Cost of non-Europe in robotics and artificial intelligence

Liability, insurance and risk management

STUDY

EPRS | European Parliamentary Research Service

Editor: Elodie Thirion
European Added Value Unit
PE 631.752 – June 2019

EN

Cost of non-Europe in robotics and artifical intelligence

Liability, insurance and risk management

Robotics is a wide and multi-faceted domain that crosses boundaries between many economic sectors and legal disciplines. The perception of a need for some kind of Europe-wide legal framework to accompany the development of robotic and artificial intelligence (AI) technologies is growing. A harmonised EU regulatory framework concerning liability and insurance regarding robotics and AI specifically could provide greater legal certainty and promote trust. It could also stimulate greater research and development activity by producers and increase the speed of uptake of these two new emerging technologies by consumers, resulting in a possible positive impact in terms of gross domestic product (GDP). Research suggests that, by 2030, EU GDP could be 0.04 % higher than it would otherwise be under the current regulatory framework.

EPRS | European Parliamentary Research Service

AUTHORS of the external study

This study has been written by Bob Martens and Jorren Garrez of DLA Piper UK LLP and Cambridge Econometrics at the request of the European Added Value Unit within the Directorate-General for Parliamentary Research Services (EPRS) of the European Parliament.

ADMINISTRATOR RESPONSIBLE

Elodie Thirion, European Added Value Unit

To contact the publisher, please e-mail: eprs-europeanaddedvalue@ep.europa.eu

LINGUISTIC VERSIONS

Original: EN

Manuscript completed in June 2019.

DISCLAIMER AND COPYRIGHT

PE 631.752
ISBN: 978-92-846-5184-9
DOI: 10.2861/522252
CAT: QA-01-19-611-EN-N

eprs@ep.europa.eu
http://www.eprs.ep.parl.union.eu (intranet)
http://www.europarl.europa.eu/thinktank (internet)
http://epthinktank.eu (blog)

Executive summary

'I am an optimist and I believe that we can create AI for the good of the world. That it can work in harmony with us. We simply need to be aware of the dangers, identify them, employ the best possible practice and management, and prepare for the consequences well in advance'.[1]

One of the most pressing issue for researchers, consumers, manufacturers and stakeholders concerning the rise of the robotics and artificial intelligence (AI) sectors lies in the uncertainty surrounding liability and the potential for damages to be incurred.

This 'Cost of non-Europe' report on liability and insurance related to robotics and AI aims to provide an insight into the regulatory gaps and challenges of the current liability and insurance frameworks in this field, as well as the potential benefits and opportunities of a harmonised EU regulatory framework. It has been prepared by the European Added Value (EAVA) Unit of the European Parliamentary Research Service (EPRS) for the European Parliament's Committee on Legal Affairs (JURI) in support of its legislative initiative resolution on civil law rules on robotics (Rapporteur: Mady Delvaux).

This study starts by providing a brief introduction to robotics and AI. It sets out the definition(s) used for these concepts and presents their emergence and their social potential in the EU, before describing recent EU initiatives in the field. These include recent legal and policy initiatives, from the framework programme for research and innovation 'Horizon 2020' to the Ethics Guidelines for Trustworthy AI.

Second, the study outlines the current regulatory frameworks regarding liability and insurance applicable to robotics and AI in the EU. The lack of specific EU or national regulatory frameworks regarding liability and insurance in the context of robotics and AI is noted. At EU level, in particular the Product Liability Directive is reviewed. At national level, both civil law and common law regimes are discussed.

Third, the study highlights the existing regulatory gaps and challenges in the current liability and insurance frameworks. In particular, robotics and AI are prevented from reaching their full potential in the single market owing to the absence of a specific regulatory framework regarding liability and insurance in the context of robotics and AI, at EU level as well as at national level, and the consequent need for actors within the field of robotics and AI to fall back upon the Product Liability Directive and national civil law rules regarding liability and insurance.

Several EU policy options are considered in response to the regulatory gaps and challenges identified. First, there could be no additional intervention, entailing the application of the existing regulatory framework to current robotics and AI issues. Second, the EU could intervene by enlarging the scope of the Product Liability Directive to tackle the barriers of the current regulatory framework identified in the limited scope of the Product Liability Directive. Third, a new specific regulatory framework at EU level could be introduced to avoid fragmentation of the single market in robotics and AI. In this context, two policy options are considered: (i) an 'electronic personhood' could be created, or (ii) a new specific regulatory framework based on the existing regulatory framework could be introduced, allowing a tailor-made approach to robotics and AI.

[1] Stephen Hawking, speech at the Web Summit on 6 November 2017.

The advantages of policy options aimed at introducing a harmonised, EU regulatory framework are to a large extent confirmed by the possible economic benefits and opportunities. A harmonised EU regulatory framework would stimulate greater research and development (R&D) activity by producers and increase the speed of uptake of these two essential new emerging technologies by consumers, resulting in a potentially positive impact in terms of gross domestic product (GDP). By 2030, EU GDP could be 0.04 % higher than it would otherwise be under the current regulatory framework.

However, the quantitative impact on the EU economy of harmonised regulation in the markets considered is highly uncertain, with some factors providing a positive effect and others negative. Overall, analysis of the scenario suggests that harmonised regulation would increase EU trade competiveness, bring a small increase in GDP and employment through increased R&D efforts, and bring a small decrease in GDP and employment once the wider economic impacts of robotics and AI are taken into account.

It is important to note that robotics and AI are wide and multi-faceted domains, crossing multiple legal disciplines. In order to provide EU citizens with an adequate EU regulatory framework relating to robotics and AI, as well as to promote the rise of robotics and AI in the EU, enabling it to become a global leader, coordinated legal action at the EU level would seem to be necessary.

Table of contents

Table of figures

Table of tables

List of acronyms

AI	Artificial intelligence
AI HLEG	High-level expert group on AI
CoNE	Cost of non-Europe
CPA	Consumer Protection Act 1987
E3ME	Cambridge Econometrics' global macro-econometric model E3ME
EC	European Commission
EPRS	European Parliamentary Research Service
EU	European Union
FDI	Foreign direct investment
GDP	Gross Domestic Product
JURI	European Parliament Committee on Legal Affairs
MEP	Member of European Parliament
MS	Member State (of the European Union)
R&D	Research and Development
SME's	Small and Medium-sized Enterprises
SPARC	The Partnership for Robotics in Europe
Study	Study on the Cost of Non-Europe in robotics and AI
SWD	Staff Working Document

1. Opening analysis (by EPRS)

1.1. Background and context

Robotics and artificial intelligence (AI) are becoming increasingly important more and more appliances operating interactively and autonomously to some extent. Although these technologies are advancing at an accelerating pace, society has yet to come to terms with what this will mean, just as it also needed time to adapt to the rise of internet 20 years ago. However,the public has a generally positive view of these developments, with 72 % of Europeans believing robots are good for society because they help people.[2]

The ambition of the European Union (EU) to promote innovation and foster competitiveness in the internal market makes robotics and artificial intelligence strategic sectors. On 16 February 2017, the European Parliament adopted a legislative initiative resolution on civil law rules on robotics,[3] drafted by Mady Delvaux (S&D, Luxembourg). The resolution calls on the European Commission to come forward with legislative and non-legislative initiatives in the field of robotics and artificial intelligence, and to submit a proposal for a legislative instrument providing civil law rules on the liability of robots and artificial intelligence. To support this demand, the Committee on Legal Affairs of the European Parliament (JURI) commissioned a series of studies and research papers on topics related to robotics and artificial intelligence. The first issue to be covered was liability, insurance and risk management related to robotics and artificial intelligence.

The main objective of this study is to provide a qualitative and quantitative assessment on the cost of non-Europe in liability, insurance, and risk management rules related to robotics and artificial intelligence. The 'Cost of non-Europe' studies are intended to evaluate the possibilities for gains and/or the realisation of a 'public good' through common action at EU level in specific policy areas and sectors. The cost of non-Europe in liability, insurance and risk management related to robotics and artificial intelligence analyses the current legal framework and its civil law implications, both in terms of contractual and non-contractual liability; it then identifies potential opportunities and challenges that liability, insurance and risk management rules would create within the EU robotics and AI market. Finally, it estimates the possible benefits and costs of the failure to take a common EU approach in this area, highlighting that the quantitative impact on the EU economy of harmonised regulation in the markets considered is highly uncertain.

1.2. Methodology

The study is based on information gathered from different sources and includes information from a review of primary and secondary EU legislation, international, peer-reviewed academic literature, policy papers and statistical data.

In addition, questionnaires were used to gather national information from various Member States. The questions on the standardised questionnaire focused, inter alia, on the existence of specific regulation, (discussions on) upcoming specific regulation, the current rules applied, and current barriers in the national jurisdiction, possible case law or studies.

2 Special Eurobarometer 427, Autonomous systems report, June 2015.

3 European Parliament resolution of 16 February 2017 with recommendations to the Commission on civil law rules on robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.2.2017.

The study relied both on quantitative and qualitative analysis of data. The parameters used for the econometric model, in particular the variables and assumptions and how they interact, are explained in Annex I.

1.3. Regulatory framework

1.3.1. Existing framework

Currently, there is no specific EU or national regulatory framework for liability and insurance in the context of robotics and AI. Under the existing legal regimes, robots and AI cannot be held liable themselves for acts or omissions that cause damage to third parties. Liability for robots and AI rests with the natural or legal person liable for them under general rules of law. Manufacturers, owners, or users of robotic technologies may indeed be held liable for damage caused by robots, in cases of negligence or if appropriate measures were not taken to prevent the robots' behaviour under rules of fault liability. They can also be held strictly liable for acts or omissions of the robot, for example, if the robot can be qualified as a dangerous object, where the general principles of the legal system applicable provides for liability in such cases, or if it falls under codified strict liability, such as product liability rules.

However, it may be difficult to prove the link between human behaviour and the damage caused by robotic technologies, particularly in cases where a person cannot distinctly control the actions of a robot. The damage may also be the result of a multitude of factors, or by emergent behaviours, i.e., modes of behaviour that were not predicted by the designer but that arise as a result of unexpected interactions among the components of the system or with the operating environment. This makes the liability risks difficult to estimate, leading to legal uncertainty. This problem of damage occurring as a result of a robot's action and the associated liability are generally considered the most pressing questions by researchers, manufacturers and other stakeholders.[4]

1.3.2. Gaps and barriers

The study demonstrates that the current level of harmonisation on liability in the EU is not sufficient to obtain an optimal, functioning single market in robotics and AI. Indeed, matters not explicitly covered by the Product Liability Directive are not harmonised at EU level. The current scope and concepts of the Product Liability Directive create legal uncertainty regarding robotics and AI, in particular in the context of services and software. In addition, application of the current national regulatory frameworks leads to widely varying outcomes.

Finally, the insurance market regarding robotics and AI is not fully developed owing to a lack of information and a clear assessment of the robotics and AI market.

1.4. Quantitative assessment

The analysis of the impact on the EU economy of the change in legislation on liability rules for robotics and artificial intelligence uses a scenario-based application of the macroeconomic model E3ME. The results are generally reported for 2030 as compared with a fragmented regulatory framework baseline, i.e. business as usual.

[4] See RoboLaw Guidelines on Regulating Robotics, 2014.

Table 1 – Scenario impacts on GDP, employment and net trade in 2030, EU-27,[5] and (percentage difference from the current regulatory scenario)

Scenario name	GDP	Employment	Extra-EU net trade
Scenario (1) - Increased R&D in robotics and AI	0.04	0.01	0.45
Direct employment change	N/A	-0.37	N/A
Scenario (2) - Robotics and AI adoption with no additional investment	-0.11	-0.37	0.91
Scenario (3) - Robotics and AI adoption with additional investment	0.03	-0.23	0.77

Source: Cambridge Econometrics.

A harmonised EU regulatory framework on liability and insurance in robotics and AI is assumed to lead to increased R&D efforts, greater uptake of these two new essential emerging technologies and higher insurance costs. The overall impact of harmonised regulation depends greatly on the extent to which the jobs are displaced by the faster uptake of AI, and robotics are matched by new employment opportunities created elsewhere. The analysis suggests that the impact on the EU economy of a harmonised EU regulatory framework is highly uncertain, but shows that favourable price effects do not offset much of the direct impact on the EU-27 as a whole. It is argued that a harmonised framework would stimulate greater R&D activity by producers and increase the speed of uptake of these two essential new emerging technologies by consumers, resulting in a possible positive impact in terms of GDP: in 2030 GDP could be 0.04 % higher than it would be in 2030 under the current regulatory framework.

1.5. EU policy options

The study explores four policy options:

- Option 1: No policy change;
- Option 2: Adaptation of the current regulatory framework;
- Option 3: New EU-specific framework;
- Option 4: Electronic personhood.

Policy option 3b, creating an EU-specific framework, would require thorough debates, but offers the possibility of a tailor-made, future-oriented approach with regard to robotics and AI. Moreover, a new specific regulatory framework regarding liability and insurance on robotics and AI at EU level could avoid fragmentation across the Member States, stimulate trust and innovation, and harmonise the single market in robotics and AI.

5 The results for the EU-28 are not significantly different.

The table below assesses the four policy options presented in the study.

Table 2 – Assessment of EU policy options

	Option 1: no policy change	Option 2: adaptation of the current regulatory framework	Option 3a: electronic personhood	Option 3b: EU-specific framework based on existing regulatory framework
Legal feasibility[6]	High: already existing framework.	High: adapt the scope of the existing Product Liability Directive	Low: a first assessment did not allow for the identification of a relevant suitable legal basis.	Medium: the current lack of specific national regulatory frameworks is an opportunity for the EU to create a comprehensive and harmonised one.
Effectiveness and efficiency[7]	Low: the current framework has many gaps and barriers to an optimal, functioning single market.	Medium: this policy option would create more legal certainty. Furthermore, this adaptation could clarify and refine the concepts of the directive. However, this would not allow a tailor-made approach since the rules would have to be aligned with and take into account the existing provisions of the current Product Liability Directive. In addition, it might prove insufficiently future-proof.	Low: electronic personhood could be a specific legal status for the most sophisticated autonomous robots, similar to corporate personhood, i.e. an accepted legal fiction.[8] However, this could lead to undesirable, reverse effects. Producers and manufacturers could hide behind these new legal identities in order to limit or avoid liability. It could also entail risks of abuse for criminal purposes, such as money laundering or tax fraud.	High: this tailor-made approach could provide for a division of robotics and AI into subgroups, with specific rules and liability regimes. It could also leave out the concepts of the Product Liability Directive that are not suitable, in particular, the development risk clause and the current €500 threshold. Finally, an insurance framework could be included.

6 The options should uphold the principle of conferral. They should also respect any obligation arising from the EU Treaties (and relevant international agreements) and uphold fundamental rights. Legal obligations built into existing primary or secondary EU legislation may also rule out certain options.

7 It may already be possible to show that some options would incontrovertibly achieve a worse cost-benefit balance than some alternatives.

8 European Parliament resolution of 16 February 2017 with recommendations to the Commission on civil law rules on robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.2.2017.

Proportionality[9]	Medium: several Member States have already started introducing specific national rules. An absence of EU intervention could result in Member States adding their own specific national frameworks, creating a more fragmented approach, not providing enough legal certainty. This could hinder the implementation of robotics and AI in the single market and jeopardise competitiveness.	Medium: several Member States have already started introducing specific national rules, or interpreting general liability rules. By adapting the scope of the Product Liability Directive, the EU would reduce the fragmented approach.	Low: the power to determine who is a 'person' resides in principle with the Member States. Each Member State determines who is a natural person. It is argued that it is equally up to the Member States to determine when an entity becomes a legal person who can consequently rely upon EU law.[10].	High: the introduction of a new specific regulatory framework at EU level before each Member State adopts its own national rules, would avoid fragmentation of the single market in robotics and AI, while respecting Member States competences.
Political feasibility[11]	Low: producers and insurers have already noted that some technologies, such as completely autonomous systems might eventually require regulatory changes.	Medium: producers, insurers, and consumers acknowledge that application of the current Product Liability Directive might become problematic and/or uncertain in the light of new emerging technologies and that it needs to be revised.	Low: this policy option is not supported by a majority of the stakeholders involved.[12] In addition, 285 individuals, including experts in AI, robotics, commercial law and ethics, have signed an open letter to the European Commission denouncing the idea of the creation of electronic personhood.[13]	High: this regulatory approach has significant stakeholder support. 90 % of individual stakeholders, consider it necessary to regulate developments in robotics and AI – of which 96 % would prefer action at EU or international level.[14]

Source: EPRS.[15]

9 Some options may clearly restrict the scope for national decision-making over and above what is needed to achieve the objectives satisfactorily.

10 T. Burri, 'The EU is right to refuse legal personality for artificial intelligence', *Euractiv*, 31 May 2018,

11 Options that would clearly fail to garner the necessary political support for legislative adoption and/or implementation could also be discarded.

12 A majority of respondents (around 60 %) to the public consultation on the Future of Robotics and Artificial Intelligence, were against creating a specific legal status for robots.

13 Robotics Open Letter to the European Commission.

14 Public consultation on the Future of Robotics and Artificial Intelligence, Summary, 8.12.2017.

15 Based on TOOL #17 of the European Commission Better Regulation Toolbox.

2. Research paper: The Cost of Non-Europe in liability and insurance related to robotics and artificial intelligence (external study)

2.1. Introduction

Cost of Non-Europe Reports are designed to study the possibilities for gains and/or the realisation of public good through common action at EU level in specific policy areas and sectors. They attempt to identify areas that are expected to benefit the most from deeper EU integration, in other words where EU added value is potentially significant.

The concept of the 'Cost of Non-Europe' can be traced back to the Albert Ball report of 1983, and the study carried out by the Italian economist Paolo Cecchini on the Cost of Non-Europe in the Single Market.

The aim of this study is to analyse existing legislation, identify specific gaps and barriers where legislation at EU level could be beneficial and, on the basis of these results, conduct a cost-of-non-Europe analysis to quantify the foregone net benefits, i.e. net costs, resulting from the lack of EU action, also taking into account qualitative benefits of EU-level action or the lack thereof.

Specifically, the study is aimed at identifying potential opportunities and challenges that liability, insurance and risk management rules create within the EU robotics and AI market. The aim is also to attempt to estimate the possible benefits and costs of the failure to take a common EU approach in this area.

The study is conducted by means of a four-phased structured methodological approach.

The first phase consists of a documentary review and an analysis of regulatory as well as academic data and information through wide and in-depth research of internet sources and legal literature. The second phase consists of data collection, gathering and researching national information from Member States of the European Union regarding issues of liability, insurance and risk management related to robotics and artificial intelligence. The third phase consists of a quantitative assessment of liability, insurance and risk management related to robotics and AI with, whenever possible, and a quantification of the potential costs, benefits, intended and unintended effects of potential EU action. The fourth and final phase is a detailed review of the Study on the eve of its publication to process the latest developments. Robotics and AI in the EU are emerging at the highest-speed. Therefore, to the greatest extent possible, it is important to take account of the latest developments in these areas.

The scope of the study is the liability, insurance and risk management regulatory framework related to robotics and AI within the EU. This consists of regulatory frameworks at the EU-level as well as at the national level. It cannot be denied that these disciplines have a far-reaching and global presence. Therefore, the European Parliament is planning to commission a series of studies and research papers on the legal topics, *amongst others* liability, intellectual property, data protection, labour law... In particular, the Study looks at the issues of civil liability and insurance mechanisms. Although closely linked with the subject of this Study, criminal liability regarding robotics and AI will be touched upon, but not researched in detail. Further to this, self-driving cars and liability rules along with insurance for connected and autonomous vehicles do not fall within the scope of this Study, as they are issues specifically addressed in another study.[16]

[16] A common EU approach to liability rules and insurance for connected and autonomous vehicles, European Added Value Assessment, PE 615.635, February 2018.

2.2. Robotics and artificial intelligence

2.2.1. Definition

It is important to understand that robotics and AI are independent technologies but at times they may also be complementary to one another. Robotics have been discussed in the official texts of the EU. In the Annex of the European Parliament resolution of 16 February 2017 together with recommendations to the Commission on Civil Law Rules on Robotics[17] the characteristics that have to be taken into consideration have been prescribed and include the following:

- the capacity to acquire autonomy through sensors and/or by exchanging data with its environment (inter-connectivity) and the analysis of those data;
- the capacity to learn through experience and interaction;
- the form of the robot's physical support;
- the capacity to adapt its behaviour and actions to the environment.

Robotics can carry out decisions made by AI software, for example, robotic process automation or RPA is the use of software to perform repeatable or clerical operations, previously performed by a human.

AI is technically a field of computer science and a phrase coined by John McCarty in 1956 and refers to the simulation of human intelligence by software.

Software is defined as a set of instructions that specify the required steps for data processing by a computer. This software can come in the form of conventional systems or as AI systems. Conventional software systems do not have a 'self-learning' aspect. They operate in a linear way where they manipulate input that is provided by the user through a specific process to reach a designated output. These conventional software systems generally do not have extensive interactions between the user and the program.[18]

AI systems simulate human intelligence. They can be sub-divided into strong/hard/general AI and weak/narrow AI. Strong AI is known as true human mimicry that is the ability of the product to understand, think and reason its environment exactly as humans would. Weak AI is focused on a narrow task, for example playing chess or making search suggestions.

