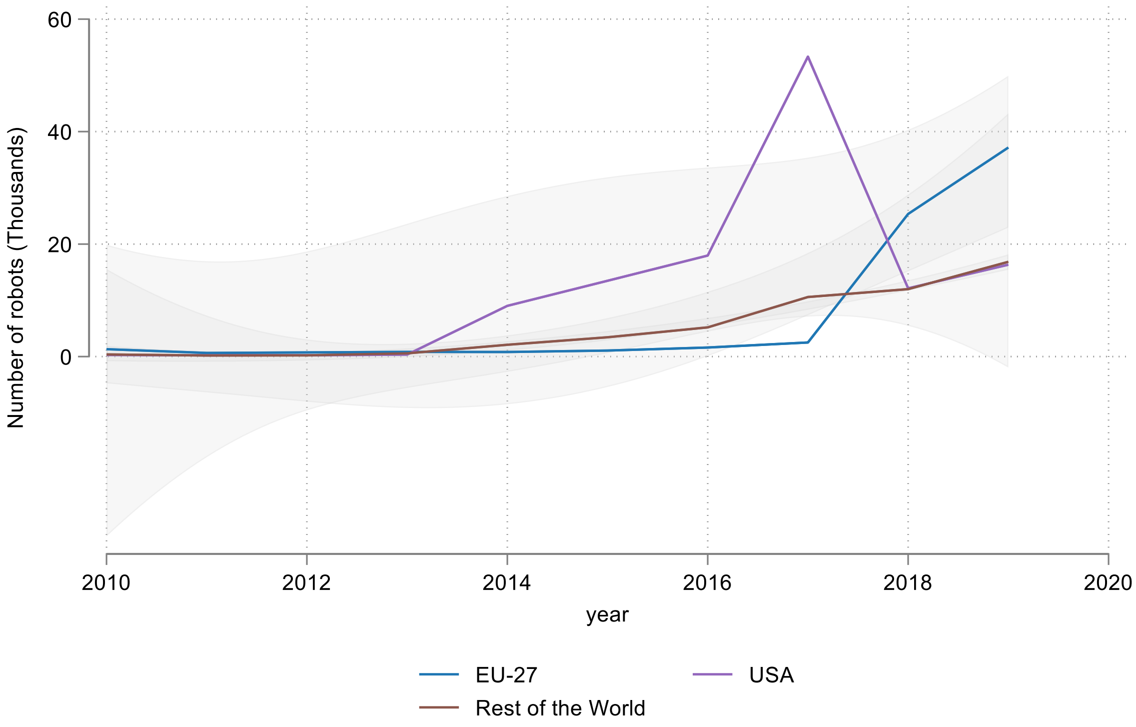
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.15: Evolution of the global volumes of logistic systems robots purchases, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

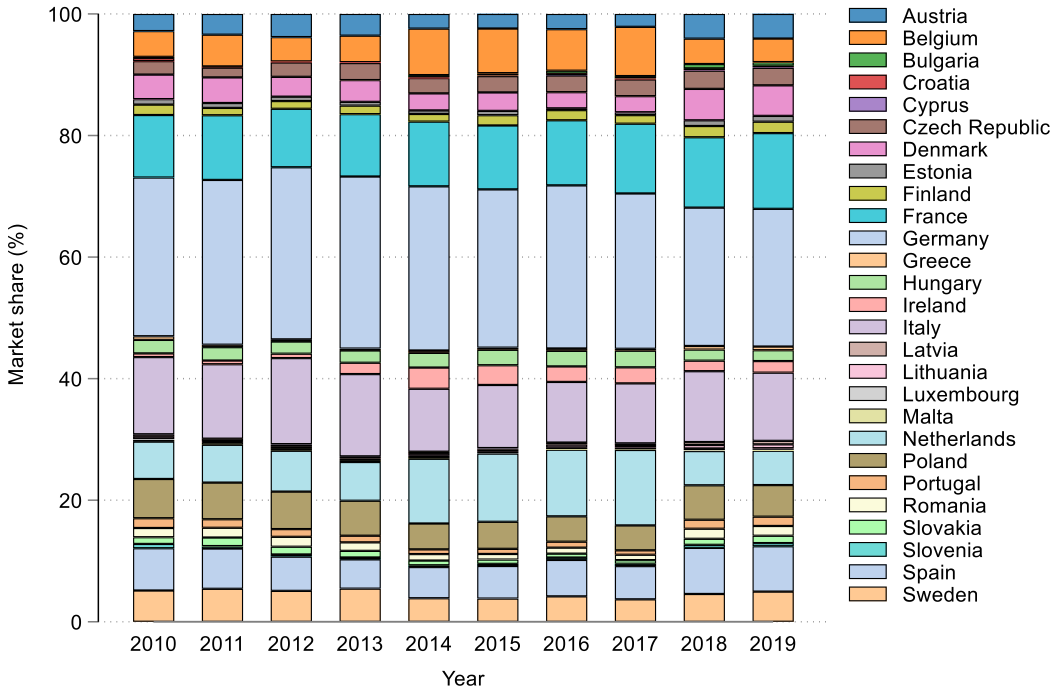
Figure A.VII.16: Evolution of the global volumes of logistic systems robots sales, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

