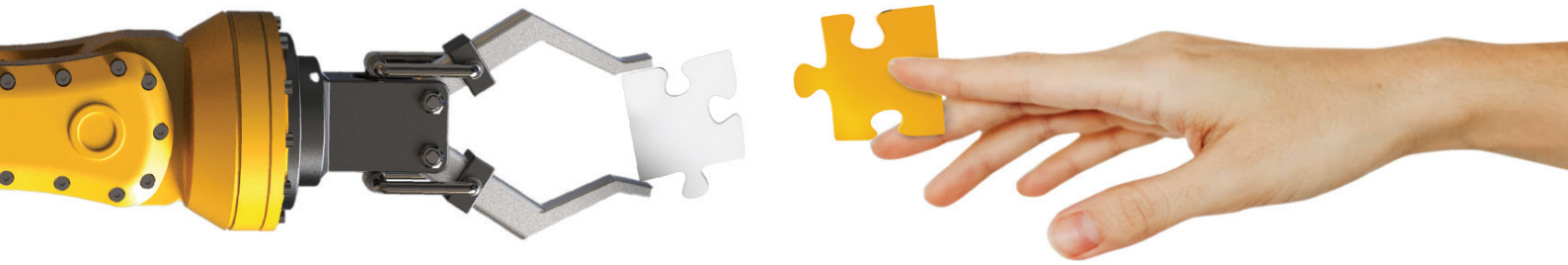
European Commission

JRC CONFERENCE AND WORKSHOP REPORT

WHAT FUTURE FOR EUROPEAN ROBOTICS?

A SCIENCE FOR POLICY PERSPECTIVE

JRC VIRTUAL CONFERENCE
27-29 JANUARY 2021



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Joint Research Centre

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CONTENTS

ABSTRACT

Europe is a world-leader in the production of robots. This industry is a key element of the digital transformation of our societies and economies that, combined with Artificial Intelligence (AI), will likely have a tremendous disruptive potential. To explore further the future of the European robotics industry and its related challenges, the Joint Research Centre organized a Science for Policy conference entitled "*What future for European Robotics?*", bringing together recognized specialists from industry, academia and policy. This report presents the main conclusions that emerged from the conference.

FOREWORD

The European Commission's science and knowledge service that I lead, the Joint Research Centre, has the mission to provide independent scientific evidence in support of the EU policy-making process. We produce state of the art, multidisciplinary research and in our "Innovation and Growth" Directorate we focus on ensuring resilient, sustainable growth for a prosper, fairer and better European society and economy. Following our mandate, we have tried always to identify those topics where we can make the most impact and approach them in a holistic way. The robotics sector is, clearly, a major topic to be studied. On the one hand, Europe is a leader in the field, manufacturing one third of the industrial robots and producing high-quality research coming both from the European private and public sector. It brings therefore high potential for economic growth and can be a tremendous asset to help on the European recovery.

On the other side, and as a lesson of the current pandemic, robotics, in combination with other ground-breaking technologies like Artificial Intelligence, can help to make a more resilient Europe. Finally, it is also true that the massive use of robots is not exempt of challenges: from the ethical impacts it could bring on their interaction with humans, in

particular with children and youngster, to the impact it could have to the labour market.

The combination of all these different facets made us take the decision to launch an international conference that could bring together the best of industry, academia and policy-makers to discuss and identify how to maximize the opportunities and minimize the risks brought by robots. The Joint Research Centre, placed at the interface of science and policy, acted as a catalyser for those debates and put forward an exciting program that, during three days and under the title "What future for European robotics?", covering many of the relevant aspect related to robotics, its impact on Europe and potential policy options. I had the pleasure to chair the last policy roundtable, where we discussed with fellow policy-makers what regulatory framework is needed for EU robotics, and how public intervention can maximizes benefits and minimizes issues in the societal uptake of the robotic technology. The present report summarizes the results of the conference and its debates. I invite you to read it carefully, as it provides insights on how to make the best of a technology that can definitively change our lives for the better.

Brussels, May 2021
Stephen Quest

Image: © European Union, 2019

ACKNOWLEDGEMENTS

The authors of the report would like to thank wholeheartedly to all the speakers that participated in the conference for their time and selfless contribution. We would also like to thank the team behind the organisation of the conference, in particular Karen Fullerton, Loizos Bailas, Miguel Querol and Silvia Mera Jimenez, without whose efforts the conference would have not taken place. Finally, we would like to thank the contribution of all colleagues from the JRC that helped during the days of the conference (taking notes, preparing flash news, assisting technically ...). To conclude, we would like to thank to Mikel Landabaso-Álvarez, Director of "Innovation and Growth" of the JRC, who had the vision for the conference and provided the necessary steer and guidance to make it a success.

AUTHORS (In alphabetic order)

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The conference was held under the patronage of the Portuguese Presidency of the Council of the European Union

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EXECUTIVE SUMMARY

Europe is a world-leader in the production of robots. This industry is a key element of the digital transformation of our societies and economies that, combined with Artificial Intelligence (AI), will likely have a tremendous disruptive potential. To explore further the future of the European robotics industry and its related challenges, the Joint Research Centre organized a Science for Policy conference entitled "*What future for European Robotics?*", bringing together recognized specialists from industry, academia and policy. This report presents the main conclusions that emerged from the conference.

POLICY CONTEXT

The conference was organized in the context of the European Commission's efforts to grasp the opportunities offered by the digital transformation to improve the EU economy, where robotics is a flagship sector, in which Europe must keep its competitive advantage while guaranteeing technological sovereignty and remaining strictly compliant with our social and ethics values.

To achieve this, the European Commission is launching several policy initiatives to ensure an adequate legal framework. Those initiatives include a broad set of different policies and range from a review of the Coordinated Plan on Artificial Intelligence, in which robotics is placed amongst the main priorities, to a horizontal regulation on Artificial Intelligence, in which conditions for high-risk use of AI are regulated; from a revision of the Machinery Directive, including various elements like robot safety, human-machine interaction and transparency, to the Product Liability Directive, in which rules for compensation to customers to whom damage has been caused from the use AI and robots will be further clarified; from legislation on working conditions to the strategy for protection of children's rights.

KEY CONCLUSIONS

As shown during the discussions of the conference but also during the different sections of this report, robots represent both a challenge and an opportunity for human society in general and for Europe in particular. Robots can be used to support humans in the performance of tedious, dangerous or hazardous tasks; they can improve efficiency and productivity, especially if combined with AI; they can help us increase our societal welfare and enhance the way we learn, allowing us to develop our potential to the maximum.

As data, Artificial Intelligence and robotics are very closely interconnected and are at the forefront of the digital transformation, a leading role in one of them can help to accelerate the European role in the others.

At the same time, robots, once out of the "cage" of their classical industrial application and, especially, in combination with powerful AI applications, can represent a real challenge to our society. From massive substitution of jobs to the de-humanization of the labour market, having workers being managed "by algorithms" to their use of for mass-control or for serious infringements of fundamental rights, especially for children. The different discussions during the conference led to one main conclusion. The only way to ensure that a massive societal uptake of the robotic technology maximizes benefits and minimizes issues is by means of a decisive, agile, horizontal, coordinated and multidisciplinary public intervention.

Additionally, and as the EU is a leading actor in the robotics industry, producing almost one third of all robots worldwide, whatever public intervention is launched by the European and national administration, it would have to ensure that Europe can retain that role. Robots will be instrumental for the successful deployment of other disruptive technologies, like Artificial Intelligence, and will also be massive producers of data which, when used with full respect of European legislation and EU rights, can boost the deployment of the European data economy. As data, Artificial Intelligence and robotics are very closely interconnected and are at the forefront of the digital transformation, a leading role in one of them can help to accelerate the European role in the others.

MAIN TAKEAWAYS

— Regarding the impact of automation and robots on employment, policy makers should keep a balance between the job destruction and the job creation potential of this technology. This requires a broad portfolio of policy initiatives to ensure that no one is left behind, including the strengthening of the welfare state, investment in life-long education and in digital infrastructure.

— Robotics technologies typically originate in research institutions and are then exploited in tech companies. Europe, with its strong basic research, could focus on the beginning of the robotics value chain, to ensure competitive advantage in the making of robotic technologies.

— For service and collaborative robots, policy makers should put a stronger focus on robotics in regionally targeted innovation and industry policies or on developing new and targeted instruments; create and nurture vibrant ecosystem for robotics start-ups to tackle the persistent problem of their weak upscaling; and seize the opportunity of a stronger involvement of the public sector.

— The massive adoption of robotics technology should ensure that machines are developed to be robust, reliable, and dependable and that their design and development should comply with human rights values.

— Policymakers should consider the negative environmental impact that massive deployment of AI and robotics technologies could bring. They should ensure that recycling plans, to reuse parts and components of the deployed machines, are already considered in the design and development phases by manufacturers.

— It is important to build methodologies to keep humans in command, for human-robot collaboration and for fusion of skills from human and robots. Robots and AI can support decision making, but responsibility stays with humans.

— Companies and organisations should think about what could go wrong when implementing, purchasing, or using robotics/AI technology. In this sense, an ethical technology assessment should be carried out before deploying AI/robotics technology.

— Policy makers could consider a regulatory framework to minimise the risk to children during social child-robot interaction.