AI is not a synonym of machine learning nor is it a synonym of deep learning. Machine learning is a subset of (weak) AI. Machine learning is the ability of a machine to improve its performance in the future by analysing previous results and creating patterns or rules from elaborated data sets. An example of machine learning is providing a machine-learning algorithm with millions of pictures of cats instead of trying to explain how a cat looks like to the algorithm. The algorithm finds recurring patterns in the images and figures out for itself how to define the appearance of a cat. Afterwards, when the algorithm is shown a new picture, it can distinguish whether it contains a cat or not.[19] Deep learning is a specialised subset of machine learning, which is concerned with the human brain's function and structure.

AI is always described as the simulation of human intelligence. However, a general (European) definition on artificial intelligence has not yet been accepted. There is not even a comprehensive

[17] European Parliament resolution of 16 February 2017 with recommendations to the Commission on civil law rules on robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.2.2017.

[18] M.E. Gerstner, 'Liability issues with artificial intelligence software', Santa Clara Law Review 1993, 239.

[19] What is machine learning?, 28 August 2017, https://bdtechtalks.com/2017/08/28/artificial-intelligence-machine-learning-deep-learning/.

and consensual definition on human intelligence.[20] There is also no general demarcation of what procedures are to be characterized as 'intelligent'.[21]

There are three main objectives of AI that can be distinguished. Some people want an AI system to think exactly the same way as people, others merely require that the work is carried out and are indifferent as to whether the computation was done by human thought or AI and a third group of people are in-between and use human reasoning as a model that can inform and inspire, but not as the final target for imitation.[22]

AI is described within the legal doctrine and jurisprudence of the EU in several ways.

An early definition by R. E. Susskind states that 'AI is concerned with the design, development and implementation of computer systems that can perform tasks and solve problems of a sort for which human intelligence is normally thought to be required.[23]

It is defined in the English Oxford Living Dictionary as: 'The theory and development of computer systems able to perform tasks normally requiring human intelligence, such as visual perception, speech recognition, decision-making, and translation between languages'.[24]

The Encyclopaedia Britannica defines AI as 'the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings'.[25]

Finally, another definition is also given by Merriam-Webster: 'A branch of computer science dealing with the simulation of intelligent behaviour in computers. The capability of a machine to imitate intelligent human behaviour'.[26]

Although a general (European) definition on AI has not yet been accepted, the High-Level Expert Group on artificial intelligence (AI HLEG)[27] set up by the Commission, recently developed a definition of AI.[28] This definition is developed for the purposes of AI HLEG's deliverables. However, the definition could serve as a starting point to achieve an accepted general European definition on AI:

'Artificial intelligence (AI) systems are software (and possibly also hardware) systems designed by humans that, given a complex goal, act in the physical or digital dimension by perceiving their environment through data acquisition, interpreting the collected structured or unstructured data, reasoning on the knowledge, or processing the information, derived from this data and deciding the best action(s) to take to achieve the given goal. AI systems can either use symbolic rules or learn a numeric

20 T. Rothkegel and M. Taylor, 'What characterizes artificial intelligence and how does it work?', *Computer and telecommunications Law Review*, 2016, pp. 98-99.
21 J. McCarthy, 'What is artificial intelligence?', 2007, http://www-formal.stanford.edu/jmc/whatisai/node1.html.
22 K. Hammond, 'What is artificial intelligence?', Contributor Network 2015, https://www.computerworld.com/article/2906336/emerging-technology/what-is-artificial-intelligence.html.
23 R. E. Susskind, 'Artificial intelligence, expert systems and law', *Denning law Journal*,1990, pp. 105-116.
24 English Oxford Living Dictionary, https://en.oxforddictionaries.com/definition/artificial_intelligence.
25 B.J. Copeland, 'Artificial Intelligence', *Encyclopaedia Britannica*, 2018, https://www.britannica.com/technology/artificial-intelligence.
26 Merriam-Webster, definition artificial intelligence, https://www.merriam-webster.com/dictionary/artificial%20intelligence.
27 The Independent High-Level Expert Group on Artificial Intelligence consists of 52 representatives of academia, business, and civil society, https://ec.europa.eu/digital-single-market/en/high-level-expert-group-artificial-intelligence.
28 High-level expert group on artificial intelligence, 'A definition of AI: Main capabilities and scientific disciplines', 8 April 2019, https://ec.europa.eu/futurium/en/ai-alliance-consultation.

model, and they can also adapt their behaviour by analysing how the environment is affected by their previous actions.

As a scientific discipline, AI includes several approaches and techniques, such as machine learning (of which deep learning and reinforcement learning are specific examples), machine reasoning (which includes planning, scheduling, knowledge representation and reasoning, search, and optimization), and robotics (which includes control, perception, sensors and actuators, as well as the integration of all other techniques into cyber-physical systems).'

2.2.2. The emergence and social potential of robotics and AI in the EU

Industry 4.0

It is undeniable that the EU stands at the beginning of the fourth industrial revolution. The first industrial revolution introduced water- and steam-powered mechanical manufacturing. The second industrial revolution introduced electric-powered mass production based on the division of labour and was the beginning of assembly lines. The third industrial revolution used electronics and information technology to drive new levels of automation of complex tasks. The fourth industrial revolution, or Industry 4.0, is a term applied to a group of rapid transformations in the design, manufacture, operation and service of manufacturing systems and products. In short, everything in and around a manufacturing operation, including suppliers, a plant, distributors and even the product itself, is digitally connected, providing a highly integrated value chain.[29]

	Time periods	Technologies and capabilities
First	1784-mid 19th century	Water- and steam-powered mechanical manufacturing
Second	Late 19th century -1970s	Electric-powered mass production based on the division of labour (assembly line)
Third	1970s-Today	Electronics and information technology drives new levels of automation of complex tasks
Fourth	Today-	Sensor technology, interconnectivity and data analysis allow mass customisation, integration of value chains and greater efficiency

Figure 1 – Industrial revolutions

Source: M. Rosenvinge, D. Olanders, Industry 4. 0 How can Industry 4. 0 create value in manufacturing companies? 2015.[30]

Robotics and AI are inherently connected to Industry 4.0. Growth in computing power, availability of data and progress in algorithms have turned AI into one of the most strategic technologies of the

[29] European Parliament, European Parliamentary Research Service, Industry 4.0 - Digitalisation for productivity and growth, September 2015.

[30] Available at: https://www.semanticscholar.org/paper/Industry-4-.-0-How-can-Industry-4-.-0-create-value-ROSENVINGE-OLANDERS.

21st century.[31] Out of more than 150 new emerging technologies, robotics and AI are categorised as two of the essential eight new emerging technologies.[32][33]

The support of the EU to reap the social potential of robotics and AI in the EU

AI can significantly improve people's lives and bring major benefits to the society and the economy through better healthcare, more efficient public administration, safer transport, a more competitive industry and sustainable farming. The social potential of robotics and AI in the EU should be fully valorised.

Robotics and AI have the potential to make more accurate and faster medical diagnoses,[34] to help surgeons operate more precisely, to carry out dangerous and repetitive tasks, to reduce the number of traffic accidents, to reduce the risk of work-related injuries, to develop smart machines that minimise their environmental impact and to free up valuable time. Robotics and AI can also help in the fight against cybercrime, minimise the use of electricity and optimise the use of water resources.[35]

Specific examples of the social potential of robotics and AI in the EU can be found in the agriculture sector, where the EU invests in project Mars, a mobile robot that plants seeds while workers monitor the process from anywhere. In the health sector, investments are made in earth observation through big data and machine learning to forecast risk scenarios. In public administration and services, SmokeBot is being developed, a civil robot that supports fire brigades in search and rescue missions to perform in harsh conditions. In the transport sector, investments are made in data-driven transformations solving urban mobility issues and developing smart motorways and proactive rails.[36]

The EU is in the perfect position to reap the full benefits of new emerging technologies, in particular robotics and AI. The EU is home to world-class researchers, labs, start-ups and an AI research community and is world-leading in robotics.[37] The EU has the world's largest single market area and is fully developing a digital single market. The EU has a wealth of industrial, research and public

---

[31] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 1, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

[32] See Huff Eckert, 'What are the essential eight technologies?', 29 July 2016, http://usblogs.pwc.com/emerging-technology/a-guide-to-the-essential-eight-emerging-technologies/.

[33] Other new emerging technologies are the internet of things, augmented reality, virtual reality, blockchain, 3D printing, drones.

[34] For example, a Harvard-based team of pathologists created an AI-based technique to identify breast cancer cells with greater precision than doctors unaided by AI. Pathologists beat the machines with respectively 96 percent accuracy versus 92 percent. But the biggest surprise came when humans and AI combined forces. Together, they accurately identified 99.5 percent of cancerous biopsies. With nearly 1.7 million new cases of breast cancer diagnosed globally each year, this translates to 68.000 to 130.000 more women receiving accurate diagnoses than if we relied on humans or machines alone; Harvard example from Accenture, Reworking the revolution, 2017, 7, https://www.accenture.com/_acnmedia/PDF-69/Accenture-Reworking-the-Revolution-Jan-2018-POV.pdf.

[35] European Commission, Digital Single Market, Factsheet on Artificial Intelligence, https://ec.europa.eu/digital-single-market/en/news/factsheet-artificial-intelligence-europe.

[36] Ibid, 2.

[37] For example is the EU producing more than a quarter of the world's industrial and professional service robots and is it home to three of the world's largest producers of industrial robots (KUKA, ABB and Comau); World Robotics 2017, International Federation of Robotics.

sector data which can be unlocked to feed AI systems and is taking action to make data sharing easier and to open up more data, which is the raw material for AI, for re-use.[38]

Capitalising on its world-leading position and with the aim of global leadership, the EU is maximising its input in robotics and AI. To be competitive, around €2.6 billion over the duration of Horizon 2020[39] has been invested in AI-related areas such as robotics, big data, health, transport and future and emerging technologies. What is more, through the European Structural and Investment Funds, €27 billion are being invested in skills development out of which the European Social Fund invests €2.3 billion specifically in digital skills.[40]

In the EU, there are already more than 400 Digital Innovation Hubs,[41] local ecosystems that help companies in their vicinity, especially small and medium-sized enterprises, to take advantage of digital opportunities.[42] In addition to these Digital Innovation Hubs, the EU supports the uptake of AI across the EU and in this context the development of an EU 'AI-on-demand platform', which will provide a single access point for all users to relevant AI resources in the EU, including knowledge, data repositories, computing power, tools and algorithms.[43]

With a view to the future, the investments in robotics and AI in the EU shall only increase. Under the research and innovation framework programme Horizon 2020 alone, the EU increases investments to around €1.5 billion by the end of 2020. The goal is to reach total investments in the EU as a whole, public and private sector combined, of at least €20 billion by the end of 2020 and more than €20 billion per year during 2020-2030. In addition, Member States are making significant investments in emerging technologies, especially robotics and AI.[44]

The EU is aiming for a position as a global leader in robotics and AI. However, in order to be able to benefit from the full social and economic potential of robotics and AI in the EU, citizens and businesses need to have trust in these industries. This trust can be achieved if dealing and working with robotics and AI is predictable, in particular with regard to the legal environment. Legal certainty is a key element for successful business development.

---

38 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 2-4, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

39 Horizon 2020 is the EU framework programme for research and innovation; see also below.

40 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 5 and 12, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

41 List of Digital Innovation Hubs: http://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-tool?p_p_id=digitalinnovationhub_WAR_digitalinnovationhubportlet&p_p_lifecycle=0&p_p_state=normal&p_p_mode=view&p_p_col_id=column-1&p_p_col_count=1&_digitalinnovationhub_WAR_digitalinnovationhubportlet_cur=2&formDate=1521718574008&freeSearch=&evolStages=3.

42 European Commission, Factsheet, A European approach on Artificial Intelligence, Questions and answers, Brussels, 25.4.2018, http://europa.eu/rapid/press-release_MEMO-18-3363_en.pdf.

43 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 6, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

44 For exemple France is investing €1.5 billion in AI over five years; Cédric Villani, Donner un sens à l'intelligence artificielle pour une stratégie nationale et européenne, 8 March 2018.

Therefore, a solid European framework is needed. A clear and stable legal framework will increase investment and in combination with research and innovation will help bring the benefits of these emerging new technologies to all businesses and citizens within the EU market.[45]

2.2.3. Recent EU initiatives

In March 2010, the Commission proposed its new long-term strategy for the EU succeeding the Lisbon strategy in what is known as the Europe 2020 strategy. The Europe 2020 strategy is the EU's agenda for growth and jobs for the current decade. It puts forward three mutually reinforcing priorities as a way to overcome the structural weaknesses in Europe's economy, improve its competitiveness and productivity and underpin a sustainable social market economy: smart growth, sustainable growth and inclusive growth.[46]

To catalyse progress under the abovementioned three priorities, the Commission put forward seven flagship initiatives. One flagship initiative is the 'Innovation Union' to improve framework conditions and access to finance for research and innovation so as to ensure that innovative ideas can be turned into products and services that create growth and jobs. Another flagship initiative is 'a digital agenda for Europe' to speed up the rollout of high-speed internet and reap the benefits of a digital single market for households and firms.[47]

In 2013, in context of the flagship initiative the 'Innovation Union', Horizon 2020 - the Framework Programme for Research and Innovation, was established.[48] Horizon 2020 is the financial instrument and key tool implementing the Innovation Union. It is the biggest EU Research and Innovation programme ever with nearly €80 billion of funding available over seven years (2014 to 2020), in addition to the private investment that this money will attract. It promises more breakthroughs, discoveries and world-firsts by taking great ideas from the lab to the market.[49] At present, Horizon 2020 contributes significantly to the development of robotics and AI in the EU. In particular on robotics, €700 million under Horizon 2020 for 2014-2020 are being invested, as well as €2.1 billion from public-private partnership investments in one of the biggest civilian research programmes in smart robots in the world, known as SPARC.[50]

In July 2014, the current President of the European Commission, Jean-Claude Juncker, indicated in his Political Guidelines for the next European Commission, 10 Commission priorities for 2015-2019. The second priority is the digital single market and breaking down barriers in order to unlock online opportunities.[51]

---

45 Commission Staff Working Document on Liability for emerging digital technologies, accompanying the document Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on Artificial intelligence for Europe, Brussels, 25.4.2018, SWD(2018) 137 final, 2, https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52018SC0137.

46 Communication from the Commission, Europe 2020, A strategy for smart, sustainable and inclusive growth, Brussels, 3.3.2010, COM(2010) 2020 final, http://ec.europa.eu/eu2020/pdf/COMPLET%20EN%20BARROSO%20%20%20007%20-%20Europe%202020%20-%20EN%20version.pdf.

47 Ibid. 5-6.

48 Regulation (EU) No 1291/2013 of the European Parliament and of the Council of 11 December 2013 establishing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020) and repealing Decision No 1982/2006/EC, *OJ* L 347/104, 20.12.2013, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32013R1291.

49 Horizon 2020, https://ec.europa.eu/programmes/horizon2020/en/what-horizon-2020.

50 SPARC is the partnership for robotics in Europe to maintain and extend Europe's leadership in robotics, https://www.eu-robotics.net/sparc/index.html.

51 Jean-Claude Juncker, A New Start for Europe: My Agenda for Jobs, Growth, Fairness and Democratic Change, Political Guidelines for the next European Commission, Strasbourg, 15 July 2014, 6.

A digital single market is one in which the free movement of goods, persons, services and capital is ensured and where individuals and businesses can seamlessly access and exercise online activities under conditions of fair competition, and a high level of consumer and personal data protection, irrespective of their nationality or place of residence. Achieving a digital single market will ensure that Europe maintains its position as a world leader in the digital economy, helping European companies to grow globally.[52]

The creation of a digital single market, including the free flow of data across borders, is key for the development of AI.

Common rules, for example on data protection and the free flow of data in the EU, cybersecurity and connectivity help companies to do business, scale up across borders and encourage investments.[53]

In January 2015, the European Parliament Committee on Legal Affairs (JURI) established a working group on legal questions related to the development of robotics and AI in the EU, with a focus on civil law aspects. In February 2017, based on the research of the working group, the European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics was adopted. The resolution of rapporteur Mady Delvaux calls for EU legislation introducing a register of robots, setting up an EU Agency for Robotics and laying down principles of civil liability for damages caused by robots and legislation which should be complemented by ethical codes of conduct.[54]

In May 2017, the Commission responded to the resolution of 16 February 2017 adopted by the Parliament.[55] With regard to civil law liability, the Commission stated that the advent of robotics can give rise to legal challenges in identifying and proving the defect which caused the damage and in determining liability among the different market players, as well as the fact that legal uncertainty may negatively impact the development and uptake of robots and data-driven products and services. The Commission declared its intention to work together with the European Parliament and the Member States of the EU on an EU response to these legal challenges. Furthermore, the Commission confirmed that it will assess whether legislative action is necessary and that 'any possible regulation in this domain will play a key role in ensuring that European products are actually rolled out onto the market and thus helping to develop a thriving robotics and Artificial Intelligence industry in the EU'.[56]

From February 2017 until the beginning of June 2017, following the Parliament resolution of 16 February 2017, the JURI committee held a public consultation specifically on the future of robotics and AI, with an emphasis on civil law rules. The aim of this consultation was to stimulate a broad debate with a wide range of stakeholders on the Parliament resolution of 16 February 2017 and to

---

[52] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, A Digital Single Market Strategy for Europe, Brussels, 6.5.2015, COM(2015) 192 final, 3, https://ec.europa.eu/digital-single-market/en/news/digital-single-market-strategy-europe-com2015-192-final.

[53] Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

[54] European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.02.2017, 2015/2103(INL), http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2017-0051+0+DOC+XML+V0//EN.

[55] Follow up to the European Parliament resolution of 16 February 2017 on civil law rules on robotics, Brussels, 16.05.2017, SP(2017)310, https://oeil.secure.europarl.europa.eu/oeil/spdoc.do?i=28110&j=0&l=en.

[56] Follow up to the European Parliament resolution of 16 February 2017 on civil law rules on robotics, Brussels, 16.05.2017, SP(2017)310, 1-3, https://oeil.secure.europarl.europa.eu/oeil/spdoc.do?i=28110&j=0&l=en.

seek views on how to address the challenging ethical, economic, legal and social issues related to robotics and AI developments.[57]

If the EU were to take action to encourage innovation, productivity and global competitiveness in robotics and AI, 21 % of the respondents considered that a better regulatory framework would certainly be helpful. Also, the respondents consider action at EU level to add value to actions taken at national level, as it helps to avoid divergent national standards (17 %), to enhance protection of fundamental rights and ethical rules (14 %), and to facilitate cross-border business opportunities (11 %). Furthermore, 21 % of the respondents indicated that the rules concerning liability would urgently need to be addressed and liability was indicated as by far the most urgent concern (51 % of the respondents are strongly concerned and 30 % are concerned).[58]

With regard to the evaluation of the current EU regulatory framework on liability, the opinions were divided between the necessity for major modifications, some modifications or no modifications. Aside from this, around 60 % of the respondents were against creating a specific legal status for robots, and stakeholders do not see a necessity for establishing an obligatory insurance scheme for damages caused by autonomous robots, nor do they see a need for a compulsory insurance and compensation fund.[59]

On 10 April 2018, 24 Member States and Norway[60] signed a Declaration of cooperation on AI.[61] In May and July 2018 respectively 3[62] and 1[63] other EU Member States countries joined the initiative. The Declaration builds on the achievements and investments of Europe in AI as well as the progress towards the creation of a digital single market. The 29 signing European countries agreed to cooperate *amongst others* on 'ensuring an adequate legal and ethical framework, building on EU fundamental rights and values, including privacy and protection of personal data, as well as principles such as transparency and accountability'.[64] The Declaration of cooperation on AI was endorsed by the European Council in June 2018.[65]

On 25 April 2018, the Commission adopted its Communication on AI for Europe.[66] The Commission sets out a European initiative on AI that will boost the EU's competitiveness and ensure trust based on European values. The European initiative consists of a three-pronged approach: boost the EU's

57 Public consultation – Future of Robotics and Artificial Intelligence, http://www.europarl.europa.eu/committees/en/juri/robotics.html?tab=Introduction.

58 Findings and results of the public consultation on the Future of Robotics and Artificial Intelligence, Summary report of the public consultation on the future of robotics and artificial intelligence (AI) with an emphasis on civil law rules, 6-7, http://www.europarl.europa.eu/committees/en/juri/robotics.html?tab=Results.

59 Findings and results of the public consultation on the Future of Robotics and Artificial Intelligence, Summary report of the public consultation on the future of robotics and artificial intelligence (AI) with an emphasis on civil law rules, 6-7, http://www.europarl.europa.eu/committees/en/juri/robotics.html?tab=Results.

60 The 25 countries are: Austria, Belgium, Bulgaria, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, United Kingdom and Norway.

61 Declaration of cooperation on Artificial Intelligence, Brussels, 10 April 2018, https://ec.europa.eu/digital-single-market/en/news/eu-member-states-sign-cooperate-artificial-intelligence.

62 Cyprus, Greece and Romania.

63 Croatia.

64 Declaration of cooperation on Artificial Intelligence, Brussels 10 April 2018, 3, https://ec.europa.eu/digital-single-market/en/news/eu-member-states-sign-cooperate-artificial-intelligence.

65 European Council conclusions, 28.6.2018, https://www.consilium.europa.eu/en/press/press-releases/2018/06/29/20180628-euco-conclusions-final/.