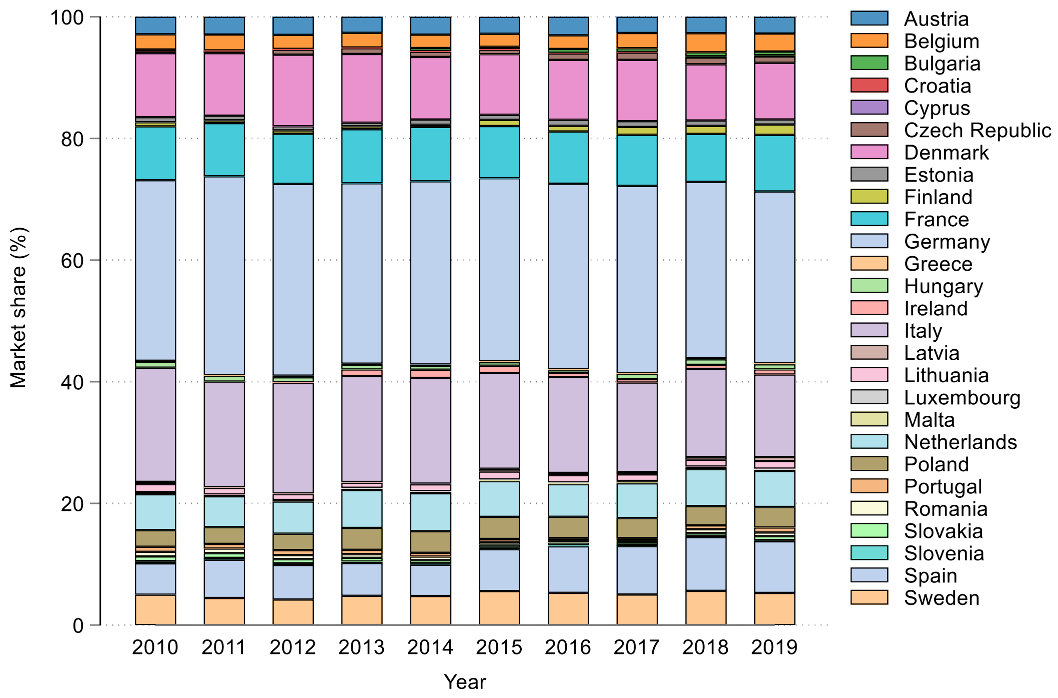
Logistic systems – EU-27 landscape

Figure A.VII.17: Evolution of the EU-27 market shares of logistic systems robots purchases, 2010-2019



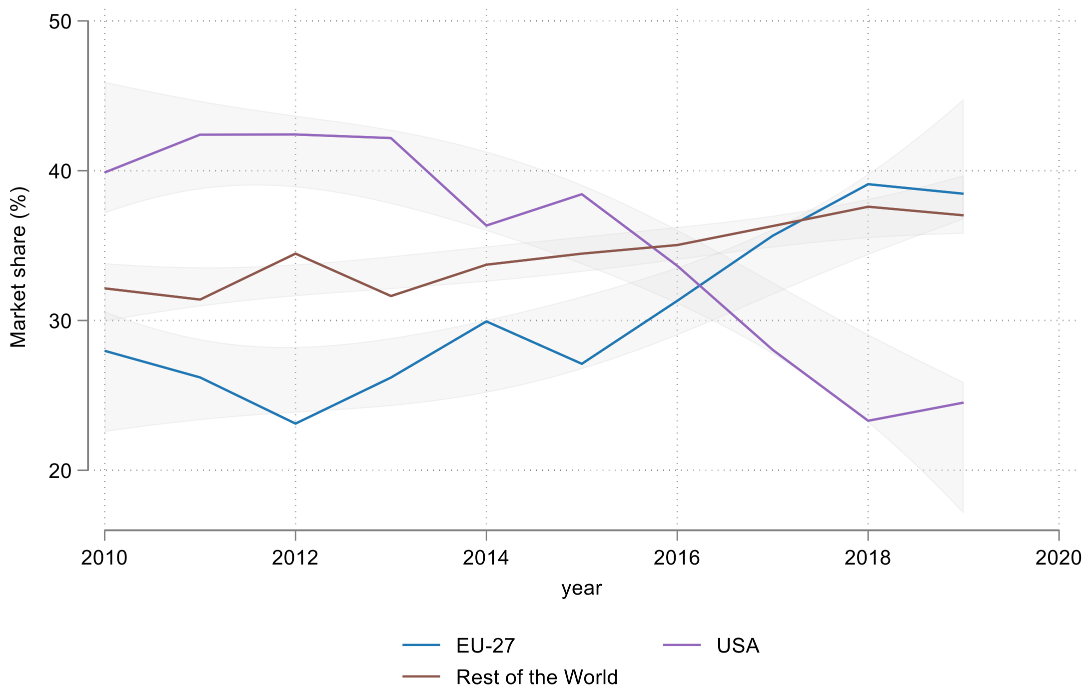
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.18: Evolution of the EU-27 market shares of logistic systems robots sales, 2010-2019