RELATED AND FUTURE JRC WORK

The JRC is carrying out related research in the areas of

— trustworthy Artificial Intelligence

— child-robot interaction

— innovation ecosystems

— digital economics

— circular economy

QUICK GUIDE

The report provides an overview of the different discussion panels organized during the conference and includes the keynotes delivered by Commissioner for Innovation, Research, Education, Culture and Youth, Mariya Gabriel, and by Vice-President for Institutional Relations and Foresight, Maroš Šefčovič. It closes with the main conclusions of the conference. The annex includes general details of the conference, including its detailed programme.

1
INTRODUCTION

This report compiles the results of the discussions that took placedur-ing the "What future for European robotics?" Science for Policy confer-ence organized by the Joint Research Centre of the European Commis-sion under the patronage of the Portugues presidency of the Council of the European Union. The conference took place on-line between 27th and 29th January of 2021 with the participation of several high-level speakers coming from industry, academia and policy. Manuel Heitor, Portuguese Minister of Science, held the opening speech on technology and higher education that inaugurated the conference.

As robotics is seen as an increasingly important area for EU economic growth and recovery, the Joint Research Centre launched this initiative with the aim of providing a scientific, policy-oriented, and EU-centred analysis of the state of this pivotal technology and to provide relevant input to the policy debate. This report, as a follow up of the conference, also aims to contribute further to such discussions by compiling the most relevant conclusions and take-away messages.

Recent advances in Artificial Intelligence (AI) and related technologies have enlarged the scope of what can be disrupted by robots, inducing important socio-economic changes.

The conference was organized in the context of the European Commis-sion's efforts to grasp the opportunities offered by the digital transfor-mation to improve the EU economy, where robotics is a flagship sector, in which Europe must keep its competitive advantage while guarantee-ing technological sovereignty. The conference brought together leading experts from industry, academia and policy to discuss the technical, economic, and social angles of robotics with the overarching goal of identifying the main policy challenges to be addressed in this field, in the short and in the long term, also in the light of the current COVID-19 crisis.

Robotics, a domain of technology that produces programmable ma-chines, is pushing the bounds of technology as we know it. Recent ad-vances in Artificial Intelligence (AI) and related technologies have en-larged the scope of what can be disrupted by robots, inducing important socio-economic changes. Since the COVID-19 crisis, we are witnessing how the use of robots can bring significant efficiency improvements in protecting health and guaranteeing security. However, there have also been concerns about the potential for cheaper and more efficient ro-

bots to replace humans in the workplace, linked to the emergence of the so-called "service robots".

Moreover, a vibrant robotics industry should stimulate innovation, and can act as a catalyst to overcome the medical and economic impacts caused by the COVID-19 pandemic. The benefits of robotics for European economies and societies, in particular in the context of the EU recovery, will only be reaped if there is a joint and coordinated effort at EU level and these actions respect European values.

Figure 1

The benefits of robotics for European economies and societies, in particular in the context of the EU recovery, will only be reaped if there is a joint and coordinated effort at EU level and these actions respect European values.

Image: © European Union, 2020

To achieve this, the European Commission is launching several policy initiatives to ensure an adequate legal framework. Those initiatives include a broad set of different policies and range from a review of the Coordinated Plan on Artificial Intelligence[1], in which robotics is placed amongst the main priorities, to a horizontal regulation on Artificial Intelligence[2], in which conditions for high-risk use of AI are regulated; from a revision of the Machinery Directive[3], incluing various elements like robot safety, human-machine interaction and transparency, to the Product Liability Directive[4], in which rules for compensation to customers to whom damage has been caused from the use AI and robots will be further clarified; from legislation on working conditions to the strategy for protection of children's rights.

The report is organized as follows: Sections 2 to 5 provide an overview of the different discussion panels organized during the conference. The topics discussed and the main conclusions are presented and summarized. Section 6 includes the keynote delivered by Commissioner for Innovation, Research, Education, Culture and Youth, Mariya Gabriel, around the impact of robots in our society and Section 7 tackles the particular topic of robotics and foresight, which was addressed by the keynote delivered by Vice-President for Institutional Relations and Foresight, Maroš Šefčovič. Section 8 includes an overview of the main conclusions of the report. Finally, Annex I includes general details of the conference, including its detailed programme.

2
ECONOMIC IMPACT OF ROBOTISATION ON EMPLOYMENT, PRODUCTIVITY AND COMPETITIVENESS

A broad policy portfolio is required to ensure that no one is left behind in the transition towards a more automated economy.

The first panel of the conference discussed the topic of the **impact of robotisation on employment, productivity and competitiveness**. It was chaired by Robert Marschinski, from the Joint Research Centre, and featured Daron Acemoglu, from the Massachusetts Institute of Technology, Anna Salomons, from the University of Utrecht and José Mendonça, from the University of Porto.

Robotic technology has made impressive advances in recent decades. José Mendonça, in the first presentation of this panel, showed examples from hospital logistics, harvesting of grapes or robots operating in dangerous environments such as flooded mine shafts. This leaves citizens and policy-makers alike wondering how such technologies might affect the future of the economy and society at large, which was the key question addressed in this panel.

Two competing **narratives have emerged**: **A rather dystopian** future, in which highly efficient robots have crowded out all but the most proficient human workers and wealth is concentrated in the hands of a minority of rich robot-owners; **and a more utopian one**, in which workers enjoy a fifteen-hour workweek and otherwise engage in different leisure activities as envisioned almost a century ago by the great economist John Maynard Keynes (2010). The truth likely lies somewhere in the middle, and, more importantly, is to some extent determined by our policies today.

Regarding employment, **automation seems to be a double-edged sword**, as emphasized in the second presentation by Anna Salomons: On the one hand, it has the **potential to create new jobs through innovation and shifts in demand**; on the other hand, it might also **polarise the income distribution** depending on where new jobs are created. One particular type of automation that has recently been studied in detail is **industrial robotics**. It is crucial to acknowledge that indus-

trial robotics is a highly specialised technology that is concentrated in a few sectors (see Fig.2) - more than one quarter of all robots in the EU are installed in German car manufacturing - which ex ante limits their impact on employment (Fernández et al., 2020). Some studies find that this technology is associated with reduced employment, particularly for low-skill workers (Acemoglu and Restrepo, 2019; Graetz and Michaels, 2018). However, it appears that this outcome depends strongly on the years and countries included in the analysis: using a wider sample of EU countries, Klenert et al. (2020) and Anton et al. (2020) **find a positive association between robots and aggregate employment, in particular after 2005**. This is confirmed by studies using firm-level data (Domini et al. 2019, Jäger et al. 2016, Koch et al. 2019).

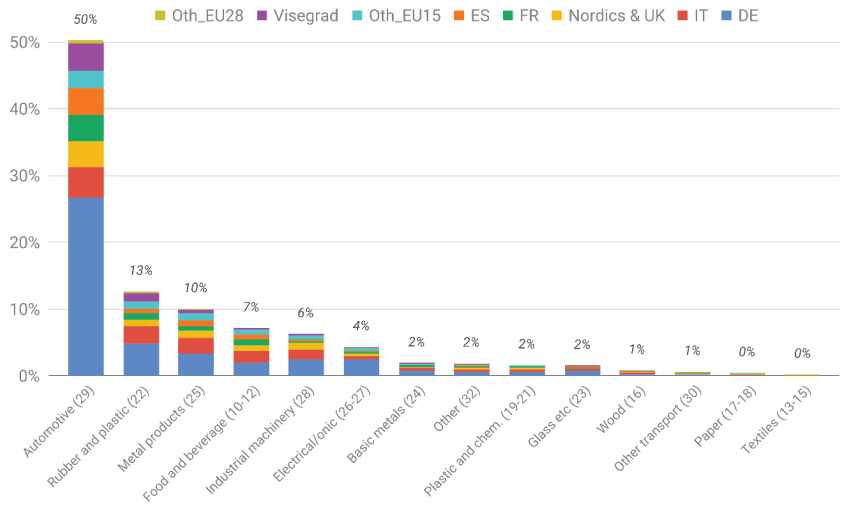


Figure 2

Distribution of industrial robots by sector and country in Europe in 2016.

Note: Nordic countries: Denmark, Sweden, Finland, UK; other EU15: Austria, Belgium, Greece, Ireland, Netherlands, Portugal; other EU28: Bulgaria, Croatia, Estonia, Latvia, Lithuania, Malta, Romania, Slovenia; Visegrad: Hungary, Poland, Czech Republic and Slovakia.

Source: Fernández-Macías et al. (2021).

Not explicitly discussed in the panel, but still important for the topic is the **positive effect of new technologies on productivity**: Industrial robots (Graetz and Michaels, 2018; Jungmittag and Pesole, 2019), Information and Communication Technologies (Jorgenson and Stiroh, 2008; Strauss and Samkharadze, 2011) and Software (Adarov et al., 2020) are all key drivers of productivity.