66 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

technological and industrial capacity and AI uptake across the economy both by the private and public sectors, prepare for socio-economic changes brought about by AI and ensure an appropriate ethical and legal framework, based on the Union's values and in line with the Charter of Fundamental Rights of the EU.[67]

In its Communication, the Commission notes that the economic impact of the automation of knowledge work, robots and self-driving vehicles could reach between €6.5 and 12 trillion annually by 2025. However, overall, Europe is behind in private investments in AI that totalled around €2.4 - 3.2 billion in 2016, compared with €6.5 - 9.7 billion in Asia and €12.1 - 18.6 billion in North America.[68] Therefore, the Commission is increasing investments in AI under Horizon 2020 to around €1.5 billion by the end of 2020, which represents an average of €500 million per year and an increase of around 70 %. The Commission foresees that, under the existing public-private partnerships, its investment will trigger an additional €2.5 billion over the same period. The aim of the Commission is for the public and private sectors of the EU to increase the investment in AI to at least €20 billion by the end of 2020 and more than €20 billion per year over the decade 2020-2030.[69]

In the context of the third pillar of its three-pronged approach, ensuring an appropriate ethical and legal framework, the Commission indicated their wish to establish a European AI Alliance to develop draft AI ethics guidelines with due regard to fundamental rights, and to issue a guidance document on the interpretation of the Product Liability Directive[70] in light of technological developments.[71]

With regard to ensuring an appropriate ethical framework, the European AI Alliance was established in June 2018.[72] The European AI Alliance is a forum engaged in a broad and open discussion of all aspects of AI development and its impacts, and the members of the AI Alliance can interact in a forum-style setting with the experts of AI HLEG, established by the Commission. Most recently, with input from members of the European AI Alliance and after a first draft released on 18 December 2018, AI HLEG developed the (non-binding) Ethics Guidelines for Trustworthy AI.[73] The aim of the Ethics Guidelines for Trustworthy AI is to promote trustworthy AI and to set out a framework for achieving trustworthy AI.[74] According to the Ethics Guidelines, trustworthy AI has three components

---

67 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 3, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

68 McKinsey Global Institute, *Digitization, AI, and the future of work: Imperatives for Europe*, Chicago: McKinsey & Company, Briefing Note prepared for the European Union Tallinn Digital Summit September 2017, https://www.mckinsey.com/~/media/McKinsey/McKinsey%20Global%20Institute/Overview/2017%20in%20review/Whats%20next%20in%20digital%20and%20AI/Digitization%20AI%20and%20the%20future%20of%20work%20imperatives%20for%20europe/MGI-Tallinn-Briefing-Note-1213.ashx.

69 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 6, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

70 Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, *OJ* L 210/29, 07.08.1985, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31985L0374&from=EN.

71 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Artificial Intelligence for Europe, Brussels, 25.4.2018, COM(2018) 237 final, 14-16, https://ec.europa.eu/digital-single-market/en/news/communication-artificial-intelligence-europe.

72 European AI Alliance, https://ec.europa.eu/futurium/en/eu-ai-alliance.

73 High-Level Expert Group on Artificial Intelligence, 'Ethics Guidelines for Trustworthy AI', 8 April 2019, https://ec.europa.eu/futurium/en/ai-alliance-consultation.

74 Chapter III of the Ethics Guidelines for Trustworthy AI present a trustworthy AI assessment list. This assessment list will undergo a piloting phase by stakeholders to gather practical feedback and a revised version of the list, taking into account the feedback gathered through the piloting phase, will be presented to the Commission in early 2020.

which should be met throughout the system's entire life cycle: (i) AI should be lawful, complying with all applicable laws and regulations, (ii) AI should be ethical, ensuring adherence to ethical principles and values and (iii) AI should be robust, both from a technical and social perspective since, even with good intentions, AI systems can cause unintentional harm.[75] The Commission supports the Ethics Guidelines for Trustworthy AI and launches a targeted piloting phase to ensure that the resulting ethical guidelines for AI development and use can be implemented in practice. The Commission will also work to forge a broad societal consensus on human-centric AI, including with all involved stakeholders and international partners.[76]

With regard to ensuring an appropriate legal framework, on the 25 April 2018, the Commission published its Staff Working Document on Liability for emerging digital technologies accompanying its Communication on AI for Europe. In its document, the Commission states that a clear and stable legal framework will stimulate investment and, in combination with research and innovation, will help bring the benefits of emerging digital technologies to every business and citizen.[77]

Furthermore, with regard to ensuring an appropriate legal framework, on 7 May 2018 the Commission published its Staff Working Document on the evaluation of the Product Liability Directive.[78] The evaluation assesses in particular and retrospectively the function and performance of the Product Liability Directive. However, the evaluation also investigates whether the Product Liability Directive and its objectives and requirements remain fit for purpose with regard to emerging digital technologies.

On 15 May 2018, the Commission also published its communication on 'Completing a trusted digital single market for all, together with an annex on digital single market legislative initiatives 2015-2018.[79] In view of the informal EU Leaders' meeting on data protection and the digital single market, the Communication presented a set of concrete actions to ensure full protection of citizens' privacy and personal data and to accelerate the completion of the digital single market in 2018.

In addition, building on the abovementioned communication on AI for Europe and the Declaration of cooperation on AI, the Commission worked with the Member States of the EU on a coordinated plan to foster the development and use of AI in the Europe. On 7 December 2018, the Coordinated

---

75 Ibid., 2.

76 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Building Trust in Human-Centric Artificial Intelligence, Brussels, 8.4.2019, COM(2019) 168 final, 9, https://ec.europa.eu/jrc/communities/en/community/digitranscope/document/building-trust-human-centric-artificial-intelligence.

77 Commission Staff Working Document on Liability for emerging digital technologies, accompanying the document Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions on Artificial intelligence for Europe, Brussels, 25.4.2018, SWD(2018) 137 final, https://ec.europa.eu/digital-single-market/en/news/european-commission-staff-working-document-liability-emerging-digital-technologies.

78 Commission Staff Working Document on the evaluation of Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, accompanying the document Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee on the Application of the Council Directive on the approximation of the laws, regulations, and administrative provisions of the Member States concerning liability for defective products (85/374/EEC), Brussels, 7.5.2018, SWD(2018) 157 final, https://ec.europa.eu/transparency/regdoc/rep/10102/2018/EN/SWD-2018-157-F1-EN-MAIN-PART-1.PDF.

79 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Completing a trusted Digital Single Market for all, Brussels, 15.5.2018, COM(2018) 320 final; and Annex to this Communication, https://ec.europa.eu/commission/sites/beta-political/files/communication-trusted-digital-single-market-for-all_en.pdf.

Plan on Artificial Intelligence was published. The communication from the Commission highlights the main objectives and initiatives of the coordinated plan, while its Annex details the actions to be started in 2019-2020 and prepares the ground for activities in the following years.[80] The coordinated plan proposes joint actions for closer and more efficient cooperation between the Member States of the EU, Norway, Switzerland and the Commission in four key areas: (i) increasing investment, (ii) making more data available, (iii) fostering talent and (iv) ensuring trust. The plan will be reviewed and updated annually. The ambition for Europe is to become the world-leading region for developing and deploying cutting-edge, ethical and secure AI, promoting a human-centric approach in the global context.[81]

In support of all European initiatives on AI of the Commission, in particular with regard to ensuring an appropriate legal framework, this Study has been commissioned by the Parliament. The Study has the goal of providing insights into the regulatory gaps and challenges of the current liability and insurance frameworks with regard to robotics and AI, as well as the potential benefits and opportunities of acting at the EU level. This Study is the next step in paving the way to a harmonised EU regulatory framework.

80 Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Coordinated Plan on Artificial Intelligence, Brussels, 7.12.2018, COM(2018) 795 final; and Annex to this Communication, https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-795-F1-EN-MAIN-PART-1.PDF.

81 Annex to the Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions, Coordinated Plan on Artificial Intelligence, Brussels, 7.12.2018, COM(2018) 795 final, 1, https://ec.europa.eu/knowledge4policy/publication/coordinated-plan-artificial-intelligence-com2018-795-final_en.

2.3. Regulatory framework regarding robotics and AI in the EU

2.3.1. Existing legislation applicable to robotics and AI

Key findings

- At present, there is no specific EU nor specific national regulatory framework regarding liability and insurance in the context of robotics and AI;
- At EU level, stakeholders will in particular fall back upon the Product Liability Directive;
- With regard to the current adequacy of the Product Liability Directive in light of emerging technologies, such as robotics and AI, there is a notable difference between the opinion of producers and insurers, who believe that changes to the directive would be premature, and consumers, who believe that the directive needs to be revised;
- At national level, stakeholders will fall back upon their existing general rules on liability and insurance, in particular their national rules implementing the Product Liability Directive and their national civil or common law rules regarding extra-contractual liability;
- Throughout the EU, a variety of legal possibilities could be relied upon in the event of damages caused by robotics or AI.

At present, there is no specific EU nor specific national regulatory framework regarding liability and insurance in the context of robotics and AI.

If citizens and businesses were currently confronted with liability and insurance issues caused by robotics or AI, they would fall back upon the existing general regulatory framework. As a result, it must be addressed whether these frameworks on both an EU and national level are entirely appropriate for robotics and AI technologies and what system should be put in place going forward. Therefore, what this chapter will aim to provide is an overview of the existing regulatory framework at EU level. This chapter will then look at what rules exist at a national level.

Existing legislation applicable to robotics and AI at EU level: Product Liability Directive

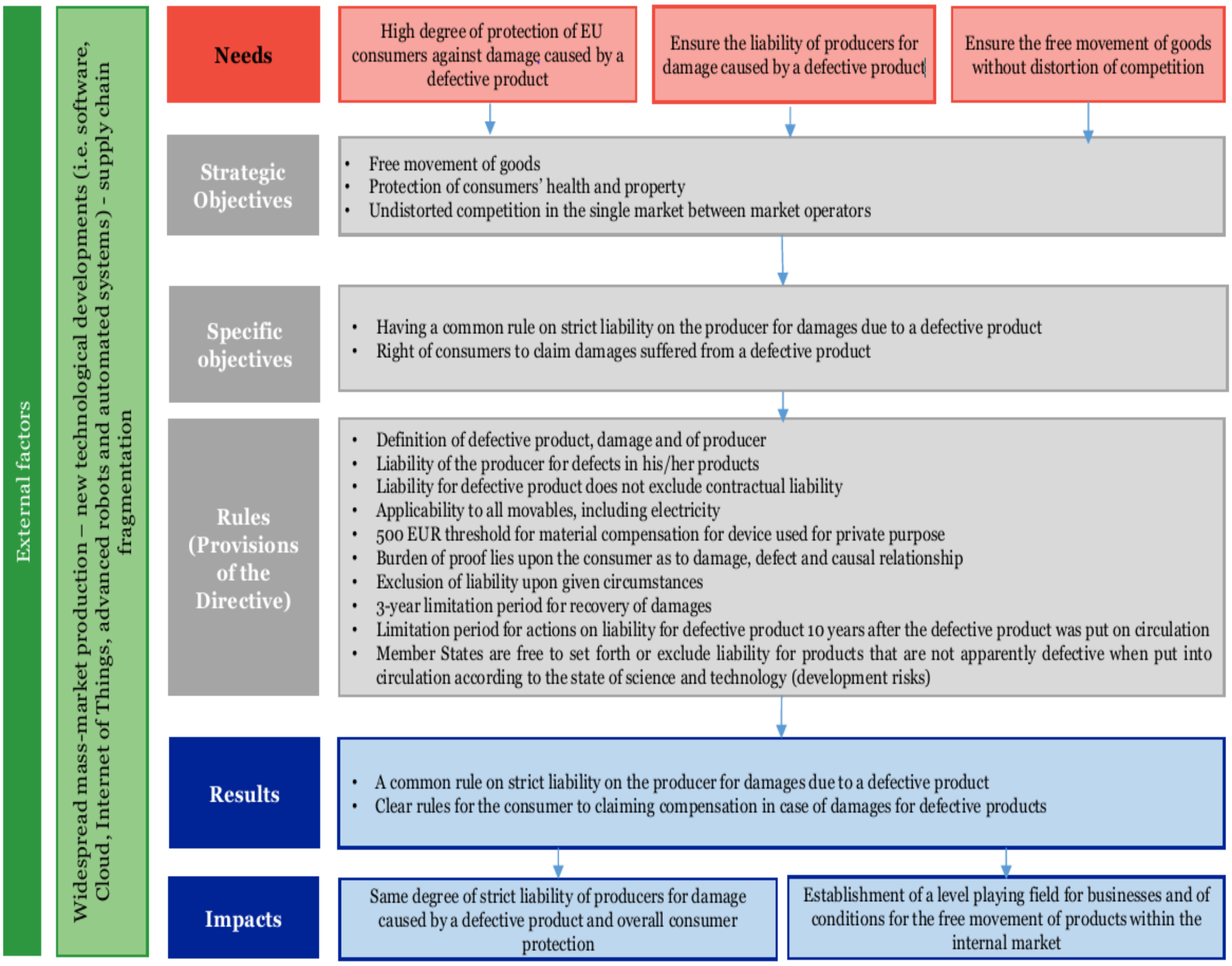
The EU liability regulatory framework consists of the Product Liability Directive,[82] the Machinery Directive[83] and the Consumer Directive.[84] These Directives provide a stable framework and they encourage investment, innovation and risk-taking.

82 Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, *OJ* L 210/29, 7.8.1985, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31985L0374&from=EN.

83 Directive 2006/42/EC of the European Parliament and of the Council of 17 May 2006 on machinery, and amending Directive 95/16/EC, *OJ* L 157/24, 9.6.2006, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32006L0042&from=EN.

84 Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on consumer rights, amending Council Directive 93/13/EEC and Directive 1999/44/EC of the European Parliament and of the Council and

Figure 2 - Intervention logic of the Product Liability Directive



Source: Study for the evaluation of the Directive; Commission Staff Working Document, Evaluation of Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products.

The core text of the liability regulatory framework is the Product Liability Directive. The Directive was adopted based on two specific objectives, namely common rules on strict liability for producers and the right for consumers to claim damages.

Relevant scope and level of harmonisation of the Product Liability Directive

The Product Liability Directive lays down common rules on strict liability for producers, that the injured person do not need to prove a fault on behalf of the producer, for damages caused by defective products. The victim only carries the burden of proving the defect, the actual damage and the causal link between the defect and the damage.

This Directive has an overarching definition of a producer over which an injured party may bring their claim and this includes: the manufacturer of a finished product, the producer of any raw material or component part or any person who by placing its name, trademark or other distinctive feature holds themselves out to be the producer. If the producer is not capable of being identified,

repealing Council Directive 85/577/EEC and Directive 97/7/EC of the European Parliament and of the Council, *OJ* L 304/64, 22.11.2011, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011L0083&from=EN.

each supplier will be treated as its producer unless they inform the victim of the actual identity of the producer.

The directive puts forward a vertical approach in the assignment of liability in the case of defects and is technology-neutral. It is intended to govern business-to-consumer relationships and is an easy point of reference for consumers and producers alike.

The directive was created around the idea of moveable, mostly tangible products. The coverage extends to all types of products, including raw materials and emerging technology products. The Court of Justice has indicated that the directive applies to products used while providing any service[85] but that the liability of a service provider does not fall within the scope of the directive.[86] However, Member States can still apply national rules under which a provider using a defective product may be liable for damage caused by the use of the product.

The directive establishes liability for producers when defective products result in damage to victims and this includes death, personal injury as well as damage to an item of property intended and used for private use and consumption with a lower threshold of €500.

The Product Liability Directive is considered to create an exhaustive harmonisation for the matters that it explicitly covers. Member States may not maintain a general system of product liability different from that provided for in the Directive.[87]

However, in accordance with the Product Liability Directive, Member States may adopt own national rules regarding some specific matters not explicitly covered by the Directive, such as the ceilings for damages resulting in death or personal injury by identical items[88], the development risk defence[89] or the rules related to non-material damages.[90][91]

At present, all Member States of the EU transposed the Product Liability Directive into their national regulatory framework.[92]Therefore, throughout the single market, there is an exhaustive harmonisation for the matters explicitly covered by the Product Liability Directive.

Applicability of the Product Liability Directive to robotics and AI[93]

In the light of this largely harmonised European regulatory framework, it is important to identify to what extent it can be applied to robotics and AI and if it would be necessary to adapt these harmonised rules.

---

85 Judgment of 10 May 2001, Veedfald, Case C-203/99, ECLI:EU:C:2001:258, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:61999CJ0203&from=EN.

86 Judgment of 21 December 2011, Dutrueux and Caisse primaire d'assurance maladie du Jura, Case C-495/10, ECLI:EU:C:2011:869, http://curia.europa.eu/juris/document/document.jsf?text=&docid=117194&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=3993945.

87 Judgment of 25 April 2002, *Commission* v *French Republic*, Case C-52/00, ECLI:EU:C:2002:252, http://curia.europa.eu/juris/showPdf.jsf?text=&docid=47307&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=3994335.

88 Article 16 (1) of the Product Liability Directive.

89 Article 15.1 (b) of the Product Liability Directive.

90 Article 9 of the Product Liability Directive.

91 See below, section on no harmonisation for the matters not explicitly covered by the Product Liability Directive.

92 https://eur-lex.europa.eu/legal-content/EN/NIM/?uri=celex%3A31985L0374.

93 With regard to an in-depth assessment whether the Product Liability Directive is fit for purpose in respect of robotics and AI, reference is made to the Guidance on the interpretation of the Product Liability directive, currently developed by the Commission and expected mid-2019.

The Product Liability Directive lays down rules on strict liability for producers. Thus, by applying the Product Liability Directive, producers of robotics and AI could be held strictly liable for their defective products.[94]

To claim damages from producers of robotics and AI, a person suffering damages first needs to prove a defect in the product of these producers. With regard to non-sophisticated robotics and AI, the proof of a regular material defect, such as a machine defect, deficient safety systems or malfunctioning, would not constitute problems. However, with regard to future sophisticated robotics and AI, it will become more burdensome to prove such defect, particularly given the self-learning ability of these products and the asymmetric information between the producers and consumers, due to which it will be difficult to ascertain what exactly caused damage, as well as the capability of autonomous behaviour. Lawful autonomous behaviour of robotics and AI causing damage may be considered not a defect.

The application of the Product Liability Directive further implies proof of the actual damages caused by defective robotics and AI. A person suffering damages has to prove physical injuries, including economic losses such as incapacity to work, or damage to items of property mainly intended for private use, exceeding €500. If defective robotics and AI cause the aforementioned damages, the application of the Product Liability Directive is straightforward. However, if defective robotics and AI cause non-material damages or non-material digital damages, such as damages to digital data, loss of information or pure economic losses not linked to property damages, the Product Liability Directive cannot be applied. Nonetheless, sophisticated robotics and AI are rather expected to cause the latter damages, thus excluding the application of the Product Liability Directive.

In addition, producers of robotics and AI will only be held strictly liable by application of the Product Liability Directive if the person suffering damages proofs the causal link between the proven defect and the proven actual damages. In this regard, the asymmetric information between producers and consumers aggravates the burden of proof in respect of the latter. If robotics and AI were equipped with a black box registering the cause of damages and identifying whether the product was defective at the time of the occurrence of the damages, the causal link would be more easily demonstrated. However, with regard to autonomous, self-learning and decision-making robotics and AI, it would still be burdensome to establish the causal link.

The strict liability regime of the Product Liability Directive is consequently still apt to cover some cases related to damages caused by robotics and AI currently marketed. However, with regard to the future, robotics and AI will become more sophisticated and autonomous. The Product Liability Directive is less adequate to solve liability issues related to autonomous robotics and AI. Also in public opinion, the adequacy of the Product Liability Directive regarding robotics and AI that are not marketed yet, is called into question.

45 % of producers, 44 % of *inter alia* public authorities and civil society and 58 % of consumers consider that the application of the Product Liability Directive might be problematic and/or uncertain for some products. In particular, around 10 % of producers, 12 % of *inter alia* public authorities and civil society and 12 % of consumers indicated specifically products based on AI as a product for which the application of the Directive might be problematic and/or uncertain[95].

[94] Without prejudice to the possibility in respect of the producer to prove he is not liable by virtue of one of the circumstances foreseen in Article 7 of the Product Liability Directive.

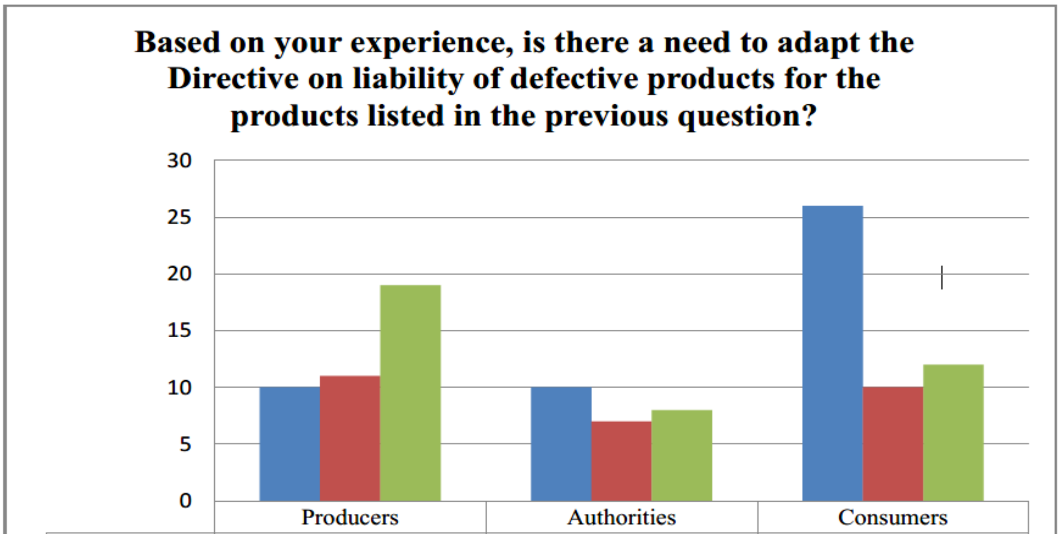
[95] European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Public consultation on the rules on liability of the producer for damage caused by a defective product; Commission Staff Working Document, Evaluation of Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products,

There is a notable difference between the opinion of producers and insurers, on the one hand, and consumers, on the other hand, with regard to the current adequacy of the Product Liability Directive in light of emerging technologies, such as robotics and AI.