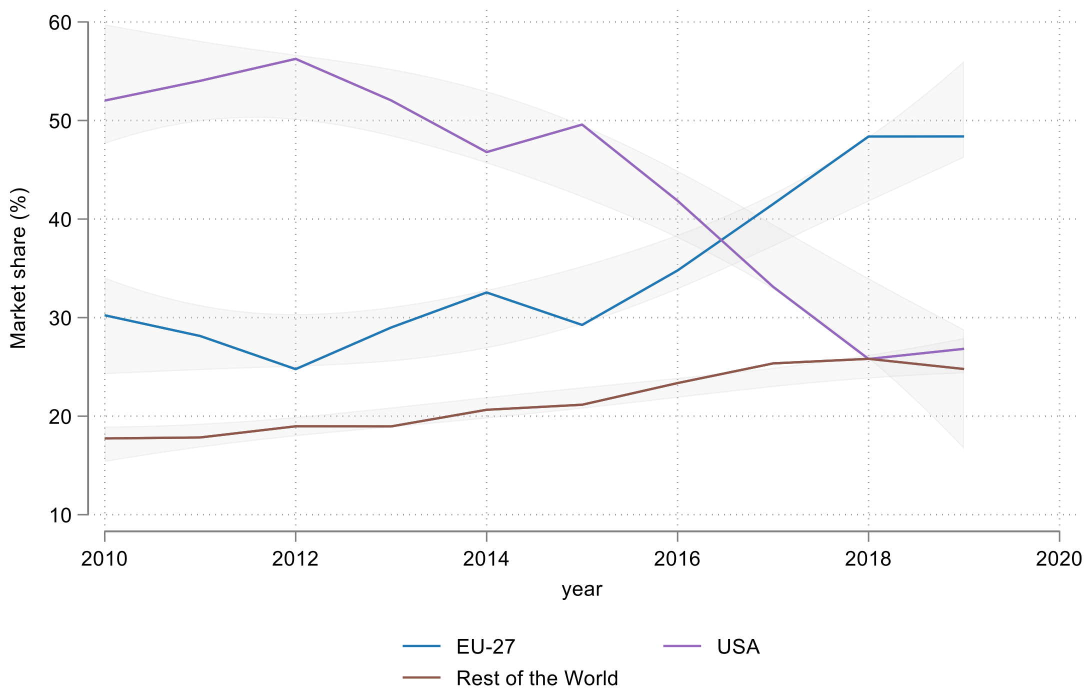
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.19: Evolution of the global market shares of medical robots purchases, 2010-2019