What Keynes wrote in 1930 describes current attitudes surprisingly well: "We are suffering, not from the rheumatics of old age, but from the growing-pains of over-rapid changes [...]. The increase of technical efficiency has been taking place faster than we can deal with the problem of labour absorption." Today, **technical change appears to be accelerating each year**, driving productivity growth and increased living standards. Simultaneously, **new jobs are being created while**

others are automated away (Autor and Salomons, 2017). As stressed by the third speaker, Daron Acemoglu, this i**mplies a responsibility for policy-making** to maintain a **healthy balance between the two effects**, since a laisser-faire approach regarding automation would pose the risk of higher unemployment, increased inequality, and in its final consequence social instability. Instead, **a broad policy portfolio is required to ensure that no one is left behind in the transition towards a more automated economy**: Strengthening of the welfare state, investment in life-long education, avoiding excessive wealth concentration and investment in (digital) infrastructure. These policies support Europe's transition into a future Mr Keynes could only dream of in his days.

3
HOW THE ROBOTICS INDUSTRY CAN SUPPORT THE EU RECOVERY

The objective of the industry panel was **review Europe's position in the worldwide context regarding the state-of-art in innovation, to analyse the EU territorial hotspots and their best practices and the future outlook**. It was chaired by Ramón Compañó and included Zoltán Cséfalvay, from the Matthias Corvinus Collegium, Helge Holm-Larsen, CEO at Syddansk Innovation A/S, Daniel Dines, Co-Founder and CEO of UiPath and Laszlo Hradszki, Senior Advisor at Hiventures.

Daniel Dines presented the Bucharest-born software company UiPath, which develops and implements an end-to-end platform for automation, combining Robotic Process Automation (RPA) with a full suite of other technological capabilities to help organizations scale their digital business operations. RPA is different from traditional automation or physical robots, as it emulates and integrates actions performed by humans on their computers. In other words, these software robots can mimic rule-based and repetitive tasks, such as copy-pasting data,

logging into applications, filling in forms, and performing calculations, among others.

In its early stages, UiPath received financing from European venture capital firms. UiPath went public in April 2021 and is now the second largest software company in Europe, after SAP, by market capitalization. Dines emphasized his vision **of (software) robots to liberate people from repetitive tasks** and the importance for Europe to **embrace RPA** (UiPath 2020). He also stressed the importance for Europe to become **more active in robotics to strengthen its competitiveness** and avoid being only a mere consumer (and no longer a producer) of technological innovation. Furthermore, Dines stated that RPA is being largely adopted in developed countries, including the US, Singapore, or Dubai governments, which embrace automation to improve administrative efficiency and the quality of public services.

Dines presented a number of examples of how RPA contributed to combatting the current COVID-19 crisis, namely UiPath implemented automation solutions in hospitals, public administrations and businesses worldwide. In the healthcare sector, the implementation of RPA in hospitals permitted (a) to clear a 160-day registration backlog in a single day; (b) to provide more accurate test results in one third of the time; or (c) to reduce the screening time of health care workers from 5 days to 4 hours. Similarly, in public administrations, the processing time of COVID-related applications was shortened from 45 to 5 minutes. In banking, RPA accelerated the disbursement of grants and loans, contributing to keeping businesses alive.

Helge Holm-Larsen presented Syddansk Innovation's experience and lessons learnt from providing pre-seed, early stage investment to **create an ecosystem of robotics companies** in the Danish Odense Region, to become a world-wide recognized "European Robotic Valley" (see **Box 1** for a detailed description of the Odense innovation ecosystem). He identified a number of success factors worth considering for other regions that would like to embark a similar path. First, there shall be a **collective vision amongst the stakeholders** on the goals and an agreed long-term action plan to implement it. The **working relationship within academia, industry and government must be tight, trustful and efficient**, where talents do easily move from academia to industry and across industries. Ideally, the network shall be run by a **recognized 'orchestrator'** with suitable means and decision

power, but no vested interest, able to provide added value to the ecosystem and able to expand it. This orchestrator must monitor regularly previously defined **Key Performance Indicators** and corrective measures are taken whenever necessary;

Laszlo Hradszki introduced Hiventures, a state-owned Venture Capital firm in Budapest, whose core business is early-stage ventures investing in Hungarian start-ups. So far, only five out of their 330 investments were robotics-related start-ups, which could be interpreted that there are relatively few robotics companies in Eastern Europe. While the number may be relatively low, this does not imply that there is little technological expertise nor that the quality of the start-ups is low (Cséfalvay 2021). In fact, one of the most successful Hiventures' exit was a Hungarian robotics start-up, the Europe's most successful scale-up, UiPath, is based in Romania. Overall speaking Venture Capital investment in deep tech, in general, and robotics, in particular, enjoy good health in Europe and abroad with a notable growth over the past decade. Venture Capital investments in Europe in the deep tech industry are up by 218% from 2015 (USD 7.3 billion) to 2019 (USD 15.9 billion). Venture Capital investments in robotics are up by 860% from 2015 (USD 160 million) to 2019 (USD 1.391 billion). In perspective, in 2019, robotics received more Venture Capital investments in Europe than education, HR tech or fashion, but less than fintech, medtech or energy tech.

Hradszki recalled that robotics technologies are deep tech technologies typically originating in universities and research institutions and that Europe is very strong in the basic research needed to make robotics technologies. Being excellent in R&D, however, is not sufficient, this knowledge needs to be exploited in tech companies.

Europe's ability to produce exploitable intellectual property was underlined also by Cséfalvay, who pinpointed to **Europe's good position in robotics in filing patents.** Europe's is particular strong in manufacturing, while Japan and Korea have leading positions in in-house robotics development. Europe, however, is not a unanimous block; there are considerable **East-West disparities**. According to Cséfalvay this disparity is correlated with labour costs: the higher labour costs, the higher degree of robot deployment.

In addition to the R&D capacity, another key factor for success is that the sector must fit the future value chains of manufacturing and services.

In this respect, Zoltan Cséfalvay started by highlighting the differences between industrial robots and service and collaborative robots from an economical point of view.

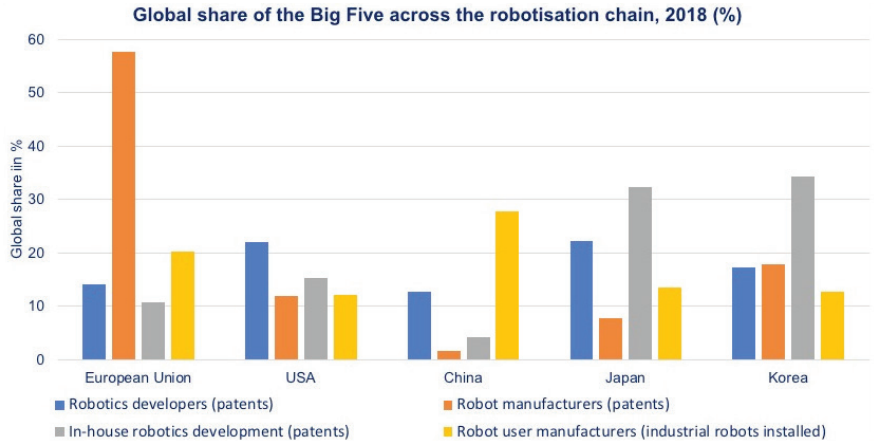


Figure 3

Global share of the Big Five across the robotisation chain, 2018 (%)

Source: Cséfalvay, Z. and Gkotsis, P. (2020) Global race for robotisation – Looking at the entire robotisation chain. JRC Technical Report, Seville, JRC121184, Tab. 2.

For more information: https://europa.eu/!JB79yu

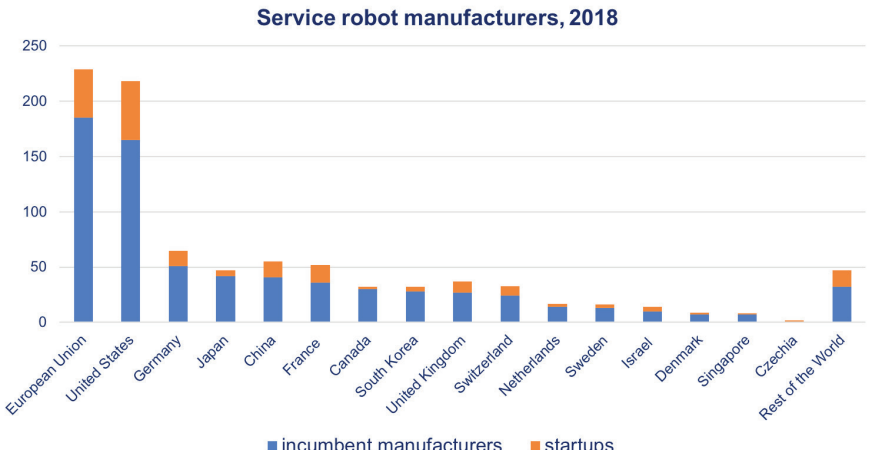
Industrial robots target **mass production covering an essential important, but narrow part of the economy**. These kinds of robots are dominated by few global multinationals and they operate mostly in factories of developed economies where labour is a critical manufacturing cost. In contrast, the deployment of s**ervice and collaborative robots is still comparatively low**, but their **application areas are wide**. Typically, they are locally embedded in services or small-scale industrial settings and driven by the dynamics of global companies and start-ups.