Most of producers and insurers believe there is, at present, no need to adapt the Product Liability Directive when it comes to emerging technologies. They agree the directive is technology-neutral and changes to the directive would be premature. Only some technologies, such as completely autonomous systems, might eventually require regulatory changes but these are not even marketed yet. They do consider for business-to-consumer relations, difficulties may arise in the future.[96]

A vast majority of consumers however believe the Product Liability Directive is not fit for purpose in light of emerging technologies and needs to be revised, already at present.

Figure 3 – Need to adapt the Product Liability Directive for emerging technologies[97]



	Producers	Authorities	Consumers
Yes	10	10	26
No	11	7	10
I do not know	19	8	12

Nonetheless, when it comes to new emerging technologies that are not marketed yet but will be marketed in the future, both producers and insurers as well as consumers acknowledge the application of the Product Liability Directive might become problematic and/or uncertain. This in particular with regard to products with changing complexities over its lifetime that are no longer controlled by the producer (e.g. self-learning aspects) and products which become increasingly intangible (e.g. software), such as robotics and AI.

Accompanying the document Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee on the Application of the Council Directive 85/374/EEC on the approximation of the laws, regulations, and administrative provisions of the Member States concerning liability for defective products, Brussels, 7.5.2018, SWD(2018) 157 final, https://ec.europa.eu/transparency/regdoc/rep/10102/2018/EN/SWD-2018-157-F1-EN-MAIN-PART-1.PDF.

96 Ibid.

97 Ibid.

Existing legislation applicable to robotics and AI at national level: general rules on liability and insurance

Currently, the Member States of the EU did not yet adopt specific national regulatory frameworks regarding liability and insurance related to robotics and AI.[98]

Member States are conducting policy debates on robotics and/or AI. The approach taken by the Member States varies. Some Member States have laid down AI specific and comprehensive AI strategies (e.g. France, UK[99]), while others are integrating AI technologies within national technology or digital roadmaps (e.g. Denmark). Regardless of the approach pursued, it emerges that countries are engaged in an AI race that aims at achieving AI leadership.[100]

The policy responses in Member States are in general aimed at supporting AI deployment in industries and in public services. The national strategies address obstacles to the uptake of AI in businesses, foresee public and private funding and provide for specific measures ensuring that enough investments are made in the development and application of AI technologies.[101]

Member States also discussed a legislative approach towards liability and insurance related to robotics and AI. In Germany for example, the Justice Ministers of the German federal states adopted a resolution in June 2017 calling for legislative action, including at EU level, where extra-contractual liability for the operation of autonomous systems is concerned.[102] Estonia officially undertook a discussion on the legal matters related to the use of AI-based technologies. Estonia focuses on a general plan of AI laws, legal systems, and systems of liability, accountability, data integrity and ethics. This cross-sector approach is based on figuring out AI issues such as liability in a holistic way, in order to minimise the time it otherwise takes to establish regulations for individual sectors and to be able to use these technologies more quickly and reap the benefits faster. Through this approach Estonia seeks to establish a business friendly and clear-cut AI legal framework that would attract more investors to the Member State.[103]

However, due to the current lack of a specific regulatory framework, the existing general rules on liability and insurance will apply in the Member States in context of robotics and AI. In most jurisdictions in the EU, the general national regulatory framework consists of strict liability rules and fault-based liability rules. Respondents to market research confirmed the national rules implementing the EU liability regulatory framework, in particular the national rules implementing

98 In response to an own market research, respondents from Belgium, Hungary, Italy, Netherlands, Sweden and United Kingdom indicated there were no specific rules on liability related to robotics and/or artificial intelligence adopted in their relevant Member State.

99 In the United Kingdom, the Department for Business, Energy and Industrial Strategy's wrote in November 2017 a paper 'Industrial Strategy: Building a Britain fit for the future' and the House of Lords Select Committee discussed on the Artificial Intelligence's Report of Session 2017-19 'AI in the UK: ready, willing and able?'. Also in Sweden there are policy debates on AI in the context of the national Swedish focus on AI decided by the Swedish Government on 9 May 2018 and in the context of the research and innovation policy proposition 'Knowledge in collaboration - for society's challenges and strengthened competitiveness'.

100 L. Delponte, European Artificial Intelligence (AI) leadership, the path for an integrated vision, Study requested by the ITRE committee, September 2018, 22, http://www.europarl.europa.eu/RegData/etudes/STUD/2018/626074/IPOL_STU(2018)626074_EN.pdf.

101 Ibid., 25-27.

102 Own market research of the authors.

103 European Commission, Workshop Report, The European AI Landscape, 8, https://ec.europa.eu/digital-single-market/en/news/european-artificial-intelligence-landscape.

the Product Liability Directive, and the national civil or common law rules regarding extra-contractual liability would be called upon.[104]

Because strict liability and fault-based liability rules govern the general rules on liability in the Member States of the EU, these will be further investigated in order to emphasise what should be considered by regulators going forward. A distinction is made between the current two coexisting legal systems in the EU; the civil law regime and the common law regime.[105]

Applicability of national strict liability rules to robotics and AI

1 Civil law regimes

In the EU Member States applying a civil law regime,[106] with regard to strict liability, the national rules implementing the Product Liability Directive will apply in context of robotics and AI.

In civil law regimes, a defective product is a product that does not provide the safety that a person is reasonably entitled to expect, taking into account the presentation of the product, the use that can reasonably be expected of it and the time when it was placed on the market.

A producer is strictly liable for the damage caused by a defect of its product, whether it was contractually bound to the claimant or not, unless he/she can prove in certain specified circumstances that it is imputable to another cause such as compliance with mandatory legislation or regulation. The claimant must then prove actual damage, a defect of the product and the causal link between the defect and the damage. Further to this, in relation to the causal link, a standard of proof by presumption can be allowed.

Strict liability rules are adequate to apply in context of current robotics and AI. Moreover, they alleviate the burden of proof in respect of the person suffering damages to receive compensation from producers. Strict liability is, however, less adequate to solve liability issues related to autonomous robotics and AI. For example, the use that can reasonably be expected of non-sophisticated robotics and AI can be established. However, how would one determine the use that can reasonably be expected of robotics and AI with self-learning aspects, thus continuously evolving over time, and autonomous behaviour, thus making its own non-preprogramed choices?[107]

2 Common law regimes

From the perspective of common law and to take the UK as an example,[108] consumers can also make use of the avenues of strict liability (or fault-based liability, see below). As in any jurisdiction, whether civil or common, there are many ways in which liability can present itself but in particular, common law systems operate under a system of precedent where the courts can extend and mould legal concepts with greater ease and as a result the boundaries are less defined.

---

104 In Hungary, product liability rules as well as general civil liability rules would be applied. In Italy, they would call upon the principles on liability set forth in the Italian Civil Code and in the Italian Consumers' Code provided by the Legislative Decree of 6 September 2005 No. 206, including the provisions on product liability implementing the Product Liability Directive. In Netherlands, the provisions on liability of the Dutch Civil Code would be applied. In Sweden, issues would be resolved by application of the Swedish Tort Act ("Skadeståndslagen") and, in case of contractual liability, the Swedish Contract Act ("Avtalslagen"), as well as by application of the general principles in Swedish tort and/or contract law. In the United Kingdom, they would fall back upon the Consumer Protection Act 1987, implementing the Product Liability Directive, and the common law tort of negligence.

105 At the time of writing the Study, the United Kingdom forms part of the European Union.

106 The Member States of the EU applying a civil law regime are Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain and Sweden.

107 See also above, section on EU level, Product Liability Directive.

108 Other Member States of the EU applying a common law regime are Cyprus, Ireland and Malta.

In the UK, product liability is governed by the Consumer Protection Act 1987 (CPA) which brought the Product Liability Directive into effect.

Section 2 of the CPA imposes strict liability for any damage caused by a defective product. This means that the claimant does not need to prove fault and it is a similar reversal of the typical burden of proof required for such claims.[109] The aim is to compensate the victim; to place him/her in the position he/she would have been if the product would not have been defective. In order to succeed in such a claim, it must be shown that the product was defective, that the claimant suffered damage and that a causal link exists between the defective product and the damage suffered.[110] A product will be deemed to be defective if the safety of the product is not such as persons generally are entitled to expect, taking into account all of the circumstances including factors such as purpose, instructions, what might reasonably be expected to be done with or in relation to the product as well as the time when the product was supplied.[111]

Applicability of national fault-based liability rules to robotics and AI

1 Civil law regimes

With regard to fault-based liability, the national rules regarding extra-contractual liability can be called upon.

In general, in EU Member States' civil law regimes, fault can result from the fact that a person did not act as a reasonable person would be expected to act. Here, a claimant must prove that the defendant is responsible for either a fault whether intentional or not or negligence, that he/she has suffered loss, and that there is a causal link between the loss and the fault. Any party can be liable if they have the power to use, control or manage the item. To add to this, a person will be strictly liable under the rules for damage caused by things that are considered to be in his/her custody. What is of note, however, is that a product can be considered to remain in the custody of a person in certain circumstances even when it has been transferred to the user. This is an important example of the wide-reaching nature of tort liability within some civil law regimes. Here, a person remains liable for the consequences of his/her fault or for the fault of persons for whom it is responsible.

The liability may be mitigated for a number of reasons, including where it can be shown that the defect was caused by the fault of the claimant or of a person for whom the claimant is responsible. It is also possible for a person to defend his/her position by contesting the causal link between the fault and the damages.

Fault-based liability can be applied in context of robotics and AI. In contrast to strict liability, the person claiming damages has to prove fault, intentional or not, or negligence. In addition, similar to strict liability, the person claiming damages has to prove damages/loss and a causal link between the fault and the damages/loss. A user and/or owner of robotics and AI can thus be held liable if he/she causes damages by faulty or negligent use of robotics and AI, e.g. by using robotics and AI not as a reasonable user/owner would be expected to use it. Also producers and manufacturers of robotics and AI can be held responsible for committing a fault or negligence, nonetheless the burden of proof is aggravated due to the asymmetric information. However, actors will not be held liable if they can prove that the damages caused by robotics and AI was not reasonably predictable. In context of sophisticated and autonomous robotics and AI, there is a risk that this concept could be given a broad interpretation, since even the behaviour of these robotics and AI cannot be predicted.

[109] Consumer Protection Act 1987, Section 2.
[110] Ibid., Section 2.
[111] Ibid., Section 3.

In most jurisdictions, there also exists the possibility of an owner or user incurring liability for damages caused by animals, whether they were in their custody or not or whether they had escaped or strayed. Parental liability also exists for minors who cause damage.

Also this principle of liability could be applied to robotics and AI. Robotics and AI are than seen as subjects capable of making independent choices over which the owner/user has control. The owner and/or user of the robotics and AI has a general duty to prevent damages and would be liable if damages are caused anyway.

In sum, general civil law regimes of EU Member States provide persons who suffer damages with an accommodating system. If currently damages would be caused by robotics and AI, they may bring a claim under defective product liability, a claim by using the system of extra-contractual liability or even, if applicable, a claim under their contractual rules.

2 Common law regimes

It is also possible to bring a common law action under the fault-based liability rules for negligence, an area that is likely to see a lot of developments over the coming years. The essence of negligence within common law is a duty to take 'reasonable care'. In order to establish liability, in particular in relation to products, it is necessary to prove on the balance of probabilities that the defendant owed the victim a duty of care, that that duty was breached, that the breach caused the resulting damage and that the producer could have reasonably foreseen the consequences. Here, the standard is objective and in particular, the claim is focused on the behaviour of the producer, the gravity of the consequences along with the likelihood of harm. It will usually be established that the defendant owes a duty of care to the intended end users of the product which includes intermediate parties in the supply chain if the product is a component. Like other jurisdictions, the claimant or victim is responsible for proving that he/she was injured and that the defendant is responsible for the actions.[112] The loss must be within the scope of the defendant's duty and must not be interrupted by a breach in the chain of causation. Policy considerations can sometimes assist the claimant if the limits of scientific knowledge prevent him/her from establishing conclusively which of a number of tort feasors are actually responsible for causing the harm.[113]

Aforementioned, in such jurisdictions, judges also have the power to stretch and shape the law. Some examples of this include the rule created in the case of *Rylands* v *Fletcher*; that if you bring something dangerous onto your property and it escapes and causes an accident, this is at the burden of the owner.[114] In addition, the principle of 'res ipsa loquitur' implies that the defendant's particular control of an item is used to establish that the accident could only have occurred through a negligent act.[115] As in civil jurisdictions, assumption of risk can be used as a defence as well as the requirement that the claimant do all in their power to mitigate the risk.[116]

The US as an example?

While civil law and common law jurisdictions have not witnessed many cases invoking liability in the robotics and AI sphere, the US provides a good example of how the courts in Member States might choose to handle this issue in the future. The general approach of the courts has been more remedial than preventative and as in Member States of the EU, the key issues tend to lie in whether

[112] *Heaven* v *Pender* (1883) 11 QBD 503 at 507.

[113] *Matthews* v *Associated Portland Cement Manufacturers (1978) Ltd* [2002] UKHL 22, [2003] 1 AC 32, [2002] 3 All ER 305.

[114] *Rylands* v *Fletcher* [1868] LR 3 HL 330.

[115] See *Farrell* v *Snell* [1990] 72 DLR (4th) 289.

[116] *Thrussell* v *Handyside & Co* [1888] 20 QBD 359.

the technology can be viewed as a product or a service and in how wide the net should be cast when invoking liability.[117]

To evidence this, an example of the application of the principle of 'res ipsa loquitur' can be found in the recent Toyota case which involved allegations that software defects had caused their vehicles to accelerate notwithstanding measures which drivers had taken to stop. The court rejected Toyota's assertion that there could be no liability because the plaintiff's experts could not identify a precise manufacturing defect, instead finding that a reasonable jury could conclude fault on behalf of the defendant via the principle of 'res ipsa loquitor'.[118]

Conclusion

Both national strict and fault-based liability rules and principles could be applied to damages caused by robotics and AI. The courts in the Member States can interpret these rules and principles further in the light of robotics and AI. However, the legal systems may find themselves navigating through uncharted waters if the boundaries of liability in context of robotics and AI cannot be established.

While none of the above provisions of national legislation are specifically applicable to damages potentially caused by new emerging digital technologies, they provide helpful precedents and are points of reference to which one can turn to when considering how best to address certain distinguishing elements of risk and damages created by robotics and AI. From both a civil and a common law perspective, producers and investors are faced with the possibility that liability can come from a variety of angles. On the other hand, persons suffering damages have to realise that, regarding strict and fault-based liability, they carry the burden of proof and the causal link will not be easily proven, especially regarding future sophisticated and autonomous robotics and AI.

Several Member States of the EU have begun to consider the implications of these two essential emerging technologies on their domestic liability regimes. However, despite the positives of Member State involvement in this issue, the more national rules that would be implemented, the more difficult it will be for the EU to harmonise its regulation of the sector across its Member States.

[117] See U.S. Chamber Institute for Legal Reform, Torts of the Future II, Addressing the Liability and Regulatory Implications of Emerging Technologies, April 2018, 7-19.

[118] Re Toyota Motor Corp. Unintended Acceleration Mktg., Sales Practices, & Prod. Liab. Litig., 978 F. Supp. 2d 1053 1100 01 (C.D. Cal. 2013).

2.3.2. Gaps and barriers

Key findings

- One generally accepted definition of robotics and AI in the EU is necessary to introduce trust and harmonisation;
- The current harmonisation on liability in the EU is not sufficient to obtain a fully harmonised and optimal functioning single market in robotics and AI:
  - Matters not explicitly covered by the Product Liability Directive are not harmonised at EU level;
  - The current scope and concepts of the Product Liability Directive create legal uncertainty regarding robotics and AI, in particular in the context of services and software;
  - The application of the current national regulatory frameworks lead to widespread outcomes;
- The insurance market regarding robotics and AI is not fully developed due to a lack of information and a clear assessment of the robotics and AI market;
- The current (legal) skill base is inadequate, in particular with regard to more complex liability cases and with a view to the future, as robotics and AI will become more autonomous.

Lack of one generally accepted definition

There does not exist a generally accepted (EU) definition of robotics and AI. Whilst most of the current definitions take into consideration more or less the same general characteristics, there is still no generally accepted definition.

The absence of a common (EU) definition of robotics and AI poses a problem to the development of these two essential emerging technologies as well as to the development of a framework regulating these technologies.

It is impossible to hold actors within the field of robotics and AI accountable and to establish liability, even cross-border, if there are no clear boundaries, starting with a common definition of robotics and AI and its capabilities. The use of plural definitions, for example different definitions used in different Member States, would lead to different outcomes of similar cases in Member State A compared to Member State B. Even more, the use of different definitions in Member States could lead to different outcomes of similar cases in the same Member State, if one of these cases contains a cross-border element and subsequently the same national court has to apply, on the one hand, the regulatory framework of its Member State and, on the other hand, the regulatory framework of another Member State.[119] This would add to the uncertainty amongst actors within the field and

[119] By virtue of Regulation (EC) no 864/2007 of the European Parliament and of the Council of 11 July 2007 on the law applicable to non-contractual obligations, *OJ* L 171/12, 7. 7. 1999 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0864&from=en), in general, the applicable law is the law of the country in

hinder the optimal functioning of the single market. Moreover, without producers, insurers, consumers and other actors knowing exactly what falls within the scope of robotics and AI, it is impossible for them to calculate and take risks, which is an inherent part of innovation.

Therefore, focus should also be placed on the basic aspects requiring trust and eventually harmonisation, such as one common definition of robotics and AI. Doing so will reassure actors within the field of robotics and AI the anticipated risks are being addressed.

Lack of a harmonised liability framework

There is no specific regulatory framework regarding liability and insurance in the context of robotics and AI, nor at EU level nor at national level. Actors within the field of robotics and AI would fall back upon the Product Liability Directive and the national civil law rules regarding liability and insurance. (see above)

Via its transposition in the national regulatory frameworks of the Member States, the Product Liability Directive introduces a largely harmonised regulatory framework in the EU.

However, with regard to robotics and AI, the current harmonisation reached by the Product Liability Directive as well as the current existing national rules are not sufficient to obtain a fully harmonised and optimal functioning single market in robotics and AI.

No harmonisation for the matters not explicitly covered

The Product Liability Directive is considered to create an exhaustive harmonisation for the matters that it explicitly covers.[120] However, Member States may adopt own national rules regarding some specific matters not explicitly covered by the Directive.

The transposition of the Product Liability Directive therefore did not introduce a fully harmonised regulatory framework in the EU.

In particular, with regard to the possible derogation for the development risk clause,[121] five Member States of the EU[122] opted for this derogation. These Member States thus foresee in their national rules that a producer will be liable even if he/she proves that the state of scientific and technical knowledge at the time when he/she put the product into circulation was not such as to enable the existence of a defect to be discovered.

Moreover, even this derogation does not constitute a harmonised derogation in the five aforementioned Member States. Two Member States[123] adopted the derogation without limitations and apply the derogation to all categories of producers and products. One Member State[124] applies the derogation, but not for pharmaceutical products. Another Member State[125] excludes medicinal products, foodstuffs or food products intended for human consumption from the derogation. The last Member State[126] applies the derogation solely to products derived from the human body.

which the person sustaining the damage had his or her habitual residence when the damage occurred, if the product was marketed in that country, which can differ from the competent national court.

120 Judgment of 25 April 2002, *Commission* v *French Republic*, Case C-52/00, ECLI:EU:C:2002:252, http://curia.europa.eu/juris/showPdf.jsf?text=&docid=47307&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=3994335.

121 Article 15 (1) (b) *juncto* Article 7 (e) of the Product Liability Directive.

122 Finland, France, Hungary, Luxembourg and Spain.

123 Finland and Luxembourg.

124 Hungary.

125 Spain.

126 France.

Furthermore, four Member States[127] transposed the Product Liability Directive and introduced a criterion to determine when a product is put into circulation. Six Member States[128] elaborated the reasonable time by which the supplier of the product, in order not to be seen as its producer, must inform the injured person of the identity of the producer or of the person who supplied him with the product where the producer cannot be identified. One Member State[129] specified the nature of the damages that can be indemnified and another Member State[130] specified the term for recourse against the producer held liable for a defect.[131]

Thus, the Product Liability Directive creates an exhaustive harmonisation for the matters that it explicitly covers, but does not create harmonisation in the Member States for the matters it does not explicitly cover. There are national differences in the current regulatory liability framework in the EU. These national differences also apply in context of robotics and AI.

Actors within the field of robotics and AI falling back upon the Product Liability Directive and its national transpositions will encounter different applicable national rules throughout the Member States of the EU[132]. They will have to take into account plural, different regulatory frameworks in the Single Market. This adds to the legal uncertainty in respect of producers and consumers and has a negative impact on the costs of and doing business across the Single Market.

No harmonisation for all emerging technologies

Although the Product Liability Directive creates a largely harmonised regulatory framework in the EU, its scope is not unlimited.