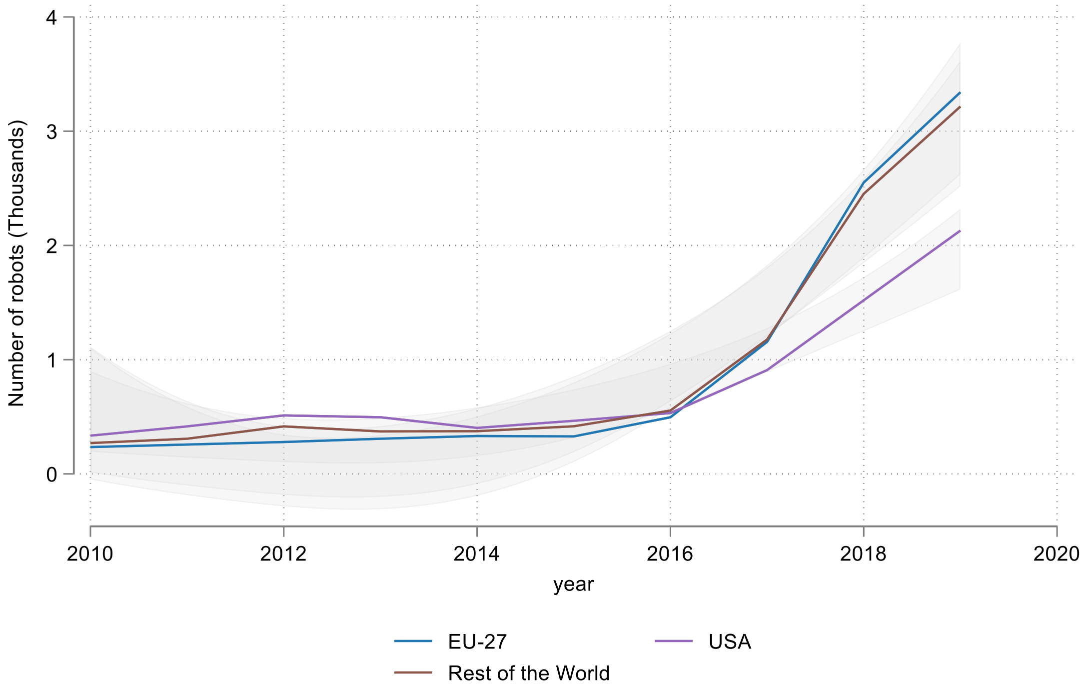
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.20: Evolution of the global market shares of medical robots sales, 2010-2019



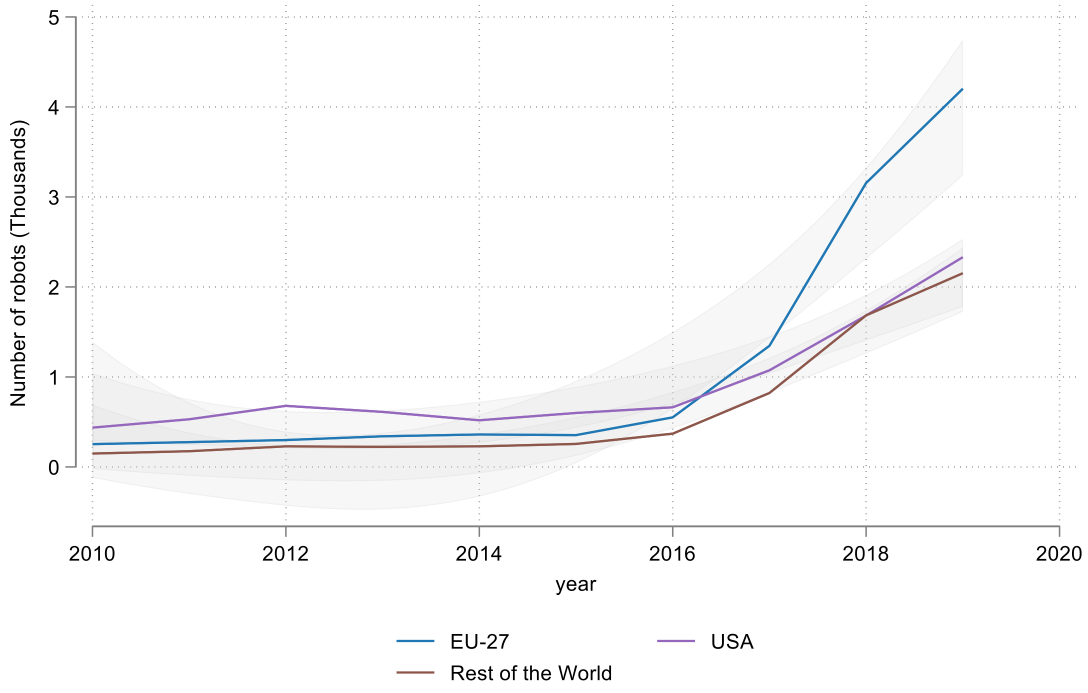
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.21: Evolution of the global volumes of medical robots purchases, 2010-2019