While there are no more than one or two dozen significant industrial robotics producers worldwide, there are several hundreds of companies producing service and collaborative robots in the world. Many of these companies are highly innovative start-ups. These start-ups face the challenge of finding the financial means to scale up to grow their business. While this is a general problem for start-ups, this is particularly aggravated in Europe given the well identified funding gap. While the number of start-ups is very similar in the US and the EU, start-up funding is 10 times higher in the US. Better funding possibilities do not only refer to the number of deals but also amounts, given that in the US there are larger Venture Capitalists able to accompany scale-ups until they arrive at an Initial Public Offering (IPO) at high valorisation. Thus, it is not astonishing that many robotics unicorns are located in Silicon Valley, Boston and Pittsburgh, while the only European unicorn is UiPath.

Figure 4

Service robot manufacturer, 2018

Source: Cséfalvay based on data of IFR (2019) for service robot manufacturers



Finally, Cséfalvay mentioned a number of policy challenges for Europe for the different types of robots (Cséfalvay and Gkotsis 2020).

For industrial robots in highly robotised countries, there is a trade-off between further job losses in manufacturing and the necessity to strengthen their industrial base and trade, while for less robotised countries, the challenge is to climb up the added-value chain by introducing more robots in the manufacturing chain. A more general aspect for developed countries is to which extent industrial robots can contribute to the reshoring of previously off-shored production processes.

Industrial robots target mass production covering an essential important, but narrow part of the economy.

For service and collaborative robots, the policy priority should be not to miss the upcoming trend. Europe should enable targeted instruments to create and nurture a vibrant ecosystem for robotics start-ups. One priority is to tackle the persistent problem of weak upscaling. Another one to seize the opportunity of a stronger involvement of the public sector. One strategy could be to start by creating place-based innovation ecosystems in robotics in a number of European regions. For this to happen, regionally targeted innovation and industry policies should be implemented aligned with Industry 4.0 policies and Smart Specialisation strategies.

In the ensuing discussion, the panellists debated the question, **how the situation in Europe in will evolve in the coming 5-10 years assuming there is no policy intervention**, and what would be necessary to make a difference?

For industrial robots, Helge Holm-Larsen foresees a further consolidation of the market around the established manufacturers. In this mature

market, he sees the role of the policy maker to defend the position of European players. For service robots and co-bots, however, the market is not consolidated yet. This market is expected to grow significantly and the policymakers are urged to act in order to set a favourable framework so that these kinds of innovative products and markets are developed in Europe. These measures should not be focussed narrowly on the R&D of the sector; it is equally important to invest in state-of-the-art digital infrastructures, including more bandwidth.

In the scenario that Europe is not taking an active policy intervention, Laszlo Hradszki predicts that the robotics sector may suffer a gradual decline similar to the European ICT sector, where a couple of decades ago we passed from producing ICT products (e.g. mobile phones) and components (e.g. microelectronics) in Europe to importing them from abroad. Here, active policy intervention could influence particularly the future of co-bots and service robots. The reason being that both the suppliers and the main market of service robots and co-bots are SMEs. SMEs are notoriously more fragile than larger companies because the return investment is longer and riskier for R&D intensive products. Policy makers can contribute to promising SME to scale-up, to consolidate their business and to gain more market weight in a shorter time and more sustained manner.

Europe should enable targeted instruments to create and nurture a vibrant ecosystem for robotics start-ups.

Zoltan Csefalvay pointed out that, while in the EU it is more difficult to scale up businesses than in the US and China due to its incomplete internal market, different languages and diverging legislation in the Member States, its diversity and the way Europe evolved independently also has also some advantages. One of them being that the R&D capacity is very high and more evenly distributed across and within the Member States than in the USA or China. In fact, all European countries have numerous public and private research institutions, many of which are conducting both excellent basic and applied research. While Europe is good in developing technologies, it must improve how it commercialises these technologies and brings them to the market in a more systematic way.

Box 1
Case study of an Innovation Ecosystem: The Odense Robotics Cluster

The Robotics Cluster around the metropolitan area of the Danish town of Odense is a case study of a successful regional innovation ecosystem.

The Odense innovation ecosystem stands out due to its size and its assets. With close to 180.000 inhabitants, it is Denmark's third largest city and still relatively small with regard to other European innovation hotspots. Despite its relatively modest size, it has succeeded in setting up a vibrant and promising industry structure, based upon its pre-existing industrial base, technological capabilities and assets. The region used to host Denmark's largest shipyard, and when entering into decline due to fierce competition from Asian competitors, it succeeded in keeping hold of the technological capabilities and turn the constituents of the former shipyard industry into a prolific sub-supplier industries serving both the domestic and international market. In addition to the industrial tissue, additional regional assets comprise public institutions, such as the University of Southern Denmark with 30.000 students or the University Hospital with over 1000 beds and technological and human capabilities to perform more than 1.1 million treatments annually.

Odense's industrial transition into a Robotics Hub started early when the first signs of a declining shipyard industry appeared, and regional decision makers took the first steps towards defining an encompassing strategy. Albeit located outside traditional innovation metropolises in Europe, it has gained considerable momentum and placed Odense as one of the robotics hotspots in the world. The lessons from this case study inspired the initiation of a series of dialogues, led by Odense Seed and Venture, to mobilize all stakeholders around a shared vision. The participants of these dialogues soon recognised the potential of the emerging megatrend on robotics in general, and the opportunities of building on their existing infrastructure, techno-

logical capabilities and expertise to focus on collaborative robots, or co-bots, in particular. This vision materialized into a strategic multi-annual development plan, to be put into place by an expert team with a high degree of strategic and financial autonomy.

A key element of the Odense plan was to set up a seed and venture structure to bridge the gap between start-ups and investors. This structure permits start-ups to benefit from a thematically targeted incubator and accelerator programme on the one hand, and seed money and the services offered by dense network of peers on the other. Odense Seed and Venture acts as a facilitator taking care of targeted measures to create a shared vision and external visibility, such as establishing regular investment summits and developing further the ecosystem by organizing internal seminars, generating trust building measures or offering ecosystem access to potential newcomers.

Currently, the Odense robotics cluster is composed by a dense network of producers (>50), integrators (>20) and component suppliers (>12), complemented by specialized sales / distributors and automation consultancy firms. While some companies cover a range of collaborative robots (Universal Robots, Smartshift, etc.), AI & Machine Learning (Happtec, Norbo Robotics) or Internet of Things solutions (Nord Modules, KK-tech, etc.), many of the companies have specialized in particular verticals, such as aerial drones, sub-sea drones, autonomous terrestrial mobile robots, medial robots, robots for construction or for food & agriculture. In other words, the industrial landscape covers the full range of application areas, from generic mobile service robots to robots covering a specific niche, such as bin-pickers.

An important factor contributing to the growth of the ecosystem is the collaboration of the industry with the local university, since knowledge and new ideas are moving from the university to the industry and vice-versa. The university provides a constant flow of highly qualified students and is also an entry point of professionals coming from abroad. This knowledge flow goes beyond the academia-to-industry relationship and encompasses also the intra-industry

ones. There is a kind of "revolving doors" setting, where employees naturally move from one company to another, which creates a positive reinforcement within in the cluster. In addition, having gained working experience at different places, some professionals embark on establishing their own businesses.

With regard to the size of the ecosystem, € 170M were invested in Danish robotics and automation start-ups in the period Jan 2015 to June 2020, of which the vast majority in the Odense Cluster (Figure 5). This represents the fourth largest investment by country in Europe.

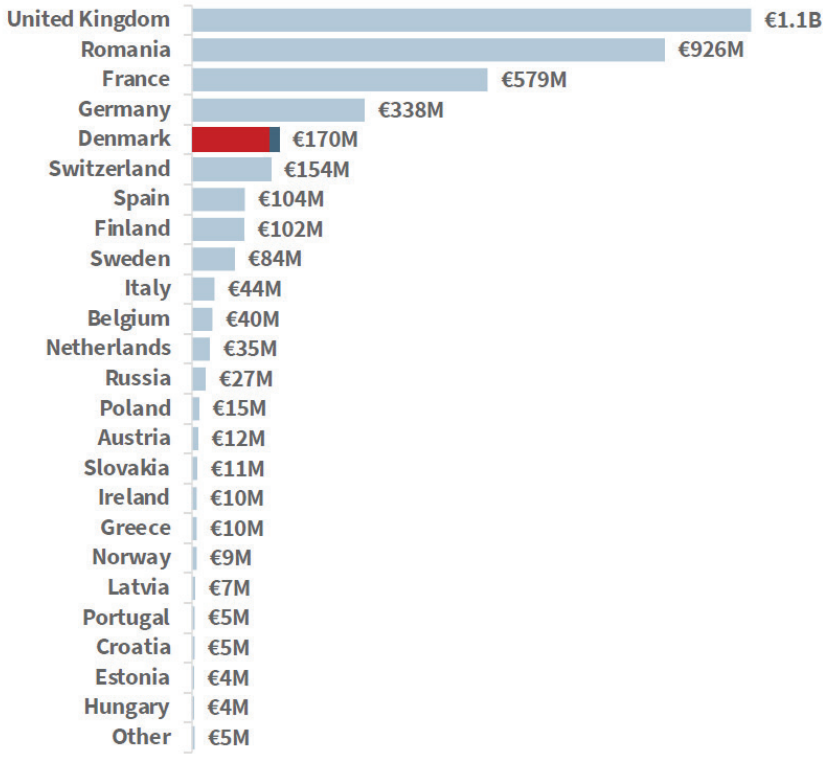


Figure 5

Investment in Robotics and Automation in Europe in the period 01/2015 – 06/2020.