At present, the Product Liability Directive and its national transposition laws[133] are applicable to emerging technologies, such as robotics and AI, solely when they qualify as a product, i.e. movables, even though incorporated into another movable or into an immovable.[134] Services and non-material damage do not fall within the scope of the Product Liability Directive.

However, it is also possible that robotics and AI technologies are considered not as a product but as a service.[135] In these cases, the Product Liability Directive and its national transposition laws will not apply.

Moreover, robotics and AI can refer to the simulation of human intelligence by software. Software is a key component of these essential emerging technologies. The Product Liability Directive and its national transpositions will thus only be applicable if robotics and AI as software fall within their

---

127 Austria, Belgium, Cyprus and Czech Republic.

128 Hungary, Italy, Poland, Portugal, Spain and Sweden.

129 Germany.

130 Netherlands.

131 Commission Staff Working Document, Evaluation of Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, Accompanying the document Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee on the Application of the Council Directive 85/374/EEC on the approximation of the laws, regulations, and administrative provisions of the Member States concerning liability for defective products, Brussels, 7.5.2018, SWD(2018) 157 final, https://ec.europa.eu/transparency/regdoc/rep/10102/2018/EN/SWD-2018-157-F1-EN-MAIN-PART-1.PDF.

132 By virtue of Regulation (EC) no 864/2007 of the European Parliament and of the Council of 11 July 2007 on the law applicable to non-contractual obligations, *OJ* L 171/12, 7. 7. 1999 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0864&from=en), in general, the applicable law is the law of the country in which the person sustaining the damage had his or her habitual residence when the damage occurred, if the product was marketed in that country.

133 Except for two Member States, Greece and Lithuania. (see below)

134 Article 2 of the Product Liability Directive.

135 See for example the case of *Motorola Mobility, Inc.* v *Myriad France SAS*, 850 F. Supp. 2d 878 (N.D.Ill.2012).

scope. However, with regard to software, there is no unanimous opinion whether software should be considered as a product or as a service.[136] Also with regard to embedded software, it is unclear whether the Product Liability Directive and its national transpositions would apply.[137] Moreover, the relevance of this distinction in light of new emerging technologies such as robotics and AI becomes uncertain.[138]

If robotics and AI are seen as a product (or software considered as a product), protection from damages caused by defects is provided for by the Product Liability Directive and its national transposition laws.

However, if robotics and AI are seen as a service (or software considered as a service), protection from damages caused by defects will be based on other legal bases. In this regard, six Member States[139] provide for protection from damages caused specifically by defects of intangibles (such as software) or services by means of a broad interpretation of general rules regarding liability. In one Member State,[140] protection from damages caused by defects of intangibles or services is provided for not only by interpretation of general rules regarding liability but also by specific legislation. Only two Member States[141] stretched out their national rules transposing the Product Liability Directive to include strict liability for services and intangibles. Nonetheless, eighteen Member States[142] do not have any specific legislation nor a specific interpretation of general rules regarding liability to offer protection from damages caused by defects of services or intangibles.[143]

Thus, if robotics and AI are seen as a product (or software considered as a product)[144] and fall within the scope of the Product Liability Directive, actors within the field of robotics and AI will be able to fall back upon a largely harmonised regulatory framework.

---

136 To determine whether a software is to be considered as a product or as a service, requires at the moment a case-by-case analysis; for example in Estonia and in France, computer software has been considered products; see question N° 15677 de M. de Chazeaux Olivier, question published in JO 15/06/1998, 3230, answer published in JO 24/08/1998, 4728.

137 Software embedded in products at the moment the products are put into circulation by the producer, could fall within the scope of the Product Liability Directive for damages caused by defects in the software. However, the applicability of this Directive may pose more challenges with regard to the more open nature of new products, e.g. robotics and AI, where the producer is no longer able to control software subsequently installed in or learned by the product; see Commission Staff Working Document on the evaluation of Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, accompanying the document Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee on the Application of the Council Directive on the approximation of the laws, regulations, and administrative provisions of the Member States concerning liability for defective products (85/374/EEC), Brussels, 7.5.2018, SWD(2018) 157 final, 52, https://ec.europa.eu/transparency/regdoc/rep/10102/2018/EN/SWD-2018-157-F1-EN-MAIN-PART-1.PDF.

138 European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Final report by EY, with the support of Technopolis Group and VVA, for the evaluation of Council Directive 85/374/EEC on the approximation of laws, regulations and administrative provisions of the Member States concerning liability for defective products, Luxembourg: Publications Office of the European Union, 2018.

139 Estonia, Germany, Malta, Netherlands, Slovak Republic and Slovenia.

140 France.

141 Greece and Lithuania.

142 Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Ireland, Hungary, Italy, Latvia, Luxembourg, Poland, Portugal, Romania, Spain, Sweden and United Kingdom.

143 European Commission, Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, Final report by EY, with the support of Technopolis Group and VVA, for the evaluation of Council Directive 85/374/EEC on the approximation of laws, regulations and administrative provisions of the Member States concerning liability for defective products, Luxembourg: Publications Office of the European Union, 2018.

144 A product is in this context defined as all movables, with the exception of primary agricultural products and game, even though incorporated into another movable or into an immovable, including electricity.

On the other hand, if robotics and AI are seen as a service (or software considered as a service)[145] and do not fall within the scope of the Product Liability Directive, actors within the field of robotics and AI will encounter or interpretations of different national general rules regarding liability, or interpretations of national general rules combined with specific legislation, or strict liability rules. Therefore, actors have to take into account similar cases will lead to different outcomes throughout the EU.

The current scope and concepts of the Product Liability Directive leaves room to legal uncertainty amongst actors in the field of new emerging technologies, such as robotics and AI. This *inter alia* because at present services are excluded from the scope of the Product Liability Directive and because the question still remains whether software does or does not fall within its scope. Moreover, the distinction between products and services may become irrelevant.

As long as there is no clarification on this point, uncertainty regarding robotics and AI will remain and will hinder innovation and trust in the applicable regulatory framework.

Difference in application of national liability rules throughout the EU

General national civil or common law rules regarding extra-contractual liability can be applied to damages caused by robotics and AI. However, the EU consists of a differing and widespread legal landscape across its Member States.

Actors within the field of robotics and AI could have to take into account a difference in application of law/national rules regarding extra-contractual liability throughout the Member States of the EU. It is not excluded that, with regard to the same event giving rise to damage, Member State A applies its national strict liability rules and Member State B its fault-based liability rules[146]. In straightforward cases, the application of national liability rules would not cause much difficulty. In complex cases, on the other hand, there will be a need to interpret the national rules and principles in the light of robotics and AI, leading to different outcomes of similar cases in each Member State.

Taking into account the widespread legal landscape regarding extra-contractual liability in the Single Market, at least four different legal solutions, with each its own traits, could be applied to similar events causing damages by robotics and AI. These events and its legal solutions would in each Member State be interpreted in context of the national rules and principles.

1 Strict liability

Member States could apply strict liability on damages caused by robotics and AI. Strict liability can be found in both common and civil law jurisdictions. Strict liability stipulates that a person causing damage is liable for any damage caused irrespective of whether the victim can prove fault.[147] A system of strict liability would alleviate the burden of proof carried by the victim. If producers or manufacturers of robotics and AI are held strictly liable however, this might result in the slow adoption of beneficial technology since large and uncertain risks have to be taken. It has also been argued that many applications of AI do not have clear profit margins, making it difficult to pre-define the potential costs. Thus even in clearly profitable areas, such solution being applied in respect of

[145] A service is in this context, on the contrary, immovable in nature, excluding electricity.

[146] By virtue of Regulation (EC) no 864/2007 of the European Parliament and of the Council of 11 July 2007 on the law applicable to non-contractual obligations, *OJ* L 171/12, 7. 7. 1999 (https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32007R0864&from=en), in general, the applicable law is the law of the country in which the damage occurs irrespective of the country in which the event giving rise to the damage occurred and irrespective of the country or countries in which the indirect consequences of that event occur.

[147] See below sections on strict liability within both civil and common law jurisdictions.

producers or manufacturers would likely hinder innovation to a certain level.[148] On the contrary, if users or owners of robotics and AI would be held strictly liable, producers and manufacturers would be triggered to take more risks, following which innovation would be stimulated. However, it is deemed unlikely that Member States would apply strict liability in respect of owners or users of robotics and AI rather than in respect of producers or manufacturers.

2 Fault-based liability

Member States could apply fault-based liability on damages caused by robotics and AI. Fault-based liability is based on tort law and can be found in both common and civil law jurisdictions.[149] It is inherently more difficult for the victim to be successful than in a strict liability case. Further to this and as previously discussed, in particular in common law jurisdictions, there is potentially a wider set of situations in which a producer, manufacturer, owner or user may be held liable, as courts are capable of setting precedent and adapting the liability landscape as they see fit.

3 Risk management

Member States could apply a risk management approach in context of damages caused by robotics and AI. The idea is that, in order to allocate risk, the level of risk and the ability to control that risk should determine the level of liability. However, in certain situations, it may be difficult to put the control of specific technologies solely within the hands of one actor, placing the liability on the user instead and perhaps incentivising users to create precautions and to demand producer innovation in certain fields. It is also possible that, in this solution, the liability burden will shift only towards producers, particularly when more emphasis is being placed on the ability and desire of AI products to become autonomous.[150]

4 Vicarious and parental liability

A good example of the concept of risk management within the existing legal system is that of vicarious liability; a form of secondary strict liability imposed on those seen to be in a position capable of controlling other persons and their acts.[151] Vicarious liability, as well as parental liability, can be found in both common and civil law jurisdictions. Member States could apply this concept to damages caused by robotics and AI, following which robotics and AI are considered agents or employees. To use the UK as an example, vicarious or secondary liability exists in the area of employment law. Where an employment relationship can be established and the act is committed within the scope of the employment, generally speaking the employer can be held strictly liable for the acts of the employee. As long as it falls within the scope of employment, the employer is liable.[152] On top of this, there also exists the possibility for parents to be held liable for minors who commit tortious acts. This may occur where the parent has control of a dangerous thing that causes damage,[153] where the parent has been negligent in some way[154] or where the parent has previously authorised or ratified the act of the minor.[155] It is also possible for a parent to be liable for injuries

[148] *The Liability Problem for Autonomous Artificial Agents,* Asaro P M, Association for the Advancement of Artificial Intelligence, 2016.

[149] See below sections on fault-based liability within both civil and common law jurisdictions.

[150] *Punishing Robots: Issues in the Economics of Tort Liability and Innovation in Artificial Intelligence* Galasso A and Hong L, NBER Working Paper no. 14035, 2018.

[151] *Majrowski* v *Guy's and St Thomas' NHS Trust* [2006] UKHL 34.

[152] *Bilta (UK) Ltd* v *Nazir (No 2) [2015] UKSC 23*.

[153] *North* v *Wood* [1914] 1 KB 629.

[154] *Dixon* v *Bell* (1816) 5 M & S 198.

[155] *Moon* v *Towers* (1860) 8 CBNS 611.

suffered by third persons where an innocent act of a child should have been reasonably anticipated.[156]

These two concepts of vicarious and parental liability, considering the ability to control a situation or the acts of another as a decisive factor in the distribution of liability, can be interpreted to include damages caused by robotics and AI. However, as the level of control will inevitably differ depending on the product and its design and will become less over time by robotics and AI achieving autonomy, this may prove to be a difficult solution.

The abovementioned four solutions are merely general possible legal solutions that could be applied by Member States.[157] These solutions will further be given a different national interpretation throughout the EU. As a consequence, similar cases with regard to robotics and AI could lead to different outcomes in each Member State.

Actors within the field of robotics and AI have to take into account these differences when acting in the single market. This adds to the legal uncertainty in respect of producers as well as consumers and has a negative impact on the costs of and doing business across the single market.

Lack of a clear insurance framework

Producers will continue to want to shield themselves from liability, while insurance could alleviate some of these problems and possibly protect producers and consumers. This arena has not been fully developed based on a lack of information and because it is still largely an emerging market. However, even when one considers the more regulated markets, high liability risk is capable of deterring entry as a result of high premiums.[158]

The lack of clear information poses issues for consumers and producers as well as for insurance companies themselves. Justice requires an understanding of the scope and the level of risk assumed. This in turn enables insurers to assess the risks, requiring specific expertise.[159]

From the perspective of producers there exists more general tort insurance or the concept of risk-pooling insurance; the idea being that those involved can pool together to avoid larger risks. This is a system used more generally by insurance companies to safeguard themselves from catastrophic pay outs if an unanticipated event occurs. However, this idea is only likely to work well when there are large corporations involved capable of compensating victims. This option could encourage investment and innovation if producers know there is a way for them to avoid an unexpected risk.[160] On the other hand, however, where the risk is essentially shared this may result in producers actively limiting the ability of consumers to modify or adapt advanced products, potentially stifling

[156] *Carmarthenshire County Council* v *Lewis* [1955] AC 549, [1955] 1 All ER 565, HL.

[157] For example, in Bulgaria (case no. 20942/2012), a consumer bought a storage unit, i.e. a product on which the consumer could install software and apps from different sources after purchase. However, the storage unit was defective and malfunctioning in the sense that the computer could not recognise the storage unit. As a consequence, due to these defects in the external hard disk, the consumer lost stored information. For these damages, the consumer claimed a compensation of approximately €800. However, the court rejected this claim by ruling that the claimant was neither able to prove the damages suffered through the loss of the information (the actual damage) nor able to prove that the information had been stored on the external disk prior to the occurrence of the defect (the causal link between the defect and the damage).

[158] *Punishing Robots: Issues in the Economics of Tort Liability and Innovation in Artificial Intelligence* Galasso A and Hong L, NBER Working Paper no. 14035, 2018.

[159] *The Liability Problem for Autonomous Artificial Agents,* Asaro P M, Association for the Advancement of Artificial Intelligence, 2016.

[160] Ibid.

innovation in certain sectors. Another option could be to make it mandatory for consumers to purchase insurance for robotics and AI products that are autonomous or at a particularly high risk[161].

The insurance market regarding robotics and AI has not been fully developed due to a lack of information and a clear assessment of the robotics and AI markets. Producers and consumers as well as insurers are more likely to want to engage with robotics and AI if they can assess and understand the implications of doing so. This should be looked at from the perspective of balance; to provide an appropriate framework while not placing producers and insurers in a position which causes them to be fearful of engaging in the sector.

Lack of an adequate skill base and infrastructure

The application of the current regulatory framework implies the identification of the person liable for the damages caused by the courts. In context of robotics and AI, this means the identification of the person liable for the damages caused by robotics and AI.

In straightforward cases, the identification of a person liable for damages caused by robotics and AI would not pose any problem. However, in more complex cases and in particular in the future, as robotics and AI will become more autonomous, this task is likely to be far too technical for judges to identify. Moreover, the current legal (digital) infrastructure is not adapted to assign liability in such complex cases.

Speculative figures suggest that there are at present around 300 000 AI professionals worldwide with millions of positions available.[162] In the future, the demand for AI professionals will only rise, for example as court expert in liability cases. Part of the reason for this lack of adequate skill base is that the level of training, *amongst others* for those working as part of the legal system, and infrastructure available is not up to the required speed. This calls for an urgent and comprehensive upgrade of Europe's skill base.[163]

An adequate regulatory liability framework without adequate skilled judges/court experts nor adequate legal infrastructure will hinder trust of producers, insurers and consumers and consequently hinder the optimal functioning of the Single Market in robotics and AI.

Therefore, it is essential to not only focus on an adequate regulatory framework, but to focus as much on the overall enhancement of skills and the development of essential infrastructure.

---

161 European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.02.2017, 2015/2103(INL), http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2017-0051+0+DOC+XML+V0//EN.

162 *The AI skills crisis and how to close the gap,* Marr B, accessed 15th November 2018: https://www.forbes.com/sites/bernardmarr/2018/06/25/the-ai-skills-crisis-and-how-to-close-the-gap/#408c754731f3.

163 Report McKinsey Global Institute, *10 imperatives for AI in the age of AI and automation,* accessed 10th November 2018: https://www.mckinsey.com/featured-insights/europe/ten-imperatives-for-europe-in-the-age-of-ai-and-automation.

2.4. Quantitative assessment

Key findings

- A harmonised EU regulatory framework on liability and insurance in robotics and AI in EU-27 is assumed to lead to increased R&D efforts; uptake of these two new essential emerging technologies and insurance costs;
- Greater R&D efforts on its own would lead to small positive impacts on GDP and employment;
- However, the uptake of robotics and AI is expected to bring about a wide range of economic and social implications, including the loss of employment;
- The overall impact of harmonised regulation depends greatly on the extent of which the jobs displaced by the faster uptake of AI and robotics are matched by new employment opportunities created elsewhere. The analysis suggests that favourable price effects do not offset much of the direct impact on the EU-27 as a whole;
- Should the faster adoption of AI require additional investment, this would go some way to mitigate the adverse impact on GDP from net job losses.

This quantitative assessment (economic analysis), presents a consistent CoNE/value-for-money approach to identify and quantify the foregone net benefits and the cost of not introducing EU-level action in relation to selected markets (liability, insurance and risk management) for robotics and AI.

The approach is to compare the prospects for the EU economy under two alternative regulatory regimes, with the CoNE identified by the difference in EU GDP between the scenarios in 2030. The analysis is carried out within Cambridge Econometrics' E3ME Macroeconometric model – a tool that has been used extensively for economic impact assessments.

In coming to an assessment of the CoNE this chapter: reviews the literature on broad impacts of robotics and AI; reviews the background policy context; sets out an agreed scenario for what EU-level action in these markets would mean; provides an overview of how the policy scenario is represented within the E3ME model; reviews the literature on impacts for similar EU-policy initiatives in equivalent markets for evidence of impact that can be used to guide the quantification for AI; and concludes with a the quantification of CoNE.

As the analysis will show, the quantification of the CoNE is challenging in this context since the technology is developing rapidly globally and it is difficult to conceive what products and services will be available in 10-15 years' time. The quantification should therefore be seen as indicative, rather than a precise estimate, showing the relative importance of different effects and potential sensitivities to the outcome.

2.4.1. Broad impacts of robotics and AI

Robotics and AI are expected to bring about a wide range of economic and social implications, and consequently they have been discussed in a rich and ever-widening literature. The studies in the literature often arrive to congruent conclusions with regards to potential impacts on productivity, work and employment, prices or investment levels.

According to PwC[164] the macroeconomic impact of AI will be driven by two key mechanisms: productivity gains stemming from business automation processes and from augmentation of existing labour force; and increased consumer demand as a result of more personalised / tailored products and services. The study estimates that in sum, global GDP could be about 14 % higher by 2030 as a result of robotics and AI compared to their baseline scenario, with gain in GDP of about 15% in consumer goods, of around 12 % in technology and media, and of 10 % in transport and logistics. PwC also highlights that labour productivity improvements are expected to account for more than 55 % of total GDP gains that stem from AI over the period 2017-2030.[165]

With regards to employment, McKinsey[166] finds that overall and in the longer run, the adoption of AI may not have a significant impact on net employment since the anticipated negative impact stemming primarily from automation is expected to be compensated by new jobs driven by investment in AI and by AI expanding economic activities through innovation. Two other PwC studies provide selected country-level analysis. In the UK, around 20 % (in absolute terms, 7 million) jobs are projected to be displaced by 2037 due to AI, but 7.2 million new jobs are expected to be created, resulting in a net positive impact[167]. China is projected to see a job loss of 200 million driven by AI, however about 300 million jobs are expected to be created as a result of the same, thus ending up in a net positive job impact by 2037.[168]

A recent report by JRC[169] analyses the available literature and evidences on the potential impacts of robotics and AI on work, growth and inequality. With respect to inequality, the report suggests that AI can have unfavourable effect on income distribution globally, primarily in the following aspects: by increasing job polarisation, reducing job quality at the lower end and by making it more difficult for lower-skilled employees to adjust to changes – thereby potentially making the average period of unemployment for them relatively longer vis-à-vis workers with higher qualifications. AI developments, on the more positive side, enable better (and more efficient) tracking of consumer preferences, and at the same time, AI is able to personalize products at scale due to large data analysis capabilities.

2.4.2. Impact of harmonised EU legislation

Current scenario – current regulatory framework

The current legislative framework regarding liability and insurance at EU level ensures a stable and homogenous treatment of producers in the single market of the EU. This framework is however

---

164 PwC, *The Macroeconomic impact of artificial intelligence*, 2018, https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf.

165 Ibid.

166 McKinsey Global Institute, *Notes from the AI Frontier: Modelling The Impact of AI on the World Economy*, Chicago: McKinsey & Company, September 2018, https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Notes%20from%20the%20frontier%20Modeling%20the%20impact%20of%20AI%20on%20the%20world%20economy/MGI-Notes-from-the-AI-frontier-Modeling-the-impact-of-AI-on-the-world-economy-September-2018.ashx.

167 PwC, *What will be the net impact of AI and related technologies on jobs in the UK?*, UK Economic Outlook July 2018, https://www.pwc.co.uk/economic-services/ukeo/ukeo-july18-net-impact-ai-uk-jobs.pdf.

168 PwC, *What will be the net impact of AI and related technologies on jobs in China?*, September 2018, https://www.pwc.com/gx/en/issues/artificial-intelligence/impact-of-ai-on-jobs-in-china.pdf.