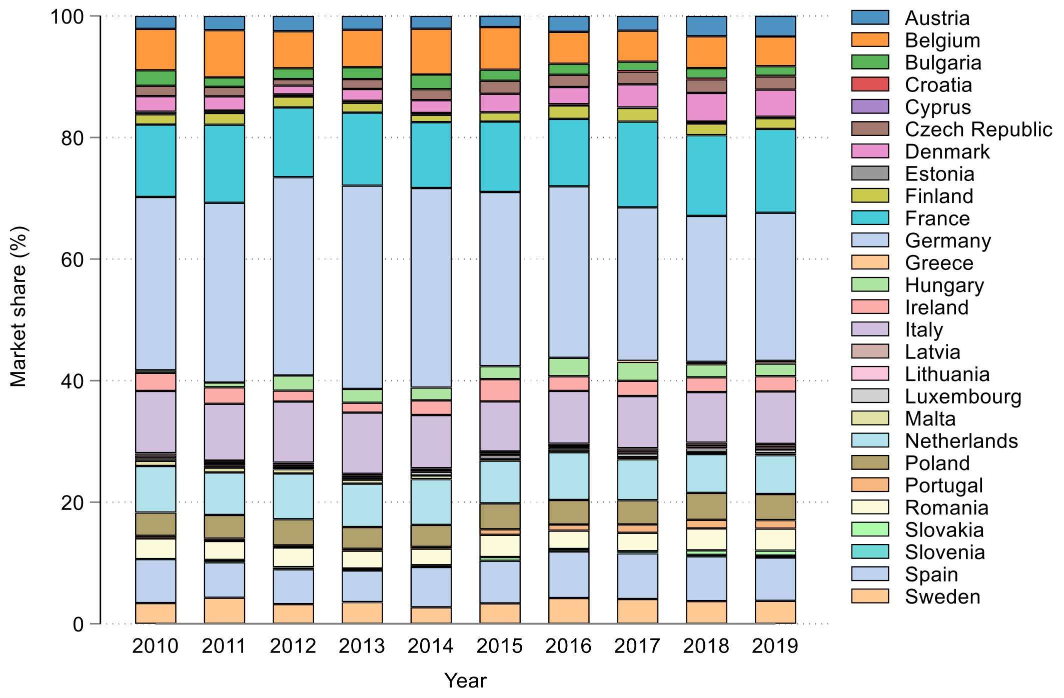
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.22: Evolution of the global volumes of medical robots sales, 2010-2019



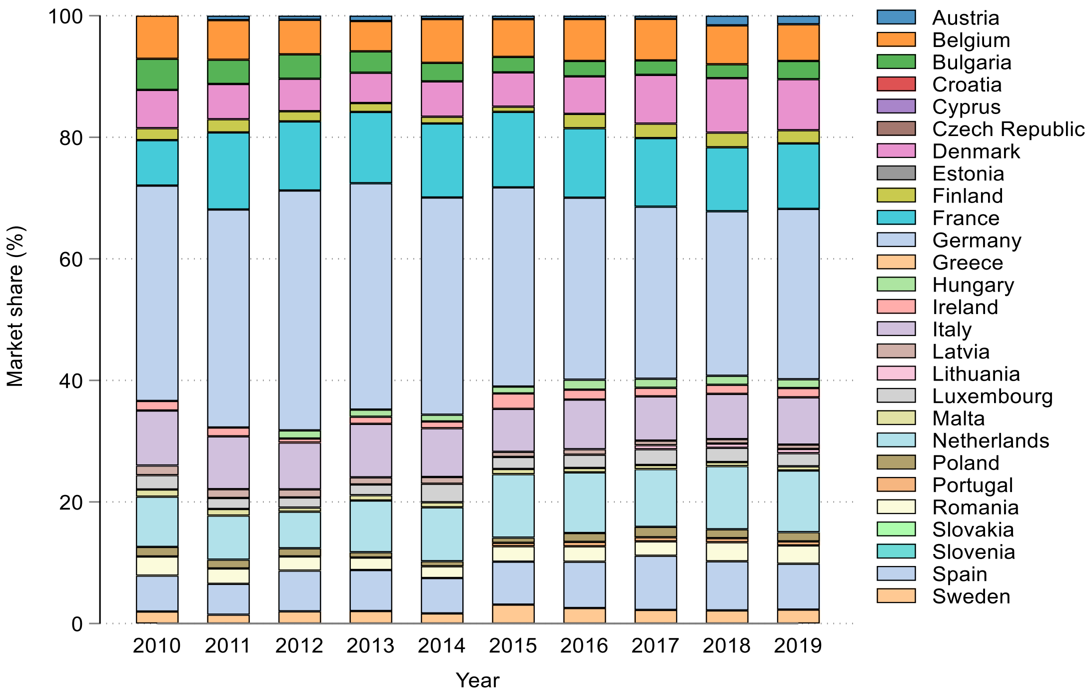
Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.23: Evolution of the EU-27 market shares of medical robots purchases, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

Figure A.VII.24: Evolution of the EU-27 market shares of medical robots sales, 2010-2019



Source: EC JRC calculations based on data from the International Federation of Robotics and UN Comtrade.

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