Source: Dealroom

In the same reporting period, exits in the Odense Clusters totalled an amount of € 605M, of which most were born in two large exits. The first one was in May 2015 when US-based Teradyne acquired Universal Robots for € 263M, the second one in April 2018 when buying MiR for € 137M. Interestingly, the exit capital was reinvested again into the local ecosystem and therefore reinforced it. Beneficiaries of reinvestments were newer start-ups such as Smooth Robotics, LifeScience Robotics, Nord Modules, Kubo, OnRobot, Rokoko, or Unicontrol.

These exits and reinvestments are tangible key indicators of the functioning of the ecosystem. Odense Seed and Venture, in its role of enabler in the ecosystem, monitor these and other KPIs, communicate them, and take corrective measures when necessary. For facilitating and enabling the work, it is indispensable to continue to count upon a solid stakeholder support in order to maintain the focus and implement the strategy. Only in a realm of trust and a good track record, Business Angels are willing to co-/re-invest and enable larger Venture Capital firms to embark in larger deals.

Robotics and automation is a capital- and resource-intensive sector where investments in research and development need to be provided during a sustained period before returns do materialize. Similar to other "deep tech" areas, the financing flow should not get interrupted during the R&D period; otherwise, promising concepts do not reach manufacturing maturity and seed investors do not get full return of their initial investments.

In addition to the funds required to sustain the development phase, decision makers should also guarantee an operational framework that enables new developments.

In conclusion, the Odense robotics and automation community has reached a global position which attracts high-potential entrepreneurs, industrial players and investors, which together create a constant output of new start-ups and collaborative activities. This community acts as a self-sustained innovation ecosystem, effectively competing with their peers in the US and Asia.

4
ASSESSING THE SOCIAL IMPACT OF AI AND ROBOTICS

This panel looked more broadly into **Artificial Intelligence (AI) technologies and robots**, considered as embodied forms of AI, and addressed the related social and ethical impact. The panel was chaired by Emilia Gómez and framed in the context of the HUMAINT project she is leading, where the opportunities and risks of AI systems are studied together with how they impact human decision making and cognitive and socio emotional development (Gómez et al., 2021). The discussion was structured around three main topics: (1) the novel opportunities brought by AI and robotics; (2) the potential risks of these technologies; and (3) the methodologies and policies that should be implemented to embrace the opportunities and minimize the risks. The panellists were Susanne Bieller, from the International Federation of Robotics, Raja Chatila, from the Sorbonne University and Aimee van Wynsberghe, Alexander von Humboldt Professor.

4.1 OPPORTUNITIES BROUGHT TO SOCIETY BY ROBOTS

Susanne Bieller outlined some **benefits of industrial robots** (e.g. resilience, energy efficiency), professional service robots, able to provide **improved and reliable services**, and service robots for private use such as for entertainment. She also emphasized the **opportunities of robots in manufacturing to increase competitiveness** (e.g., automated production or performance optimisation).

Additionally, she referred to the future of work and quoted Paul R. Daugherty in saying that *"AI has the potential to re-humanise work, giving us more time to be human, rather than using machines"*. She highlighted the **need to reimagine work processes as a fusion of skills between humans and robots for creating better outcomes** (compared to working independently). Apart from the above, she warned the audience not to overestimate AI/robotics technology as today, what is simple even for children (e.g., sensorimotor and perception skills), is still difficult for machines (and vice versa). Human and machine intelligence should therefore be considered complementary.

Figure 6
Human and machine intelligence should be considered complementary.

Image: © European Union, 2020

Raja Chatila emphasized the **role of robots to support human well-being when replacing people in costly, difficult, dangerous or boring tasks**. This clearly contributes to an increase of societal well-being, productivity and sustainable economic growth. In addition, the use of robotic technology can also bring further rights and freedom for people who, for instance, have problems of autonomy, cannot drive, etc.

It must be ensured that machines are developed to be robust, reliable and dependable.

Finally, Aimee van Wynsberghe emphasised that robots are, in general, having a strong impact on human well-being as this sort of technology is being applied in an increasing number of ways in society.

4.2 CHALLENGES AND RISKS BROUGHT BY AI AND ROBOTS

Raja Chatila mentioned **some potential risks with respect to the physical operation of the robotic systems**. Robotic technologies imply risks as any other technology interacting with humans, so it **must be ensured that machines are developed to be robust, reliable and dependable** and that their design and development should comply with human rights values. Furthermore, any sort of delegation of decision-making should be done in a dependable manner. He also mentioned that there are additional risks with respect to the deployment of the system, with respect to the labour market, where he outlined that there will surely be some level of destruction of labour-related tasks or

jobs, plus some sort of substitution / transformation / creation of new jobs. However, it is very difficult to predict accurately how the balance will be.

One of the main points mentioned by Aimee van Wynsberghe was the **negative environmental impact of both robotics and AI developments.** In addition to the prevailing risk assessments, she highlighted the usually neglected costs paid in the development and deployment of AI systems and robots including software resources, computing costs, (recycled) materials, waste, carbon footprints, power consumption, waste, etc. She also highlighted the need to **have recycling plans** and warned about the several internalities and externalities in terms of costs that are paid throughout the life-cycle of this sort of systems which fall differentially on different individuals and countries and vary in magnitude.

4.3 METHODOLOGIES THAT WE NEED TO BUILD TRUST ON AI AND ROBOTS

Susanne Bieller pointed out several focus areas to shape trust in the use of robots at work such as **building methodologies to keep humans in command,** for human-robot collaboration and for fusion of skills from human and robots; getting young people involved in STEM subjects; inclusion and participation of the less-favoured segments of the society. She also provided some take home messages in this respect: **although robots and AI can support decision making, responsibility stays with humans/organisations** developing and using the systems, the society should be aware of the risks, but also seize the opportunities, we need to use our competences and address real market needs, and education and skills are the most important elements to build trust.

Prof Raja Chatila outlined **trustworthiness, robustness, safety and compliance with human rights as the main pillars when developing (AI) software for robots**. In this regard, he pointed out that people developing robots should significantly learn from other areas such software engineering where there are usually very strict standards, certifications or testing tools in place concerning all the design and development phases. He stressed that this topic is attracting a lot of attention from international organizations (e.g., OECD, IEEE), which

are already working towards the definition of implementing strategies, methodologies, and procedures for the development of trustworthy AI systems and robotics.

Figure 7

Trustworthiness, robustness, safety and compliance with human rights as the main pillars when developing (AI) software for robots.

Image: © European Union, 2017

Aimee van Wynsberghe presented some ideas on how to identify and address ethical risks. She suggested that **companies and organisations should think about what could go wrong when implementing, purchasing, or using robotics/AI technology**. In this sense, an **ethical technology assessment should be carried out before deploying AI/robotics technology**. And this should be carried out by using one's "moral imagination" to think what could go wrong in terms of the EU values and fundamental rights such as freedom, democracy, equality or human rights. **Incorporating ethics in the design process** as well as in the implementation phase of any AI/robotics-related developments or product **is nowadays a crucial part of the design process**, not as an afterthought but as something intrinsic and embodied in the design phase. This procedure needs **interdisciplinary views**, incorporating ethicists in the design teams, embedded in the organisation, performing ethical technology assessments, and asking questions about how to align the developments with European values and goals. She finally suggested that funding for these assessments should come by public and independent bodies so that the exercise can be performed with job security and impartiality.

As a conclusion of the panel, the following elements can be highlighted: the need to assess opportunities and risks from the very beginning of

the uptake process of AI and technology, and to establish the proper mechanisms for truly human-centred and trustworthy AI and robotics. In addition, research, beyond the risks-opportunities balance, on the transformative power of AI and robotics in society and how they affect EU values and fundamental rights is needed.

5
HUMAN-ROBOT INTERACTION AND ROBOTICS IN EDUCATION

This panel focused on aspects of the current state-of-the-art of research on **Human-Robot interaction** and included reflections about the impact of robots on human development and education. The panel was chaired by Vicky Charisi, who is leading the JRC's work on child-robot interaction with a focus on the impact of embodied robotic artefacts on child's development (e.g. Charisi, et al. 2020; Charisi, et al. 2021a). The discussion included perspectives of research on (i) the impact of robots on human behaviour in human-robot joint tasks, (ii) the emerging technical challenges for the design of robots suitable to interact with humans and (iii) the identification of policy directions in the field of robotics in education. The panel consisted of Tony Belpaeme, from the University of Ghent, Stéphan Vincent-Lancrin, from the OECD and Hae Won Park, from the Massachusetts Institute of Technology.

A fast-growing area of application in robotics, during the last decade, is that of **robotic artefacts especially designed to interact with humans** in a socially appropriate way. More recently, we observe an **increase in robotic platforms especially designed for children**, ranging from simple robotic toys to more advanced social robots. The scientific area that explores the emerging design principles, the corresponding technical developments in robots for children and the impact of robots' behaviour on children's development is framed as the particularly multidisciplinary field of child-robot interaction. This field is grounded on and considers two main paradigms, (i) robots that can be used as a tool for children's development of computational thinking

and programming skills and (ii) robots that can provide cognitive and social support for children's learning and development and are especially designed to interact with children in a socially appropriate way. In several cases the line between these two types of applications is blurred.