169 Craglia M. (Ed.), Annoni A., Benczur P., Bertoldi P., Delipetrev P., De Prato G., Feijoo C., Fernandez Macias E., Gomez E., Iglesias M., Junklewitz H, López Cobo M., Martens B., Nascimento S., Nativi S., Polvora A., Sanchez I., Tolan S., Tuomi I., Vesnic Alujevic L., *Artificial Intelligence - A European Perspective*, EUR 29425 EN, Publications Office, Luxembourg, 2018, ISBN 978-92-79-97217-1, doi:10.2760/11251, JRC113826.

transposed into national law with different degrees of liability for the producers. The EU Member States can be split into three broad groups[170] on this basis:

i. Basic level of product liability protection for consumers: Bulgaria, Croatia, Denmark, Ireland, Latvia, Slovakia, Slovenia, United Kingdom;

ii. Medium level of product liability protection for consumers: Belgium, Cyprus, Czech Republic, Estonia, Greece, Hungary, Lithuania, Luxembourg, Malta, Poland, Portugal, Romania, Sweden;

iii. High level of product liability protection for consumers: Austria, Finland, France, Germany, Italy, Netherlands, Spain.

In the case of robotics and AI, there is no accepted definition at EU level, therefore it will also be difficult from legislation point of view to make the distinction between the products/tangible and the services and intangible (software) parts of the robot. This will call the existing allocation of responsibility between manufacturers, suppliers of components, owners, keepers and operators of such devices into question[171] and lead to resolving current issues by means of interpretation of the national courts. Depending of the importance of the R&D sector in the Member State, it might lead to possible creation of national regulatory frameworks that would leave producers open to a higher risk of liability in a fragmented single market, a risk that might change over time depending on the uptake levels.

Narrative of impact of harmonised EU legislation

The development of robots and other technical agents operating with the help of AI will transform many, if not all product markets. The impact of AI crosses borders and therefore supra-national (EU-level) policy frameworks need to be established[172] to regulate it effectively. The development of a framework of liability for autonomous systems should be done with a view to maximize the net surplus for society by minimizing the costs associated with personal injury and property damage.

The alternative scenario considered assumes the adoption of a specific regulatory framework that can be based on the Product Liability Directive.[173] Introducing a generally accepted definition of robotics and AI would further contribute to harmonisation in the Single Market.

Since robotics and AI are still currently under development, the ethical and regulatory frameworks are assumed to foster the development of robotic and AI technology and the uptake of goods and services utilising robotics and AI by citizens and industry operators, while economic actors also need sufficient legal certainty to provide financial capital in AI technology.[174] It is assumed that the EU will invest in R&D as per its current plans by the end of 2020 and beyond and by 2030 it is expected that the technology would have been adopted (to some degree) in those markets under consideration: transport/logistics- (excluding self-driving vehicles), households/domestic-; hobby/entertainment- and medical-robotics and AI.

---

170 This classification is an assumption, whereby the basic level essentially corresponds to the level of protection provided for by the Product Liability Directive.

171 Wagner, Gerhard, Robot Liability, June 19, 2018, Available at SSRN: https://ssrn.com/abstract=3198764 or http://dx.doi.org/10.2139/ssrn.3198764.

172 EESC opinion on artificial intelligence – The consequences of artificial intelligence on the (digital) single market, production, consumption, employment and society, INT/806 – EESC-2016-05369-00-00-AC-TRA (NL) 1/6

173 This is in our opinion the most adequate policy option, see below, Section 0 policy option "Specific regulatory framework based on existing regulatory framework"

174 Craglia M. (Ed.) et al, *Artificial Intelligence - A European Perspective*, EUR 29425 EN, Publications Office, Luxembourg, 2018, ISBN 978-92-79-97217-1, doi:10.2760/11251, JRC113826.

A harmonised EU regulatory framework on liability and insurance in robotics and AI among the (future) 27 Member States is assumed to lead to:

- Increased investment in R&D by producers since liability and insurance provisions will be similar, transparent and applicable to all agents in the Single Market;
- Make the EU more attractive for overseas producers to invest in, i.e. increase in foreign direct investment (FDI);
- Increase in the speed of uptake of the technologies by the consumers since a common framework would inspire more trust and confidence in the two new essential emerging technologies (the effect might differ between markets);
- Increased insurance premiums for producers in countries with basic or medium level of product liability protection for consumers under the current legislative framework.

In turn it is assumed these direct effects will result in:

- More confidence from third-countries to buy 'AI made in Europe' and increased competitive position of EU producers on the world market;
- Improved competitive advantage on the internal market over third-countries producers that develop similar technology.

The increase in the uptake of robotics and AI in the four sectors will lead to:

- Changes in productivity in the four sectors using the two new essential emerging technologies;
- Changes in employment in the sectors using, insuring and producing AI products;
- More investment in the sectors producing the robotics and AI to further improve the technologies;
- Increase in the quality of products that bring about more consumer benefits in terms of lower prices or tailored products and that this would result in higher 'real' expenditure even if nominal expenditure is unchanged.
- Change in EU-27 GDP level by 2030.

Given the current differentiated regulatory framework, the impact of introducing a harmonised framework for robotics and AI is likely to vary between Member States, with the greater impact for those countries currently with lower levels of product liability protection.

In the table below, we summarise the effects that are expected on the different actors in the economy.

Table 3: Summary of expected impact of harmonised EU legislation

	R&D investment	FDI	Increased demand	Productivity	Prices
Technology producer	Yes	Yes	Yes		
Technology user – firms			Yes	Yes	Yes
Technology user - households					Yes

Source: Cambridge Econometrics.

2.4.3. Quantifying the impact of harmonised legislation

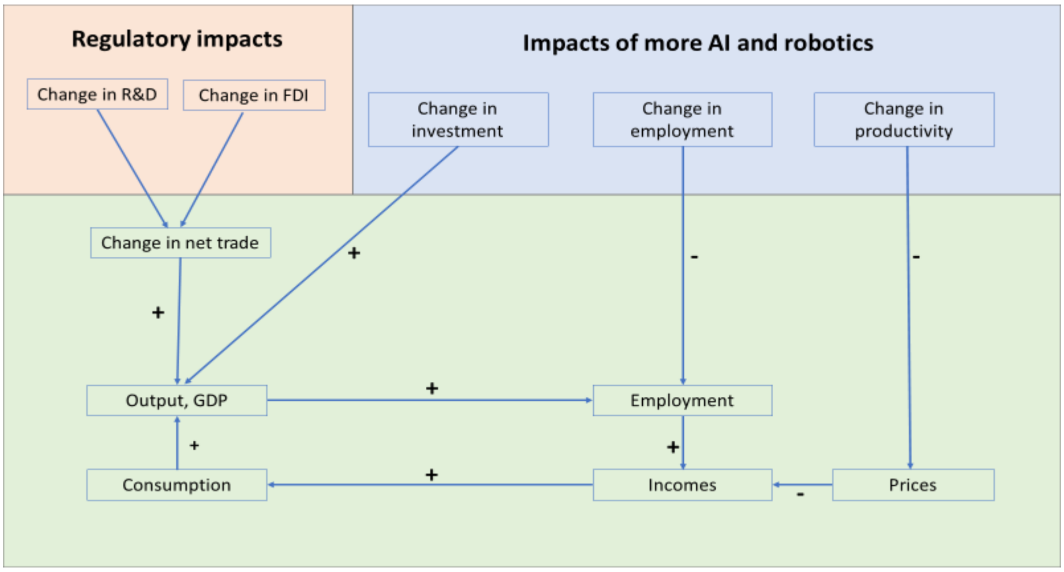
Overview

The analysis of the impact on the EU economy of the change in legislation on liability rules for robotics and artificial intelligence, uses a scenario-based application of the macroeconomic model, E3ME.[175] Representing the scenario in the model requires estimates for the scale of impact of harmonisation on various key economic drivers, including R&D activity and employment as discussed further below. These are based where possible on existing literature.

Representing the harmonised legislation scenario in the model framework

Figure 4 illustrates the model inputs and how these link to other key model variables and outcomes.

Figure 4 – How the scenarios are modelled



Source: Cambridge Econometrics.

It shows the economic logic of how the changes in regulatory framework are expected to impact on the economy and the anticipated direction of each impact (indicated by the plus and minus signs next to the linkages).

The orange box (top left corner of Figure 4) shows the model inputs that isolate the effects of the regulatory changes on 'production' of AI in Europe. A scenario with just this effect assumes that the adoption of AI across Europe is not influenced by changes in the regulatory framework, and it is only the location of the production of services that is affected (because harmonised regulations encourage EU producers to increase R&D effort and the chance of 'successful' production or because it encourages global companies to local production in the EU). In this case the change in trade feeds directly to GDP. There are secondary multiplier effects through industry supply chains and additional employed labour.

The blue box (top-right) depicts the effects where harmonised regulation leads to an increase in the adoption of AI technologies in companies in Europe. This happens alongside the trade effects from the orange box. The main additional assumptions needed are the impact of harmonisation on: investment by users of the technology (there may be no change in investment, just a redirection of

[175] See description of the model in Annex 1.

expenditure to robotic/AI products); productivity and employment in the sector using the technology (there maybe be a step-change in productivity). Each of these inputs has knock-on effects on GDP and employment that may be positive or negative. For example, if adoption in AI replaces employment, then in the absence of other external changes, this will mean lower income, household spending (and associated multiplier effects) and hence GDP. The scenario will show the combined effects of the different model inputs.

Considering the adoption of AI amongst households requires an assessment of different spending patterns. It is reasonable to assume that total household expenditure would remain unchanged regardless of the regulatory environment in the four markets being considered and we would instead see a shift in the types of products that households spend on. The wider economic impacts will depend on the supply chains for these products and, in particular, the share of production within Europe. The macroeconomic impacts of household AI will therefore be quite similar to the regulatory effects, defined in the orange box in the diagram.

The CoNE will be measured in terms of percentage change in GDP and employment in 2030 for the EU-27 as a whole between a baseline scenario in which the existing regulatory environment is maintained and one that includes regulatory harmonisation as previously discussed (see above).

Key modelling assumptions

The discussion above identifies the key assumptions required to model the impact of CoNE. The challenge is to construct plausible estimates for them in the context of the AI products being considered not yet being developed and so the markets not yet formed. A review of the literature on the AI markets and impact evaluations of similar policies was conducted to inform the decisions on the key assumptions.

Evidence for assumptions from the literature

The review of existing literature on previous harmonisation of regulations for other types of products has not identified any useful methodologies to quantitatively assess the impact of harmonisation of the regulatory framework.

In the case of the key assumptions mentioned above, the literature review focused mainly on gathering information concerning: the increase in research effort in robotics and AI; the increased attractiveness of the EU as a place to produce AI and other global players; and the rate of adoption of AI technology by users. The information uncovered[176] gives only broad understanding of the trend in the specific sectors we are interested in.

When it comes to the anticipated impacts in some of the markets in the scope of this report, we see that there are market-specific expectations derived from their anticipated exposure to AI technologies and the speed of AI take-up in the sector. The JRC report[177] highlights that AI, as opposed to most previously known technologies, can automate and accelerate the process of innovation, thereby leading to accelerated productivity growth. The report cites an example from the health sector, where the use of AI in pharmaceutical and chemical industries is evidenced to speed up the discovery of new molecules, or, as suggested by PWC study,[178] to identify other uses for drugs that are already approved. The McKinsey study[179] assumes that financial services, retail,

176 The full information identified can be found in Annex 1.

177 Craglia M. (Ed.) et al, *Artificial Intelligence - A European Perspective*, EUR 29425 EN, Publications Office, Luxembourg, 2018, ISBN 978-92-79-97217-1, doi:10.2760/11251, JRC113826.

178 PwC, *The Macroeconomic impact of artificial intelligence*, 2018, https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf.

179 McKinsey Global Institute, *Artificial Intelligence: The Next Digital Frontier?*, Chicago: McKinsey & Company, June 2017, https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/how%20artifici

health care, and advanced manufacturing will be AI adoption leaders. In these industries, the technical feasibility is relatively high based on the fact they are also the sectors with the highest degree of digital adoption to date.

The review of existing literature has not identified any solid evidence on which to base assumptions on the level of R&D and investment. The only concrete evidence was found on employment loss[180] and productivity increase as a result of adoption of robotics and AI,[181] and this information is available for broad sectors only. Therefore, the modelling approach proposed can be followed through using a pragmatic rationale (which will be clearly set out in the next section) when the concrete evidence is missing.

Key modelling assumptions

In broad terms, the effect of harmonised regulation in these markets is assumed to be the acceleration of actions by one year. For example, levels of R&D activity or adoption that would have occurred by 2031 now occur by 2030.

Although E3ME has a high level of sectoral detail for an economic model of its type, the sectoral disaggregation is not sufficient to match precisely markets/activities of focus.

Practically, there is a need to identify:

a) the detailed activities that are either producers or users of technology in the markets in question;

b) map these to the sectoral structure of E3ME and to understand the relative importance of (a) in (b).

The table below shows the detailed activities (defined on NACE classifications) related to each market and the associated sector within E3ME (together with its definition to illustrate the extent of which the model sectors extend beyond those of market relevance).

When implementing the scenario, assumptions are made for the E3ME sectors as a whole. Therefore, if the markets only account for a fraction of the E3ME sector, then assumptions put into the model need to be scaled back to reflect that part of the sector that is not subject to the direct impact of regulatory change.

al%20intelligence%20can%20deliver%20real%20value%20to%20companies/mgi-artificial-intelligence-discussion-paper.ashx.

180 PwC, *What will be the net impact of AI and related technologies on jobs in the UK?*, UK Economic Outlook July 2018, https://www.pwc.co.uk/economic-services/ukeo/ukeo-july18-net-impact-ai-uk-jobs.pdf.

181 PwC, *The Macroeconomic impact of artificial intelligence*, 2018, https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf.

Table 4: Mapping the markets in E3ME

Markets	Tech.-producing / Tech.-using sector (Producer / User)	NACE Rev.2 3-digit sectors names	E3ME sectors
Transport / logistics (not autonomous vehicles)	Producer	Manufacture of computers and peripheral equipment	Computer, optical and electronic
		Manufacture of communication equipment	
		Manufacture of instruments and appliances for measuring, testing and navigation; watches and clock	
		Computer programming activities	Computer programming, info serv.
	User	Other passenger land transport	Land transport, pipelines
		Freight transport by road and removal services	
		Transport via pipeline	
		Warehousing and support activities for transportation	Warehousing and support activities for transportation
		Postal and courier activities	Postal and courier activities
Household / consumer products	Producer	Manufacture of computers and peripheral equipment	Computer, optical and electronic
		Manufacture of communication equipment	
		Manufacture of consumer electronics	
		Manufacture of optical instruments and photographic equipment	
		Manufacture of electric lighting equipment	Electrical equipment
		Manufacture of domestic appliance	
		Computer programming activities	Computer programming, info serv.
	User	Households	Households
Hobby / entertainment	Producer	Manufacture of communication equipment	Computer, optical and electronic
		Manufacture of consumer electronics	
		Manufacture of optical instruments and photographic equipment	
		Computer programming activities	Computer programming, info serv.
	User	Households	Households

		Motion picture projection activities	Motion picture, video, television
		Gambling and betting activities	Creative, arts, recreational
		Amusement and recreation activities	Sports/recreation activities
Medical	Producer	Manufacture of irradiation, electromedical and electrotherapeutic equipment	Computer, optical and electronic
		Manufacture of medical and dental instruments and supplies	Furniture; other manufacturing*
		Computer programming activities	Computer programming, info serv.
	User	Human health activities	Human health activities
		Residential care activities	Residential care

Note: * Other manufacturing includes manufacture of medical instruments.

Source: Cambridge Econometrics.

More detail is provided below on how the key assumptions for the impact of regulatory harmonisation are constructed.

R&D in robotics and AI

It is assumed that harmonised regulatory framework results in R&D activity for robotics and AI destined to our four markets the over 2020-2030 at levels that would otherwise have occurred by 2031; R&D spending by businesses will be 10 % higher compared to the baseline scenario (fragmented regulatory framework) in the disaggregated producer sectors. Greater R&D efforts will improve the overall quality of the 'AI made in Europe'. The weight of R&D activity within the broader E3ME sector that is in scope is determined by relative value-added shares where sectorally-detailed data are not available.[182]

Investment

The discussion above identified two possible effects on investment:

1) **FDI**: The literature review did not identify any clear evidence on which to ground any assumptions and so is not included in the modelled scenario. It is commented on in the broader discussion of the quantified results.

2) **Facilitating faster adoption of AI:** We assume that regulatory harmonisation brings forward the rate of adoption of robotics and AI by users. It may be that this comes about through the improved capability of equipment/software brought about by increased R&D effort (at no net additional investment cost compared to a non-harmonised regulatory environment). Alternatively, higher investment to be realised. In which case, the assumption is that investment of €100 000 is required per additional job replaced by AI (see employment assumption below). The relative impact of the alternative investment assumptions is one of the sensitivities explored.

182 Data sourced from Eurostat: Business expenditure on R&D (BERD) by NACE Rev. 2 activity [rd_e_berdindr2], Extracted on 08.01.2019; and Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2], Extracted on: 14.01.2019.

Employment

The assumptions for the additional job losses due to the faster adoption due to regulatory harmonisation draws on the assumptions in PwC,[183] which provides a time profile for the impact of robotics/AI on employment by broad sector and the type of stimulus.[184]

It is assumed that these broad trend are representative of the detailed activities in scope of the analysis and in line with the assumption that trends in AI adoption within the four markets are brought forward by a year the associated employment effects follow.

Table 5 shows the additional percentage loss of employment assumed by detailed activity. It is assumed that the employment effects are brought forward a year due to the faster deployment of AI. The PwC report[185] presents employment losses by broad aggregate sectors, but in this Study the effects are assumed to occur for the relevant detailed activities. The assumption applied in the model is factored back according to relative size of the activities within the relevant model sector.[186]

183 PwC, *The Macroeconomic impact of artificial intelligence*, 2018, https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf.

184 The report distinguishes three waves of AI: algorithm, augmentation and autonomy. For the transport and storage sector much of the autonomy wave is due to autonomous vehicles, which is out of scope of this study.

185 PwC, *Will robots steal our jobs? The potential impact of automation on the UK and other major economies*, UK Economic Outlook 2017. URL: https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf.

186 For the employment shares Eurostat Structural Business Statistics (sbs_na_1a_se_r) were used. The last available data is from 2016.

Table 5: Sectoral aggregations used in the employment effect calculations

PwC sectors[187]	% Job loss by 2030 according to PwC[188]	NACE Rev.2 3-digit sectors names	% Job loss in 2030 compared to the baseline
Transportation and storage	25 %*	Other passenger land transport	2.8 %
		Freight transport by road and removal services	
		Transport via pipeline	
		Warehousing and support activities for transportation	
		Postal and courier activities	
Human health and social work	17 %	Human health activities	1.9 %
		Residential care activities	
Arts and entertainment	22 %	Motion picture projection activities	2.5 %
		Gambling and betting activities	
		Amusement and recreation activities	

Source: Cambridge Econometrics.

Note: * this figure was taken from PwC(2018a) in order to exclude job loss due to autonomous vehicles, which is out of scope of this study.

Capacity

On labour productivity, we have two effects: an implicit effect coming from the employment loss, i.e. the remaining workers become more productive; and an increase in capacity, i.e. robotics and AI create more output than the people they replace.

Following the assumption of greater activity in R&D and greater adoption of 'AI made in Europe', we assume an increase in capacity. Estimates for the scale of the effect are based on the analysis in PwC,[189] which estimates the increase in capacity resulting from an increase in the deployment of AI per worker. Estimates for the elasticity are calculated by sector and broad geographical region; an increase by 1 % in, for example, health sector, means that capacity in health sector would be expected to increase by 0.07 % in Northern Europe and 0.33 % in Southern Europe. The results for the broader geographic regions (Northern and Southern Member States) are mapped to the EU-27 Member States as appropriate and the sector mapping to the markets/activities in scope is as shown in table 5.

187 PwC, *Will robots steal our jobs? The potential impact of automation on the UK and other major economies*, UK Economic Outlook 2017. URL: https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf.

188 Ibid.

189 PwC, *The Macroeconomic impact of artificial intelligence*, 2018, https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf.

Additional insurance costs

The alternative regulatory regime represented by the scenario has a new regulation on product liability contain robotics/AI with greater legal consequences of a stricter liability regime. In response, producers of the technology will increase their insurance cover thus increasing input costs. This rise in costs must be taken into account to fully assess the economic impact of the adoption of a new product liability regulation.

The need for additional cover by producers is assumed to vary depending on the current liability regime in domestic markets (see section 0):

- 20 % if the MS currently has a basic level of product liability protection for consumers;
- 10 % if the MS currently has a medium level of product liability protection for consumers;
- 0 % if the MS currently has a high level of product liability protection for consumers.

As with the assumptions or other variables, these assumptions enter E3ME weighted by the share of the detailed activity in the markets in question within the relevant model sector.[190]

Results

A scenario-based approach was used to model the quantitative outcomes of the impact of introducing a harmonised regulatory framework for robotics and AI in EU-27. The results are generally reported for 2030 as comparison with a fragmented regulatory framework baseline, i.e. business as usual.

The key features of each scenario are summarised in table 6 below and a more detailed description of each scenario is provided in the sections below.

190 The scaling takes account of (a) sales by the detailed activity to the four markets compared to overall sales, and (b) these sales compared to sales of the E3ME sector overall. The importance of the four markets to overall sales is estimated from Input-Output tables while estimates of the share of the E3ME sector covered by the detailed activities are taken from data on sales extracted from Eurostat: Annual detailed enterprise statistics for industry (NACE Rev. 2, B-E) [sbs_na_ind_r2]; and Annual detailed enterprise statistics for services (NACE Rev. 2 H-N and S95) [sbs_na_1a_se_r2]. Extracted on: 10.01.19.