Figure 8

Recently, we observe an increase in robotic platforms especially designed for children, ranging from simple robotic toys to more advanced social robots.

Image: © European Union, 2017

The panel discussion aimed to reflect on the available scientific results and the emerging considerations in the field of child-robot interaction and robotics in education. The specific topics of discussion were motivated by (i) the Digital Education Action Plan 2021-2027 of the European Commission[5] which aims to foster the development of a high-performing digital education ecosystem for Europe and (ii) the current global initiatives on Artificial Intelligence and Child's rights, such as the Policy Guidance by UNICEF[6] which seeks to raise awareness on child-centred approaches in the design, development and use of AI for children with a focus on children's fundamental rights. Around the above-mentioned axes, throughout the discussion of this panel, several inter-connected narratives emerged.

5.1 SCIENTIFIC DEVELOPMENTS IN THE FIELD OF CHILD-ROBOT INTERACTION

First, this panel discussion sought to give an overview of the scientific contributions in the field of human-robot interaction and robotics in education. Tony Belpaeme emphasised the fact that **social robots are highly likely to have a profound impact on children and young**

people, especially through entertainment and education. Robots, due to features that trigger social interaction are persuasive and can have a significant impact on human behaviour (Bartneck, Belpaeme et al., 2020). Belpaeme mentioned examples from various contexts such as in cardiac rehabilitation therapy, in children that are diagnosed with diabetes and in second language learning. Even more, he referred to one of the most well-researched areas in child-robot interaction with robust results which highlight the **effectiveness of social robots for diagnostic and therapeutic interventions for children with autism**. On a similar line, the work led by Park utilises existing theories of social learning and highlights the fact that **children's interaction with other agents, including robots, improves efficiency and retention in learning** (Park et al., 2019). Based on these theories, Park has been working on developing personalised social agents for children's learning. Personalisation in child-robot interaction can take various forms ranging from cognitive interventions to social interaction to affective bonding. With a personalised robot behaviour, children seemed more engaged and showed higher learning gain than when interacting with a robot in the role of a naive or expert. Lastly, Dr Stephan Vincent-Lancrin indicated that even though robots in specific close-ended settings can facilitate children's learning, the **teaching practice requires the combination of a large number of skills which is not possible for a robot to perform yet** (Vincent-Lancrin et al., 2020). He indicated that recently there is a sharp increase in the *ed-tech* investment on intelligent technologies with China leading the road into wide-spread *ed-tech* adoption.

The need for a systematic reflection on child-robot interaction and children's rights seems relevant for responsible and child-centred developments in robotics.

5.2 CHALLENGES AND FUTURE DIRECTIONS FOR ROBOTICS IN EDUCATION

Researchers in the field of child-robot interaction have been already working on emerging challenges such as the protection of children's privacy and prioritisation of their well-being. During the panel discussion, it was agreed that practices in child-robot interaction show that specific challenges might emerge. Tony Belpaeme highlighted that because of the potentially strong social influence of robots protective measures, such as a **regulatory framework, should be put in place to minimise the risk to children during social child-robot interaction**. However, further research is needed, especially regarding social reinforcement learning, which focuses on the ways robots learn from

how children engage in social learning and how robots should take into account differences on children's engagement in learning, as mentioned by Dr Park. To address these concerns, Dr Vincent-Lancrin proposed a set of recommendations that can be considered by all the involved stakeholders.

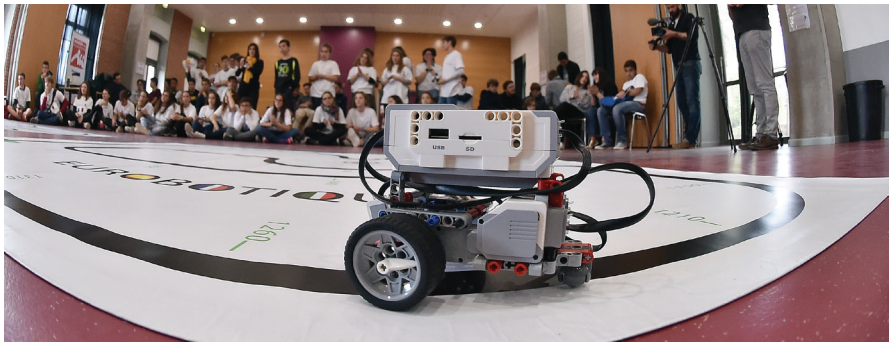


Figure 9

Protective measures, such as regulatory frameworks, should be put in place to minimise the risk to children during social child-robot interaction.

Image: © European Union, 2017

The development of any solutions should include end-users (e.g. teachers and children) in order to ensure the usefulness of the solution. In this way, it will be ensured that these solutions improve the learning outcome and children's well-being by supporting interventions that solve existing problems. This should be done **in a way that promotes equity** which means that all the involved stakeholders should be aware of the existing digital divide and work towards technology that contribute to its mitigation. Regarding the technical integration of social robots, fairness, transparency and data protection should be prioritised in order for us to ensure that the technology which is currently developed supports and promotes every child's rights in educational and play environments.

The anthropologist Sherry Turkle has repeatedly reminded us through her oeuvre that it is in our relationships with one another — not technology — that we find our most important source of meaning (Turkle, 2017). However, digital technology, artificial intelligence and robotics will have an increasing role in the ways human develop and behave. For this reason, the need for a systematic reflection on child-robot interaction and children's rights seems relevant for responsible and child-centred developments in robotics (Charisi et al., 2021b). We consider this panel discussion as an opportunity to highlight that researchers in the field of human-robot interaction have tried to systematically investigate the impact of social robots on human development for more than fifteen years and with their scientific research and the emerging evidence contribute to the design of robotic technologies that solve

existing problems and support human well-being. In this context, the community of human-robot interaction recognizes that there is a need for policy support with specific regulatory actions and multi-stakeholder synergies, including the participation of children that together with the scientific evidence will contribute to the development of a trustworthy ecosystems of AI and Robotics for human societies.

6
KEYNOTE SPEECH BY COMMISSIONER GABRIEL

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Ladies and Gentlemen,

Thank you for giving me the opportunity to address you to speak about an important subject at the centre of a societal and economic transformations.

There is no overstatement from my side recalling the big impact of Artificial Intelligence and robotics and today, I would like to talk about the important **role that research, innovation and education** already play and will increasingly play in the domains of robotics. Robotic technology is common in industrial automation for physical tasks and represent an **important support for humans to perform heavy repetitive tasks**. These robots operate mainly in isolation with limited and unidirectional interactions with humans, for the purpose of functional control. However, this is changing, and changing fast …

Powerful artificial intelligence is being embedded in robots, which increases their capabilities with more accurate sensors and actuators, larger memory and processing capacity. As reported by the International Federation of Robotics, while **industrial robotics has been one of the prominent areas of robot applications**, there is an **increased**

focus on applications requiring human-robot collaboration. There is an important economic driver. Accounted for a meagre 3.24% of total installed robots in 2018, collaborative robots are projected to take about 30% of the market by 2027.

We have to set the conditions for a human-centred approach and link it with the digital and green transitions for a robust economic recovery of Europe.

Europe is a global leader in the field with pioneer SMEs and we need to develop robots for people, operating in synergies with humans in fields in which robots and humans work together. This is very important, for instance, in the context of **preparing Europe for future large scale threats**, including pandemics, where robots can, for instance, help dealing with life-threatening situations in hospitals.

Moreover, this is not the only field in which robots can contribute. In our **fight against climate change**, they can lead to energy-efficiency in industrial production. They can also support and perform experiments in conditions that are inaccessible for humans **leading to breakthroughs in science**.

Having this in mind and facing the global trend and the challenges ahead of us, we have to **set the conditions for a human-centred approach and link it with the digital and green transitions for a robust economic recovery of Europe**.

Evolution of robotics with socio-economic impact

We expect robots to help our societies in achieving successfully these transitions and they are expected to have a **concrete and direct impact on the daily lives of all the citizens**. Given the potential transformations that robots can induce in our lives, that science fiction writers explored decades ago in all sorts of futuristic scenarios, there are growing expectations and concerns from the wider society.

To take stock of this, the Commission has published a report related the **public perception of robots**: Seen by many as unwanted substitutes of humans and 'job takers' in the pre-COVID-19 situation, may have changed during the current health emergency. In the post-COVID-19 context, **autonomous machines are now seen as useful "operators"** able to replace humans on tasks such a monitoring social distancing but also as patients controls, temperature measurements and delivery of medications in contaminated environments. This **change in the public perception of robotic platforms in the COVID-19 context** can drastically boost their adoption in many areas in the near future.

This is the perfect illustration that we **need evidence-based policy in this field to understand the impact of robot interventions on human behaviour**. The Commission in collaboration with academic institutions, international organisations and industry is working towards this. We need to advance in our understanding and knowhow on machine learning, artificial intelligence, computer science, computer vision, and complex robot control systems. These foundations will have to incorporate mechanisms to adapt to a dynamic human environment with its highly complex behaviours.

To achieve this step, technological developments have to look for knowledge in areas such as cognitive psychology, sociology, machine learning, and develop interdisciplinary approaches to human-robot interaction. At the end of this process, the **objective should be that robots operate within human environments in ways that enhance our humanity**. It is therefore important and timely to consider the possible social and ethical implications and to deepen our understanding of the consequences of robotic technology. Simply put, **robots have to follow our common social values and goals without leaving anyone behind**.

We need to be proactive on this matter and by considering human-centred designs and developments so that we can meet the prerequisites for Trustworthy Robots for our society and ensure that European values are included in their design. Human sciences, underpinned by education and culture, are essential not to leave it to a technology-centric development.

Regarding this imperative, **the new European Bauhaus is an important framework** we are developing that could contribute to a human-centred approach in this area. By addressing in the wider context of the Green transition of our economies and societies, and closer to the citizens, **it can provide the informed paths to introduce robots in the daily life of citizens** to support their efforts to make our life greener while achieving the digital transition.

In the context of the twin green and digital transitions, **the role of robots in society will keep expanding and diversifying**, bringing with it a host of issues surrounding the relationship between robots and humans. Exciting scientific and technological developments are being done where robots are designed to accompany humans in artistic expression like music improvisation, dance and painting. From another example in the field of health, we have social robots enhancing the diagnosis and therapy of social deficits in autistic children by mimicking basic human facial expressions in a predictable way for the autistic children.

These examples are showing us that the **impact goes well beyond industrial productivity** and **it is our responsibility to make the robots ethical and safe to be socially accepted**. This is why the Commission is currently working on setting the scene for the development of Trustworthy Artificial Intelligence. The High Level Expert Group on Artificial Intelligence has identified a set of ethical guidelines which should be taken into consideration for the design and development of human-centred and Trustworthy Artificial Intelligence. These guidelines are also extremely relevant for robots because they embed AI in their functioning.

It is now certain that **the use of robotics and AI will shape global innovation developments** and we need to be prepared. We have the instruments to invest in new technologies and to boost advanced competences. **Education plays a key role** also from the user perspective

which can benefit from advanced man-machine interfaces based on virtual and augmented reality. The fusion of the real and artificial is a real challenge as we can see already with the internet and it will require skills for citizens to live in such an environment.

The Commission Joint Research Centre is conducting research on **child-robots interactions** to allow critical thinking from the children while empowering them in their relation towards robots. This process of **developing trust and increasing acceptance towards robots is key** and this is an area to be further developed in the Digital Education Action Plan. Firstly, by fostering a forward-looking digital education eco-system including robots to help teachers for example, they will become part of a routine for teachers and students. Secondly, by enhancing digital skills and competences for the digital transformation, people will have a better understanding of robots and of their capabilities.

This long-term effort on education is critical. If we look at it from the perspective of future competitiveness in the robotic-related areas, **we will need investments in R&I**, as well as **in large-scale testbeds** and, in parallel, to **develop a highly skilled community**. This is the path to modernise our educational systems along with the shift in the job demand. Let me recall that 45% of the created jobs in the EU until 2030 will be in sectors requiring highly skilled people and the robotics sector is certainly one of these. Our objectives for **European citizens' digital literacy** are therefore ambitious and include AI and robotics.

On the other hand, we also want to **keep making the EU a leader in robotics innovation**. Since December 10, Europe can now count on the largest transnational programme ever supporting research and innovation worth more than €95.5 billion for the next seven years. This represents an increase of 30% in comparison to the previous programme at 27 Member States! As manufacturing, process and resources industries together account for about 60% of total investments in robotics, **strategic cooperation between public and private actors is necessary** to leverage all European forces to respond to the needs of Member States and stakeholders.

Therefore, we proposed **two Horizon Europe partnerships linked to robotics**. Under the pillar addressing "Global Challenges and European Industrial Competitiveness", the "AI, Big Data and Robotics" and the "Made in Europe" partnerships will create opportunities for funding to

develop and deploy next generation robotics and autonomous solutions, directly supporting our industry and our jobs.

In addition, with the **Communication on "A new ERA for Research and Innovation"** adopted in September, the Commission **sets a renewed framework for research in Europe**. This new ERA defines concrete actions for the wider research and innovation communities and organisations, from all disciplines, for industry, for Member States and for Regions.

In parallel, I also launched a **Joint Action Plan with the Committee of the Regions (CoR)**. This first Joint Action between the CoR and the Commission is here to improve the uptake of best practices between European regions to boost their research and innovation capacities while fostering synergies between those facing the same issues.

For the robotics sector, **the new ERA and the Horizon Europe programme will help strengthen EU's competitiveness based on cutting-edge research and innovation activities**. As an intensive deep tech R&I sector, robotics is also covered by the European Innovation Council, in particular through the EIC Accelerator supporting breakthrough innovations. **The European Innovation Council brings a radical new approach to support innovation Europe, funding start-ups by taking direct equity**. It has notably funded the projects like TIMESTORM. It developed leading edge technology predicting human expectations and taking into account behaviours and psychological states to develop human-machines synergies for robots to coordinate their actions and collaborate with humans.

Allow me to conclude by saying recalling Arthur C. Clarke well known quote that "*Any sufficiently advanced technology is indistinguishable from magic.".* It applies to all technology and surely can see it in the incredible advances in Artificial Intelligence and robotics. **We are starting decades of proliferation of these technologies permeating our activities and our lives.**

The role of robots in the society keeps expanding and diversifying, bringing with it a host of issues surrounding the relationship between robots and humans. While the field of Human-Robot Interaction is relatively new, there is already concrete evidence have a direct impact on human behaviour and consequently to human society.

I strongly believe that **together, we can lead making robots always more beneficial for people while creating opportunities for our economy**. In our future, I can see an underlying infrastructure with AI and robotics, fostering our common well-being and **strictly compliant with our social and ethics values**.

Thank you for your attention.

7
KEYNOTE SPEECH BY VICE-PRESIDENT ŠEFČOVIČ

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Good afternoon to you all.

Thank you for inviting me to speak at this event about the future of robotics and artificial intelligence, a highly important policy area. Over the past couple of days, you have been discussing issues mostly from the **'science-for-policy'** point of view; how the science you do can have a more direct impact on policy. I would like to take a different tack and talk about **how policymakers can make the best use of technology for society.**

The European Union has long **been a global leader in the research and development of robotics and AI**. Through more than 120 research projects and other coordinated action, we have worked to promote and intensify knowledge sharing and cooperation across the entire robotics ecosystem. Robotics can **make our industry more competitive and sustainable**, while helping to **solve major societal challenges**. But this field now extends **well beyond industry**. For example, there is **a growing emphasis on 'co-bots'**, collaborative robots, which are set to become 30% of the market by 2027.

The **impact of robots on our societies will be enormous**. This is true both in what they can do – such as help us successfully navigate the twin green and digital transition – but also in how people perceive them. According to a European Commission report, **robots are increasingly seen as trustworthy**. Their role helping in hospitals during the COVID-19 pandemic has no doubt boosted this.

The European robotics sector is already world-leading in terms of technological excellence. But to make it more resilient, and to increase our open strategic autonomy, we must continue to invest in research and development to advance European interests and strengthen competitiveness.

Today, I would like to outline how we can ensure **a resilient EU approach to robotics**, and **how robotics contributes to the EU's overall resilience**. The EU finds itself at **a pivotal moment**. We are not only looking to drive forward our **recovery** from the COVID-19 pandemic, but also to **build a green, digital and fair future**. In other words, we have been presented with an opportunity **not just to bounce back but bounce forward**.

And we have armed ourselves with **the right tool in the form of 'NextGenerationEU'**, our historic 750 billion euro recovery plan, which we presented together with a revamped long-term budget. But making the most of our resources is not necessarily straightforward. That is why we are **making better use of strategic foresight** in high-level policymaking.

Strategic foresight is the art of **developing intelligence about the future to inform the actions of today**. It is about anticipating, exploring and acting. We must consider not only what needs to be reconstructed today but also **what is required to build the EU of the fu-**

ture, which we cannot expect to become less disruptive. So we need to **apply strategic foresight to resilience**, which will help us **maintain Europe's standing as a global, responsible leader, an economic frontrunner and role model** shaping the world.

Resilience has become our **policy compass**, which is why it was the focus of the Commission's first annual **Strategic Foresight Report**, published last September. The Report analysed the **EU's resilience capacities, vulnerabilities and opportunities** in four dimensions: social and economic; geopolitical; green; and digital.

So **how does robotics fit** into these four categories?

First, **social and economic resilience**. Technology has always played a role in raising both productivity and living standards. We can see this today with the **increased use of robots in many sectors**, **like agriculture** – where AI can assist in crop monitoring and weed control – and **healthcare**, where robots assist in surgery and exoskeletons support rehabilitation.

But for many, **concerns remain about how many jobs robots will take away** from humans. It is true that the rise of **robotics could seriously disrupt existing business models** and that millions of jobs – most notably lower skilled ones – might be at risk. While **this will vary** across sectors and regions, robotics and AI **can also help create new jobs** in their stead, improved in both pay and quality.