Table 6: Specification of E3ME scenarios

Scenario name	Assumptions				
	Technology Producers	Technology Users			
	R&D	Employment impact	Productive capacity	Additional insurance	Additional investment
Scenario (1) - Increased R&D in robotics and AI	Yes				
Scenario (2) - Robotics and AI adoption with no additional investment	Yes	Yes	Yes	Yes	
Scenario (3) - Robotics and AI adoption with additional investment	Yes	Yes	Yes	Yes	Yes

Source: Cambridge Econometrics.

The key exogenous inputs were presented in Section 0 above. In addition, we assume no change in nominal government spending in the health sector in the scenarios (2) and (3).

The results of modelling scenarios are shown in Table 7 and the key issues are discussed below.

Table 7: Scenario impacts on GDP, employment and net trade in 2030, EU-27,[191] (percentage difference from the current regulatory scenario)

Scenario name	GDP	Employment	Extra EU net trade
Scenario (1) - Increased R&D in robotics and AI	0.04	0.01	0.45
Direct employment change	N/A	-0.37	N/A
Scenario (2) - Robotics and AI adoption with no additional investment	-0.11	-0.37	0.91
Scenario (3) - Robotics and AI adoption with additional investment	0.03	-0.23	0.77

Source: Cambridge Econometrics.

Scenario (1) - Increased R&D in robotics and AI

The impact of greater R&D effort stimulated by regulatory harmonisation is positive in terms of GDP and employment. In 2030 GDP is 0.04 % higher than it would be under the current regulatory regime, and employment 0.01 % higher. There is a direct link from R&D to investment. The effect of greater R&D effort is higher quality products from the technology-producing sectors, resulting in greater market share in the export markets and the substitution of imports by domestic demand. The additional demand for technology products stimulates additional employment (although the additional employment will not be proportional to the additional demand as process innovation is likely to accompany the product innovation leading to greater labour productivity).

The additional employment among technology producers will stimulate employment elsewhere in the economy as a result of these incomes being spent.

Direct employment effects

The faster adoption of robotics and AI as a result of harmonisation among goods/service providers in the markets is assumed to lead to a loss of 0.36 % of employment in 2030 in EU-27.[192] Most of these job-losses are in health-related sectors, as can be seen in table 8. Unless the labour released by faster AI adoption are employed by 'new' employment opportunities (not directly associated with the AI) then spending capacity will be taken out of the economy, lowering the GDP and employment further.

[191] Results for EU-28 are not significantly different.
[192] 0.37 % of employment in 2030 in EU-28.

Table 8: Direct employment loss assumed in 2030, EU-27

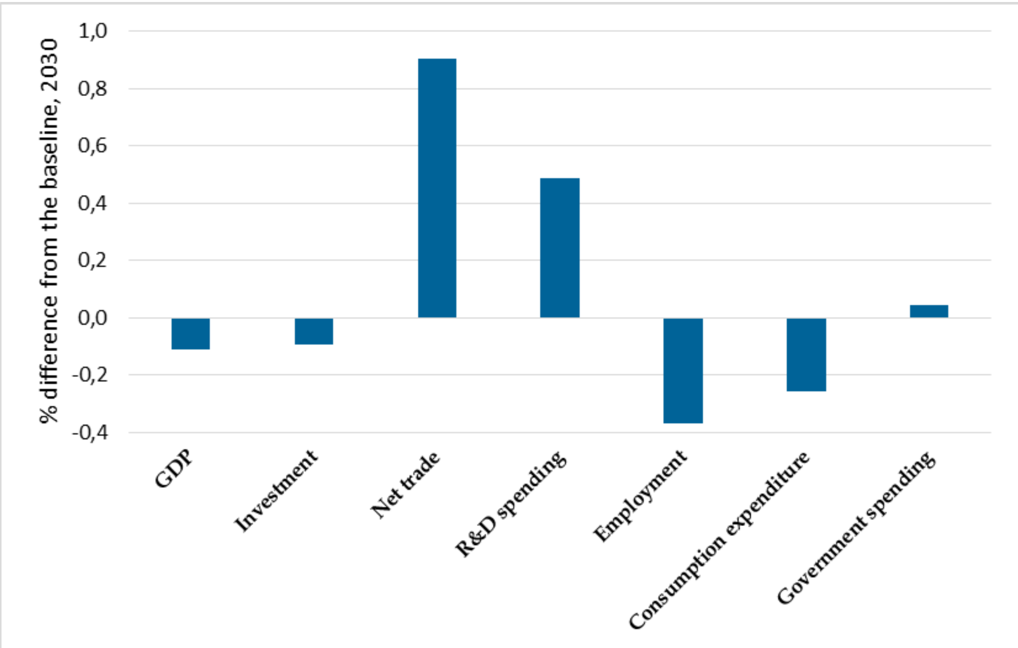
Technology Users Sectors	No of job ('000)	% of total
Land transport, pipelines	122	17
Warehousing	60	8
Postal & courier activities	40	6
Motion picture, video, television	3	0
Human health activities	240	33
Residential care	176	24
Creative, arts, recreational	46	6
Sports activities	37	5

Source: Cambridge Econometrics

Scenario (2) - Robotics and AI adoption with no additional investment

In general, the effect of robotics/AI on employment in the EU is likely to be different by sectors and Member States depending on how they benefit from the new technologies. It is expected that *technology producer* sectors, which will produce the robotics and AI based on their R&D activities, will grow and experience an increase in employment. In *technology user* sectors, which use these products in producing and providing services, the new technologies could crowd out employment. The net employment effects of all industries are the sum of these impacts, and are calculated within the E3ME model. The scenario takes into account how productivity and employment related to new technologies in each sector affect the economy as a whole, including spillovers to other sectors and indirect effects. In 2030 GDP is 0.11 % lower than it would be under the current regulatory regime, and employment 0.37 % lower.

Figure 5 – Scenario impacts in 2030, EU-27



Source: Cambridge Econometrics

In Figure 5, the scale of the employment effect is seen to dominate the R&D effect. At a sector level, the effect of the reduction in employment costs for the technology-using sectors has on competitiveness depends on the extent to which changes in input costs are passed on to customers. If none of the cost reduction is passed on (prices remain unchanged), then demand will remain unchanged (in real terms), with value-added being transferred from labour (where it would be spent in the form of wages) to company profits (some of which may be reinvested, boosting GDP). The faster adoption in AI also increases the productive capacity (notwithstanding the lower employment) which in turn will give some impetus to lower costs and stimulating demand. But, without the necessary demand, the additional capacity may not be fully utilised. For some sectors, like government spending on healthcare, the response to a fall in price is likely to be to maintain nominal levels of spending so that real demand rises in proportion to the change in costs. The price effect on demand will be moved elsewhere.

In terms of trade competitiveness, Figure 5 shows a positive change in net trade for EU-27 compared to the baseline, being driven by lower spending resulting in lower imports.

This scenario assumes that investment in equipment and software is no different to under a current legislation, but that the quality of the investment available is 'better' than would have been the case.

Scenario (3) – Robotics and AI adoption with additional investment (Scenario (2) with additional investment)

If additional investment were required to achieve faster adoption of robotics and AI, then this would mitigate in part the negative impact discussed above. However, the marginal effect on overall GDP will be less than the additional investment as some of the investment will be sourced from outside EU, increasing imports. In 2030 GDP is 0.03 % higher than it would be under the current regulatory regime, and employment 0.23 % lower.

Another possibility (not modelled) is that any additional investment in machinery or intangibles would be funded by reallocating investment that would otherwise have gone to other assets such as buildings. While not changing the overall investment, the impact would differ from the 'no additional investment scenario modelled' because it would be substituting investment in assets which typically have a high local supply content and lower labour productivity in their manufacture (buildings) with that in an asset with a greater chance of being imported and the production of which is a relatively high-productivity activity.

2.4.4. Conclusion

The impact on the EU economy of harmonised regulation in the markets considered is highly uncertain, with some factors providing a positive effect and others negative.

We have assumed that harmonisation will lead to greater development effort by producers and deployment of the technology by users than in the absence of harmonisation.

The analysis conducted shows harmonisation to bring a positive impact through additional R&D activity. However, faster adoption of robotics/AI by other sectors in the economy will be at the expense of jobs. The extent to which this adversely impacts on GDP depends on the degree to which new employment opportunities are created in other areas of the economy.

The nature of the effect depends on:

- Competitiveness effects of additional R&D efforts by technology producers, being able to secure market share;

- The degree to which faster deployment of AI displaces more jobs in the sectors using the technology and the extent to which additional jobs are created in areas of the economy;
- How the trade-off between improved quality of products and prices in different markets. If the real (quality-adjusted) price falls sharply then the same nominal spending by households, say, results in greater real spending (and GDP). However, if levels of (nominal) spending are reduced because of faster AI having replaced jobs, then the effect will be mitigated.

2.5. EU policy options

2.5.1. Option 1: No additional intervention

The existing regulatory liability framework could be applied regarding current robotics and AI issues.

In particular, the Product Liability Directive is considered to be technology-neutral and to create an exhaustive harmonisation for the matters that it explicitly covers. All Member States of the EU transposed the Directive into their national regulatory framework. Therefore, throughout the Single Market, there is a largely harmonised liability framework. This largely harmonised framework can be complemented by the known national rules and principles.

Furthermore, it is suggested to resolve current issues created by new emerging developments, such as robotics and AI, by means of interpretation of the courts only, waiting for the future evolution of robotics and AI.[193].

However, producers and insurers already noted that some technologies, such as completely autonomous systems, which can be expected to be marketed in the future, might eventually require regulatory changes and they do consider difficulties may arise in the future for Business-to-Consumer relations.

Also, as shown by this Study, the current framework already constitutes gaps and barriers to an optimal functioning Single Market in robotics and AI, *inter alia* by means of excluding services from the Product Liability Directive and not being clear whether software does or does not fall within the scope of the Directive, as well as by means of the widespread legal landscape regarding extra-contractual liability in the EU.

Moreover, no additional EU regulatory intervention could result in Member States creating their own specific national frameworks. A fragmented regulatory approach would not provide enough legal certainty for producers and consumers and would leave producers and manufacturers open to a high risk of liability. This would hinder the implementation of robotics and AI in the Single Market and jeopardise competitiveness.

The EU has made it clear that it wishes to become a key player in the sector of robotics and AI.

Therefore, on a long-term basis, this option is not preferred.

2.5.2. Option 2: Adaptation of the current regulatory framework

The EU could intervene by adapting the current regulatory framework to robotics and AI. The goal would be to remove the gaps and barriers to an optimal functioning Single Market in robotics and AI constituted by the current regulatory framework and to make this regulatory framework more adequate to handle new legal issues relating to robotics and AI.

[193] Commission Staff Working Document, Evaluation of Council Directive 85/374/EEC of 25 July 1985 on the approximation of the laws, regulations and administrative provisions of the Member States concerning liability for defective products, Accompanying the document Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee on the Application of the Council Directive 85/374/EEC on the approximation of the laws, regulations, and administrative provisions of the Member States concerning liability for defective products, Brussels, 7.5.2018, SWD(2018) 157 final, https://ec.europa.eu/transparency/regdoc/rep/10102/2018/EN/SWD-2018-157-F1-EN-MAIN-PART-1.PDF.

The Product Liability Directive is a well-known legal instrument accepted by the Member States of the EU. The Directive creates furthermore a largely harmonised liability framework. It would therefore be beneficial to adapt this Directive in the context of robotics and AI.

In particular, the scope of the Product Liability Directive could be enlarged. Important identified barriers of the current regulatory framework are to be found in the limited scope of the Product Liability Directive. The Directive foresees the possibility for Member States to adopt own national rules regarding specific matters not explicitly covered by it, excludes services from its scope and is not clear whether software does or does not fall within its scope.

By means of enlarging the scope of the Product Liability Directive to include at least services and software, robotics and AI would fall within the scope of this well-known legal instrument. Furthermore, this adaptation of the Directive could be used to clarify and refine the concepts of the Directive. The introduction of a generally accepted definition of robotics and AI would further contribute to harmonisation in the Single Market.

Both producers as insurers, with regard to new emerging technologies that will be marketed in the future, and consumers, already at present, acknowledge the application of the current Product Liability Directive might become problematic and/or uncertain in the light of new emerging technologies, such as robotics and AI, and needs to be revised. These stakeholders are therefore expected to accept and support an adaptation of the Product Liability Directive.

Moreover, several Member States already started introducing specific national rules, or interpreting general liability rules, to ensure extra-contractual liability to protect consumers from damages caused by services and/or software. By means of enlarging the scope of the Product Liability Directive, the EU would suppress and reduce further similar fragmented regulatory approach in the single market.

This policy option would enlarge the already largely harmonised regulatory liability framework. However, this policy option would not allow a tailor-made approach with regard to robotics and AI, since the rules regarding robotics and AI would have to be aligned with and take into account the existing provisions of the current Product Liability Directive. In addition, this policy option could only be beneficial for a certain amount of time. As robotics and AI will become more complex, it will become less suited to apply the same regulatory framework to, on the one hand, simple products and, on the other hand, complex robotics and AI.

2.5.3. Option 3: EU regulatory intervention - specific regulatory framework

The current lack of specific national regulatory frameworks regarding robotics and AI presents an opportunity for the EU to create a comprehensive and harmonised specific regulatory framework regarding liability and insurance on robotics and AI.

The introduction of a new specific regulatory framework at EU level before each Member State adopts its own national rules, would avoid fragmentation of the single market in robotics and AI.

Two policy options can be considered. On the one hand, an 'electronic personhood' can be created. On the other hand, a new specific regulatory framework based on the existing regulatory framework can be introduced.

Electronic personhood

A new specific regulatory framework regarding liability and insurance on robotics and AI, can be based on the idea of the creation of a new legal identity:”electronic personhood”. Electronic personhood would be a specific legal status for (at least the most sophisticated autonomous) robots similar to corporate personhood, i.e. an accepted legal fiction. These robots would have the status of electronic persons responsible for any damage they may cause.[194]

However, the creation of electronic personhood could lead to undesirable, reversed effects. Producers and manufacturers of robotics and AI could hide behind these new legal identities in order to limit or even avoid liability. Electronic personhood would also entail risks of abuse for criminal purposes, such as money laundering or tax fraud.

Furthermore, the power to determine who is a 'person', in all respects, resides in principle with the Member States and not with the EU and its institutions. Each Member State determines who is a natural person. It is argued that it is equally up to the Member States to determine when an entity becomes a legal person who can consequently rely upon EU law. The EU would not possess the power to determine who is a legal person.[195] The creation of electronic personhood by each Member State separately would lead to national differences throughout the EU and fragmentation of the Single Market.

In addition, the creation of a separate legal identity for robotics and AI is not supported by a majority of stakeholders involved[196] nor does it seem in general opinion feasible at the moment. 285 persons, of whom experts in AI, robotics, commerce law and ethics, have signed the Open letter to the European Commission on Artificial Intelligence and Robotics denouncing the idea of the creation of electronic personhood.[197]

The open letter states that the idea is based on the incorrect affirmation that damage liability would be impossible to prove and, 'from a technical perspective, on an overvaluation of the actual capabilities of even the most advanced robots, a superficial understanding of unpredictability and self-learning capacities and, a robot perception distorted by science fiction and a few recent sensational press announcements'[198].

This policy option is therefore not preferred.

Specific regulatory framework based on existing regulatory framework

A new specific regulatory framework regarding liability and insurance on robotics and AI can be introduced at EU level. This regulatory framework can be based on the existing regulatory framework, in particular the well-known Product Liability Directive. However, as opposed to the mere adaptation of the current regulatory framework, this policy option allows a tailor-made approach with regard to robotics and AI.

A new regulatory framework provides for the opportunity to divide robotics and AI further into subgroups, allowing a more case-by-case approach. In respect of each subgroup, specific rules or even different liability regimes can be declared applicable. A new regulatory framework could also

---

[194] European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.02.2017, 2015/2103(INL), http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2017-0051+0+DOC+XML+V0//EN.

[195] T. Burri, "The EU is right to refuse legal personality for Artificial Intelligence", 31 May 2018, https://www.euractiv.com/section/digital/opinion/the-eu-is-right-to-refuse-legal-personality-for-artificial-intelligence/.

[196] A majority of respondents (around 60 %) to the public consultation on the Future of Robotics and Artificial Intelligence, were against creating a specific legal status for robots, http://www.europarl.europa.eu/committees/en/juri/robotics.html?tab=Results.

[197] http://www.robotics-openletter.eu/.

[199] *Punishing Robots: Issues in the Economics of Tort Liability and Innovation in Artificial Intelligence* Galasso A and Hong L, NBER Working Paper no. 14035, 2018.

leave out the current concepts of the Product Liability Directive that are not suitable with regard to robotics and AI. In particular, the development risk clause and the current threshold of €500 could be set aside. In addition, insurance regulations could be included.

The new framework should further introduce a generally accepted definition of robotics and AI, in order to distinguish its application from the Product Liability Directive, and should consider transparency relating to robotics and AI and the level it is incorporated into the regulatory framework as an important aspect. A too high level is likely to result in producers desiring more intellectual protection over their inventions and algorithms, which is at its turn detrimental to the identification of a defect[199].

Furthermore, as opposed to the adaptation of the current regulatory framework, the introduction of a new specific regulatory framework regarding liability and insurance on robotics and AI is future-oriented. At present, it would not be impossible to apply the same regulatory framework, specifically the Product Liability Directive, both to regular products and to robotics and AI. However, as robotics and AI will become more complex, it will become less suited to apply the same regulatory framework to, on the one hand, simple products and, on the other hand, complex robotics and AI. For example, autonomous robots acting in complete independence of human intervention and replacing humans are not foreseen in the near future. It can however not be denied that at some point in the future, it is possible that these robots will be developed and implemented into the existing robotics and AI sector.

With a view to the future, a new framework should also be analysed and reviewed after a fixed period of time. This will allow for an update of the regulatory framework in due course.

In contrast to the previous policy option, the creation of an electronic personhood, this regulatory approach is significantly supported by stakeholders. A majority of 90 % of individual stakeholders, against 6 % opponents, considered it necessary to regulate developments in robotics and AI. Moreover, of these 90 % in favour of regulatory approach, a majority of 96 % preferred action at EU level or international level rather than action at Member State level, which was only supported by 4 % of the stakeholders.[200]

This policy option would require thorough debates, but offers the possibility to a tailor-made, future-oriented approach with regard to robotics and AI. Moreover, a new specific regulatory framework regarding liability and insurance on robotics and AI at EU level could avoid fragmentation across the Member States, stimulate trust and innovation, and harmonise the Single Market in robotics and AI. Therefore, this policy option is preferred over all previous mentioned policy options.

199 *Punishing Robots: Issues in the Economics of Tort Liability and Innovation in Artificial Intelligence* Galasso A and Hong L, NBER Working Paper no. 14035, 2018.

200 Public consultation on the Future of Robotics and Artificial Intelligence, 8.12.2017, http://www.europarl.europa.eu/cmsdata/130181/public-consultation-robotics-summary-report.pdf.

2.6. Conclusion

'For once, we would like to set common European principles and a common legal framework before every Member State has implemented its own and different law. Every country is mobilising, making action plans. One commissioner once told me, when Member States start to pass or prepare laws then it is really urgent that the Commission becomes active'[201].

At present, the EU lacks specific EU and national regulatory frameworks regarding liability and insurance on robotics and AI. This presents an opportunity for the EU to create a comprehensive and harmonised specific regulatory framework.

A majority of stakeholders is in favour of action at EU level rather than action at Member State level. Action at EU level, in contrast to action at Member State level, would moreover provide the possibility to tackle the current gaps and barriers constituted by the existing liability regulatory frameworks.

It is thus more beneficial to act on an EU level in comparison to having no additional intervention, or to put it in other terms, a Euro spent at the EU level is more beneficial than individual action at the Member State level.

It is argued that a harmonised EU regulatory framework would lead to greater R&D activity by producers and an increase in the speed of uptake of these two new essential emerging technologies by consumers, resulting in a possible positive impact in terms of GDP and on extra EU net trade. However, the quantitative impact on the EU economy of harmonised regulation in the markets considered is highly uncertain, with some factors providing a positive effect and others a negative one. Overall, the analysis scenarios of showed that, in the presence of a harmonised regulation, there is an increase in the trade competiveness for the EU-27, a small increase in GDP and employment through increased R&D efforts, and a small decrease in GDP and employment when the wider economic impacts of robotics and AI are taken into account.

An established and suitable framework will enable the EU to compete with other players in the robotics and AI arena, notably North America and Asia.[202] The fear is that unless these policy areas are addressed, robotics and AI will diffuse too slowly in the Single Market and the cost of not actively seeking to achieve the necessary balance will be high.

An EU regulatory framework covering liability and insurance seems to be a necessary starting-point for the completion of the Single Market in robotics and AI.

---

201 Mady Delvaux, Member of the European Parliament, European Parliament resolution of 16 February 2017 with recommendations to the Commission on Civil Law Rules on Robotics, Rapporteur Mady Delvaux, S&D, Luxembourg, 16.02.2017, 2015/2103(INL), http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+TA+P8-TA-2017-0051+0+DOC+XML+V0//EN.

202 In the EU private investments in AI totalled around €2.4 - 3.2 billion in 2016, compared with €6.5 - 9.7 billion in Asia and €12.1 - 18.6 billion in North America.