So resilience here means investing in people, in **the skills and jobs of the future** – especially those linked with our green and digital transitions – while putting an increased focus on **wellbeing** as a barometer for the health of our society. One concrete example: **our fast-growing battery industry**. According to industrial estimates, some **800-thousand workers will need to be trained** – that is reskilled or upskilled – **by 2025** to meet its labour needs. But it is **not just about ensuring the right level of technical skill**. With 45% of new jobs in the EU by 2023 set to be highly-skilled, in sectors like robotics, we also need to **ensure people are equipped to live in such an environment**, for example by training children to develop critical thinking towards robots.

Second, turning to geopolitical resilience, which means **boosting Europe's open strategic autonomy** in an interconnected and interdependent world, in order to secure its place in diversified next-generation

global value chains. Take again our work under the **European Battery Alliance** as well as the **European Raw Materials Alliance**. This can both **improve cost efficiency** and **prevent over-dependency in strategic areas**, including AI and robotics, which play important roles in sectors such as cybersecurity, space and defence.

While **open to foreign investment, Europe should also seek to safeguard its key assets**, including its critical companies and infrastructures, notably through the Foreign Direct Investment Screening mechanism. The **EU's regulatory capabilities are also important** in international cooperation. We should aim to lead the way in developing trustworthy and human-centric technology. Ultimately, we should look to **European standards to have a significant influence on emerging global ones,** through bilateral relations and action in multilateral forums.

Third, the green dimension of resilience. This means **making the most of the green transition** – for example, exploiting our urban areas to the full by repurposing office buildings and car parks to bring nature back to cities. But it also means **utilising technology to meet our ambitious plans** to become the first climate-neutral society by 2050. For example, industrial robots can help us **reduce waste and increase efficiency**. And AI and robotics can **significantly reduce the weight of factors, such as location of production**, with delivery capability, sustainability and the carbon footprint of transport increasingly coming into focus.

In this, **we must take into account the entire impact of new technologies on the environment**. For example, the carbon footprint of the production of ICT devices and the energy consumed by our digital lifestyles throughout the life cycle of our devices. Notably, I believe **'science for policy' could contribute greatly to greening the ICT sector**, and AI and robotics in particular, by supporting the development of standards and best practices.

Finally, there is the digital dimension of resilience. We must continue **to develop a strong ecosystem in Europe** by investing into our digital infrastructure, exploiting industrial data or addressing regulatory complexities. And at the same time, by fostering trust and participation. Robotics and AI will play a key role in this. **The European robotics sector is already world-leading in terms of technological excellence**. But

to make it more resilient, and to increase our open strategic autonomy, we must **continue to invest in research and development** to advance European interests and strengthen competitiveness.

Having **funded one of the world's largest civilian robotics programmes** under Horizon 2020, the EU will maintain a strong focus on robotics and AI research under the **Horizon Europe programme** – with funding of 20 billion euros per year this decade on average, public and private investment combined. In addition, the AI part of the Digital Europe Program will devote over 2 billion euros to technologies like robotics.

The new **Public-Private Partnership in AI, Data and Robotics** will take this to the next level. It will foster cross-pollination of research within these three communities as well as between industry and users, and will contribute to the overall resilience of the robotics ecosystem.

Making the most of **new technologies,** not least in the field of AI and robotics, is **paramount if we are to overcome the challenges** – and make the most of the opportunities – which stand before us. I strongly believe that making **greater use of strategic foresight** can help put your incredible work in this field to best use.

Thank you.

8
CONCLUSIONS

As shown during the discussions of the conference but also during the different sections of this report, **robots represent both a challenge and an opportunity for human society in general and for Europe in particular**. Robots can be used to support humans in the performance of tedious, dangerous or hazardous tasks; they can improve efficiency and productivity, especially if combined with AI; they can help us increase our societal welfare and enhance the way we learn, allowing us to develop our potential to the maximum.

At the same time, robots, once out of the "cage" of their classical industrial application and, especially, in combination with powerful AI applications, can represent a real challenge to our society. From massive substitution of jobs to the de-humanization of the labour market, having workers being managed "by algorithms" to their use of for mass-control or for serious infringements of fundamental rights, especially in children. The different discussions during the conference led to a main conclusion. **The only way to ensure that a massive societal uptake of the robotic technology maximizes benefits and minimizes issues is by means of a decisive, agile, horizontal, coordinated and multidisciplinary public intervention.**

Additionally, and as the **EU is a leading actor in the robotics industry,** producing almost one third of all robots worldwide, whatever public intervention is launched by the European and national administration, it would have to ensure that **Europe can retain that role.** Robots will be instrumental for the successful deployment of other disruptive technologies, like Artificial Intelligence, and will also be massive producers of data which, when used with full respect of European legislation and EU rights, can boost the deployment of the European data economy. As data, Artificial Intelligence and robotics are massively interconnected and are at the forefront of the digital transformation, a leading role in one of them can help to accelerate the European role in the others.

We know this decade is Europe's digital decade, and **we remain convinced about the extraordinary potential that the robotics industry brings to ensure that Europe is fit for the digital age.**

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Box 2
Main takeaways

— Regarding the impact of automation and robots on employment, policy makers should keep a balance between the job destruction and the job creation potential of this technology. This requires a broad portfolio of policy initiatives to ensure that no one is left behind, including the strengthening of the welfare state, investment in life-long education and in digital infrastructure.

— Robotics technologies typically originate in research institutions and are then exploited in tech companies. Europe, with its strong basic research, could focus on the beginning of the robotics value chain, to ensure competitive advantage in the making of robotic technologies.

— For service & collaborative robots, policy makers should put a stronger focus on robotics in regionally targeted innovation and industry policies or on developing new and targeted instruments; create and nurture vibrant ecosystem for robotics start-ups to tackle the persistent problem of their weak upscaling; and seize the opportunity of a stronger involvement of the public sector.

— The massive adoption of robotics technology should ensure that machines are developed to be robust, reliable, and dependable and that their design and development should comply with human rights values.

— Policymakers should also consider the negative environmental impact that massive deployment of AI and robotics technologies could bring. They should ensure that recycling plans, to reuse parts and components of the deployed machines, are already considered in the design and development phases by manufacturers.

— It is important to build methodologies to keep humans in command, for human-robot collaboration and for fusion of skills from human and robots. Robots and AI can support decision making, but responsibility stays with humans.

— Companies and organisations should think about what could go wrong when implementing, purchasing, or using robotics/AI technology. In this sense, an ethical technology assessment should be carried out before deploying AI/robotics technology.

— Policy makers could consider a regulatory framework to minimise the risk to children during social child-robot interaction.

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LIST OF ABBREVIATIONS AND DEFINITIONS

— AI	Artificial Intelligence
— CEO	Chief Executive Officer
— CoR	Committee of the Regions
— COVID	Corona Virus Disease
— EU	European Union
— ICT	Information and Communication Technologies
— IPO	Initial Public Offering
— R&D	Research and Development
— RPA	Robotic Process Automation
— SMEs	Small and Medium Enterprises
— US/USA	United States of America

NOTES

[1] COM(2018) 795 final, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:795:FIN

[2] https://digital-strategy.ec.europa.eu/en/policies/european-approach-artificial-intelligence

[3] Impact Assessment study, https://op.europa.eu/s/oTZR

[4] European Commission Staff Working Document: Liability for emerging digital technologies, https://digital-strategy.ec.europa.eu/en/library/european-commission-staff-working-document-liability-emerging-digital-technologies

[5] https://ec.europa.eu/education/education-in-the-eu/digital-education-action-plan_en

[6] https://www.unicef.org/globalinsight/reports/policy-guidance-ai-children

ANNEXES (ANNEX 1. CONFERENCE PROGRAMME)

Wednesday 27th January 2021		
15:00 - 15:15	Opening	Manuel Heitor, *Portuguese Minister of Science, Technology and Higher Education*
15:15 - 16:00	Panel Discussion	Economic impact of robotisation on employment, productivity and competitiveness
16:15 - 16:45	Keynote: **The industrial perspective**	Bernd Liepert, President euRobotics aisbl
16:45 - 17:30	Panel Discussion	How the robotics industry can support the EU recovery

Thursday 28th January 2021		
15:00 - 15:30	Keynote: **The impact of robots on society**	Commissioner Mariya Gabriel, *Innovation, Research, Culture, Education and Youth*
15:30 - 16:15	Panel Discussion	Assessing the social impact of AI and robotics
16:30 - 17:00	Keynote: **Social Robotics: Research, Ethics and Education**	Carme Torras, *Professor of Research, Spanish Scientific Research Council*
17:00 - 17:45	Panel Discussion	Human-Robot Interaction and Robotics in Education
17:45 - 18:00	Closing remarks	Carme Artigas, Spanish Secretary of State for Digitalisation and Artificial Intelligence

Friday 29th January 2021		
15:00 - 15:30	Keynote AI Robots and foresight	Maroš Šefčovič, *Vice-President, Interinstitutional Relations and Foresight*
15:30 - 16:15	Policy Round Table: **What regulatory framework is needed for EU robotics?**	Stephen Quest, *Director-General, JRC* Joost Korte, *Director-General, Employment, Social Affairs and Inclusion* Gwenole Cozigou, *Director for Sustainable Industry and Mobility, DG GROW* Roberto Viola, *Director-General, Communications Networks, Content and Technology* Paul Nemitz, *Principal Advisor in the Directorate General for Justice and Consumers*

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