REFERENCES

Accenture (2018) 'Artificial Intelligence: Healthcare's New Nervous System', https://www.accenture.com/us-en/insight-artificial-intelligence-healthcare Accessed: 18/12/18.

Bensoussan A., Bensoussan J, *Comparative handbook: Robotic technologies law*, Larcier.

Brynjolfsson E., Mitchell T., Rock, D. (2018) What Can Machines Learn, and What Does It Mean for Occupations and the Economy? AEA Papers and Proceedings, 2018, 108: 43-47.

Business Europe, ERF, ERT (2016) Impact of EU Regulation on Innovation - Repository of Industry Cases, December 2016.

CB Insights (2018) 'Top Healthcare AI Trends to Watch', https://www.cbinsights.com/research/report/ai-trends-healthcare/.

Cedefop (2018) Skills Forecast: trends and challenges 2030, Cedefop reference series 108, Luxembourg: Publications Office of the European Union, 2018, http://www.cedefop.europa.eu/files/3077_en.pdf.

Craglia M. (Ed.), Annoni A., Benczur P., Bertoldi P., Delipetrev P., De Prato G., Feijoo C., Fernandez Macias E., Gomez E., Iglesias M., Junklewitz H, López Cobo M., Martens B., Nascimento S., Nativi S., Polvora A., Sanchez I., Tolan S., Tuomi I., Vesnic Alujevic L., *Artificial Intelligence - A European Perspective*, EUR 29425 EN, Publications Office, Luxembourg, 2018, ISBN 978-92-79-97217-1, doi:10.2760/11251, JRC113826.

CSES et al. (2015). Monitoring the impacts of REACH on innovation, competitiveness and SMEs. European Commission.

Ecorys (2014). Trade Sustainability Impact Assessment on the Transatlantic Trade and Investment Partnership (TTIP) between the European Union and the United States of America Final Inception Report, http://trade.ec.europa.eu/doclib/docs/2014/may/tradoc_152512.pdf.

EPEC. (2011). Evaluation of the EU legislative framework in the field of cultivation of GMOs under directive 2001/18/EC and regulation (EC) NO 1829/2003, and the placing in the market of GMOs as or in products under directive 2001/18/EC. Brussels: European Commission - DG SANCO.

European Climate Foundation (2018) Low-carbon cars in Europe: A socio-economic assessment, https://www.camecon.com/wp-content/uploads/2018/02/Fuelling-Europes-Future-2018-v1.0.pdf.

European Commission (2014) Commission Staff Working Document Impact Assessment Accompanying the document Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions A policy framework for climate and energy in the period from 2020 up to 2030, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014SC0015&from=EN.

European Commission (2016) Commission Staff Working Document Impact Assessment: Accompanying the document Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency, Brussels, 30.11.2016 SWD(2016) 405 final, Part 1/3, https://ec.europa.eu/energy/sites/ener/files/documents/1_en_impact_assessment_part1_v4_0.pdf.

European Commission (2017) Commission Staff Working Document Impact Assessment Accompanying the document Proposal for a Regulation of the European Parliament and of the Council setting emission performance standards for new passenger cars and for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from lightduty vehicles and amending Regulation (EC) No 715/2007 (recast), https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/swd_2017_650_p1_en.pdf.

European Commission (2018) Commission Staff Working Document: Liability for emerging digital technologies, SWD(2018)137 final, Brussels 25.4.2018, https://eur-lex.europa.eu/legal-content/en/ALL/?uri=CELEX%3A52018SC0137.

European Commission (2018) Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - Artificial Intelligence for Europe, COM(2018)237 final of 24.4.2018, https://ec.europa.eu/transparency/regdoc/rep/1/2018/EN/COM-2018-237-F1-EN-MAIN-PART-1.PDF.

European Commission (2018) Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - Coordinated plan on artificial intelligence, Brussels, 7.12.2018, COM(2018) 795 final, https://ec.europa.eu/digital-single-market/en/news/coordinated-plan-artificial-intelligence.

European Commission (2018) Impacts of circular economy policies on the labour market – Final report, https://www.camecon.com/wp-content/uploads/2019/01/Circular-Economy-DG-Env-final-report.pdf.

European Commission (2017) Study on the costs and benefits of possible EU measures to facilitate work-life balance for parents and care givers – Final Report, https://ec.europa.eu/social/BlobServlet?docId=17646&langId=en.

European Commision (2016) The Macroeconomic and Other Benefits of Energy Efficiency Final report, https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf.

European Commision (2017) The macro-level and sectoral impacts of Energy Efficiency policies - Final report, https://ec.europa.eu/energy/sites/ener/files/documents/the_macro-level_and_sectoral_impacts_of_energy_efficiency_policies.pdf.

Food Chain Evaluation Consortium. (2010). Evaluation of the EU legislative framework in the field of GM food and feed. European Commission - DG SANCO.

Kirkpatrick, Colin & Raihan, Selim & Bleser, Adam & Prud'homme, Dan & Mayrand, Karel & Morin, Jean-Frédéric & Pollitt, Hector & Hinojosa, Leonith & Williams, Michael. (2011). Trade sustainability impact assessment (SIA) on the comprehensive economic and trade agreement (CETA) between the EU and Canada: Final report.

McKinsey Global Institute (2017) *Artificial Intelligence: The Next Digital Frontier?* Chicago: McKinsey & Company, June 2017, https://www.mckinsey.com/~/media/mckinsey/industries/advanced%20electronics/our%20insights/how%20artificial%20intelligence%20can%20deliver%20real%20value%20to%20companies/mgi-artificial-intelligence-discussion-paper.ashx.

McKinsey Global Institute (2017) *Digitization, AI, and the future of work: Imperatives for Europe*, Chicago: McKinsey & Company, Briefing Note prepared for the European Union Tallinn Digital Summit September 2017, https://www.mckinsey.com/~/media/McKinsey/McKinsey%20Global%20Institute/Overview/2017%20in%20review/Whats%20next%20in%20digital%20and%20AI/Digitization%20AI%20and%20the%20future%20of%20work%20imperatives%20for%20europe/MGI-Tallinn-Briefing-Note-1213.ashx.

McKinsey Global Institute (2017) *A Future That Works: Automation, Employment and Productivity*. Chicago: McKinsey & Company, January 2017.

McKinsey Global Institute (2018) *Notes from the AI Frontier: Modelling The Impact of AI on the World Economy*, Chicago: McKinsey & Company, September 2018, https://www.mckinsey.com/~/media/McKinsey/Featured%20Insights/Artificial%20Intelligence/Notes%20from%20the%20frontier%20Modeling%20the%20impact%20of%20AI%20on%20the%20world%20economy/MGI-Notes-from-the-AI-frontier-Modeling-the-impact-of-AI-on-the-world-economy-September-2018.ashx.

Pelkmans, J., & Renda, A. (2014). *Does EU regulation hinder or stimulate innovation?* Brussels: Center for European Policy Studies.

PwC (2017) *Will robots steal our jobs? The potential impact of automation on the UK and other major economies*. UK Economic Outlook 2017. URL: https://www.pwc.co.uk/economic-services/ukeo/pwcukeo-section-4-automation-march-2017-v2.pdf.

PwC(2018) *The Macroeconomic impact of artificial intelligence*, https://www.pwc.co.uk/economic-services/assets/macroeconomic-impact-of-ai-technical-report-feb-18.pdf.

PwC(2018) *What will be the net impact of AI and related technologies on jobs in the UK?*, UK Economic Outlook July 2018, https://www.pwc.co.uk/economic-services/ukeo/ukeo-july18-net-impact-ai-uk-jobs.pdf.

PwC(2018) *What will be the net impact of AI and related technologies on jobs in China?*, September 2018, https://www.pwc.com/gx/en/issues/artificial-intelligence/impact-of-ai-on-jobs-in-china.pdf.

PwC(2018) Global Consumer Insights Survey 2018 - Artificial intelligence: Touchpoints with consumers. https://www.pwc.nl/nl/assets/documents/pwc-gcis2018-artificial-intelligence.pdf.

Roland Berger and Asgard (2018) *Artificial Intelligence – A strategy for European startups. Recommendations for policymakers*, https://www.rolandberger.com/en/Media/AI-startups-as-innovations-drivers-Europe-must-take-action-to-establish-a-compe.html Accessed: 18/12/18.

Statista (2018) *Revenues from the artificial intelligence (AI) market worldwide from 2016 to 2025 (in million U.S. dollars)*, https://www.statista.com/statistics/607716/worldwide-artificial-intelligence-market-revenues/ Accessed: 18/12/18.

Wagner, Gerhard (2018) *Robot Liability* (June 19, 2018). Available at SSRN: https://ssrn.com/abstract=3198764 or http://dx.doi.org/10.2139/ssrn.3198764.

Wiesenthal, T., Condeço-Melhorado, A., & Leduc, G. (2015). Innovation in the European transport sector: a review. Transport Policy.

Wiesenthal, T., Leduc, G., Cazzola, P., Schade, W., & Köhler, J. (2011). Mapping innovation in the European transport sector. Luxembourg: Publications Office of the European Union.

Annex 1: Quantitative assessment

Description of the modelling tool – E3ME

Cambridge Econometrics' global macro-econometric model E3ME is designed to address major economic and societal policy challenges. The model was originally developed through the European Commission's research framework programmes. It continues to be refined and enhanced and is widely used in Europe and beyond for policy assessment, for forecasting and for research purposes[203].

At European level, the model is most often used to assess the economic and labour market impacts of new policy. In particular, it has been used to evaluate policies relating to the environment, energy/climate, labour markets and trade negotiations. Examples of recent studies that have made use of the model include:

- input to European Commission Impact Assessments of the Clean Energy for Europeans package and long-term decarbonisation strategy[204]
- forecasting labour market and skills supply and demand[205]
- input to the Impact Assessment of the Work-Life Balance Directive[206]
- impacts of R&D expenditure on economic growth[207]
- assessing green jobs and skills impacts of environmental policy[208]
- assessing the economic effects of a shift to low-carbon vehicles[209]
- the CETA and TTIP trade negotiations[210]

---

[203] Full details of the E3ME model can be found at https://www.camecon.com/how/e3me-model/.

[204] Contribution to IA for the Energy Efficiency Directive: https://ec.europa.eu/energy/sites/ener/files/documents/1_en_impact_assessment_part1_v4_0.pdf; https://ec.europa.eu/energy/sites/ener/files/documents/the_macro-level_and_sectoral_impacts_of_energy_efficiency_policies.pdf; Contribution to IA for the Energy Performance Buildings Directive: https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf; Contribution to IA for 2030 energy and climate package: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52014SC0015.

[205] Cedefop (2018) Skills Forecast: trends and challenges 2030, Cedefop reference series 108, Luxembourg: Publications Office of the European Union, 2018, http://www.cedefop.europa.eu/files/3077_en.pdf.

[206] European Commission (2017) Study on the costs and benefits of possible EU measures to facilitate work-life balance for parents and care givers – Final Report, https://ec.europa.eu/social/BlobServlet?docId=17646&langId=en.

[207] T he Monroe project, funded by the European Commission's Horizon 2020 research and innovation programme (grant agreement 727114), https://www.monroeproject.eu/project-publications-data/.

[208] European Commission (2018) Impacts of circular economy policies on the labour market – Final report, https://www.camecon.com/wp-content/uploads/2019/01/Circular-Economy-DG-Env-final-report.pdf.

[209] European Climate Foundation (2018) Low-carbon cars in Europe: A socio-economic assessment, https://www.camecon.com/wp-content/uploads/2018/02/Fuelling-Europes-Future-2018-v1.0.pdf; European Commission (2017) Commission Staff Working Document Impact Assessment Accompanying the document Proposal for a Regulation of the European Parliament and of the Council setting emission performance standards for new passenger cars and for new light commercial vehicles as part of the Union's integrated approach to reduce CO2 emissions from light duty vehicles and amending Regulation (EC) No 715/2007 (recast), https://ec.europa.eu/clima/sites/clima/files/transport/vehicles/docs/swd_2017_650_p1_en.pdf.

[210] Trade Sustainability Impact Assessment on the Transatlantic Trade and Investment Partnership (TTIP) between the European Union and the United States of America http://trade.ec.europa.eu/doclib/docs/2014/may/tradoc_152512.pdf; Kirkpatrick, Colin & Raihan, Selim & Bleser, Adam & Prud'homme, Dan & Mayrand, Karel & Morin, Jean-Frédéric & Pollitt, Hector & Hinojosa, Leonith & Williams,

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The model has a high level of sectoral detail, with 69 sectors defined in its structure. Short-term multiplier effects occur through the various interdependencies between different parts of the economy, including consumption, investment and trade. The labour market is also covered in detail, including both voluntary and involuntary unemployment. The model is post-Keynesian in approach meaning that, unlike many other economic models, it does not make assumptions about full employment, rational behaviour and expectations.

The model includes 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector. Outputs from the model include GDP, sectoral output, employment and unemployment, trade and investment.

More detail on the logic of the model's economy module is presented below.

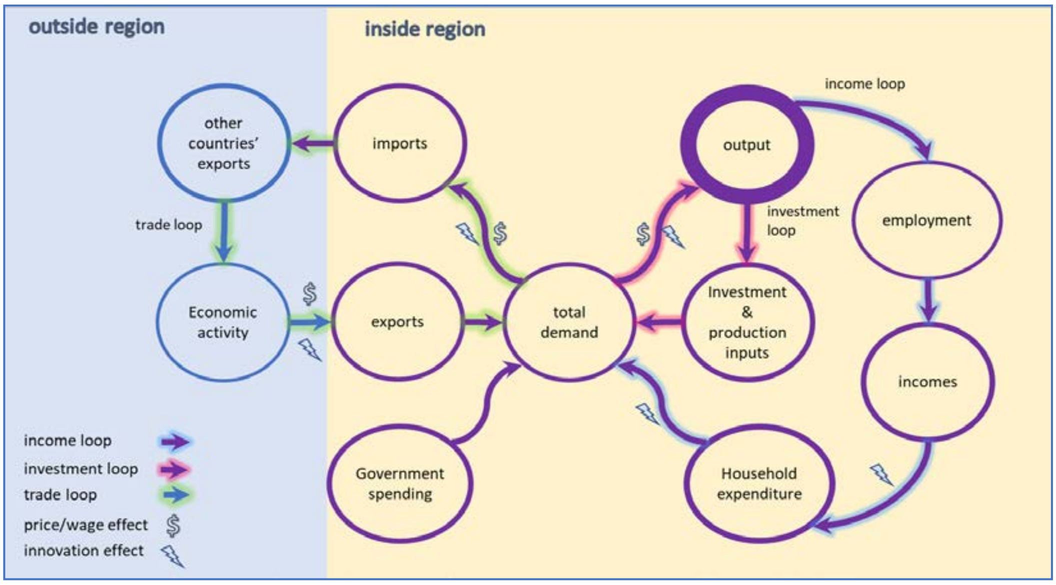
The loops of interdependency

Figure 2 illustrates the model framework. Output and employment are determined by levels of demand, unless there are constraints on available supply. The figure shows three loops or circuits of economic interdependence, which are described below. In addition, there is an interdependency between the sectors that is not shown in the figure. The full set of loops comprises:

- Interdependency between sectors: If one sector increases output it will buy more inputs from its suppliers who will in turn purchase from their own suppliers. This is similar to a Type I multiplier.
- The income loop: If a sector increases output it may also increase employment, leading to higher incomes and additional consumer spending. This in turn feeds back into the economy, as given by a Type II multiplier.
- The investment loop: When firms increase output (and expect higher levels of future output) they must also increase production capacity by investing. This creates demand for the production of the sectors that produce investment goods (e.g. construction, engineering) and their supply chains.
- The trade loop: Some of the increase in demand described above will be met by imported goods and services. This leads to higher demand and production levels in other countries. Hence there is also a loop between countries

Michael. (2011). Trade sustainability impact assessment (SIA) on the comprehensive economic and trade agreement (CETA) between the EU and Canada: Final report.

Figure 6 – E3ME's basic economic structure



Output and determination of supply

It is assumed that, subject to certain constraints, domestic supply increases to match demand. The most obvious constraint is the labour market; if there is not enough available labour then production levels cannot increase. However, the model's 'normal output' equations also provide an implicit measure of capacity, for example leading to higher prices and rates of import substitution when production levels exceed available capacity.

The labour market and incomes

The treatment of the labour market is another area that distinguishes E3ME from other macroeconomic models. E3ME includes econometric equation sets for employment, average working hours (4.8), wage rates (4.12) and participation rates (disaggregated by gender and five-year age band).

The labour force is determined by multiplying labour market participation rates by population. Unemployment (including both voluntary and involuntary unemployment) is determined by taking the difference between the labour force and employment.

Price formation

For each real variable there is an associated price, which influences quantities consumed. For example, each category of household expenditure has a price variable attached to it, which influences consumption patterns within the model.

Aside from wages, there are three econometric price equations in the model:

- domestic production prices;
- import prices;

- export prices.

These are influenced by unit costs (derived by summing wage costs, material costs and taxes), competing prices and technology. Each one is estimated at the sectoral level.

One of the key price variables in the model is the price of domestic consumption. It is also determined by sector, by taking a weighted average of domestic and import prices, subtracting off the export component. This price is then used to determine the prices for final consumption goods; for example if the car industry increases prices, this will be reflected in the price consumers pay for cars.

Aggregate deflators, including the Consumer Price Index, are derived by taking the average of prices across all products and sectors.

Evidence for assumptions from the literature

The recent JRC study on AI (Craglia et al, 2018) concludes that a strong global competition is taking place in the field of robotics and AI with three key leaders: Europe, China and the US. However, according the communication on Coordinated Plan on Artificial Intelligence (European Commission, 2018c), Europe is currently behind in private investments in AI with around €2.4-3.2 billion in 2016, compared with €6.5-9.7 billion in Asia and €12.1-18.6 billion in North America. Without major efforts, the EU risks losing out on the opportunities offered by AI, facing a brain-drain and being a consumer of solutions developed elsewhere (European Commission, 2018c).

There are remarkable market growth expectations, i.e. global AI market revenues are estimated to reach US$38 billion by 2022, more than 5-times its current size (in 2018, the global AI market is expected to be worth approximately US$7.35 billion).[211] This is why the European AI strategy published in April 2018 has set ambitious targets, i.e. public and private investments in AI must be scaled up in order to reach the target of €20 billion per year over the next decade. To reach this amount per year, according to the Communication published in December 2018[212] the following investments are envisaged:

1. the Commission is increasing investment in AI under the research and innovation framework programme Horizon 2020 to €1.5 billion in the period 2018-2020;
2. if Member States and the private sector make similar efforts, total investments in the Union will grow to more than €20 billion for the period 2018-2020;
3. under the next programming period 2021-2027, the Commission invests in AI at least €1 billion per year from Horizon Europe and the Digital Europe programmes and thus total annual public sector investment will reach €7 billion (Member States and Commission).

This communication (European Commission, 2018c) also introduces and describes the concept of Digital Innovation Hubs, the key goal of which is to foster the uptake of AI for the corporate sector, in particular for the SME firms. The Hubs are expected to provide access to the technology, to provide testing and technical support, as well as advice on available financial support to companies adopting this technology in their production processes or service provision. It also seeks to support SMEs in developing algorithms

211 https://www.statista.com/statistics/607716/worldwide-artificial-intelligence-market-revenues/.
212 https://ec.europa.eu/digital-single-market/en/news/coordinated-plan-artificial-intelligence.

and in training AI later on[213]. The Commission plans to allocate €100 million for these Hubs already for 2019 and 2020, focusing on some selected AI areas: big data, smart manufacturing.

Private investments can be leveraged through coordinated public efforts that includes eliminating the obstacles due to fragmented markets to make it easier for businesses to scale up and trade across borders and thereby further boost investments (European Commission, 2018c). Common standards and fast communication networks are important key enablers in artificial intelligence.

While health care and transport sectors are more characterized by a mix of public and private investments, consumer products and media/ entertainment AI investments predominantly come from private sector players.

Lesson learned from other technologies

The review of the EU regulations concerning chemicals[214] and genetically modified organisms (GMOs)[215] provides some lessons that could be applied also to future regulatory framework in the fields of robotics and AI. First lesson is that, while regulation could promote innovation by providing standards, improving transparency, generating knowledge and guiding the innovation effort, it also imposes costs on firms, often through lengthy and expensive processes to ensure compliance. In the case of REACH[216], the effects on costs and innovation lead to mixed results in the sector (CSES et al, 2015), while the GMO legislation pushed research and development outside of Europe ((Food Chain Evaluation Consortium, 2010), (EPEC, 2011)). Second lesson is that, particularly in the case of GMOs, the diverging opinions between different stakeholders (including the wider public) hindered the creation of an effective law that could at the same time protect consumers and foster innovation ((Food Chain Evaluation Consortium, 2010), (EPEC, 2011)). The same type of considerations might be applied to AI. Keeping in mind the GMOs experience, the future liability regime should not be as tight as to discourage R&D efforts in the EU, thus leaving Europe behind on the world market. On the other hand, the application of a liability regime to AI would probably trigger research to develop safer AI services and therefore foster innovation. Moreover, a clear liability framework for AI might promote social acceptance within the wider public for a yet to discover technology, thus avoiding the societal divisions that affected the GMOs legislation.

Pelkmans and Renda (2014) found that EU regulation can at times be a powerful stimulus to innovation and it matters at all stages of the innovation process. More prescriptive regulation hampers innovative activity, whereas the more flexible EU regulation stimulate innovation. Overall, their study found that lower compliance and red-tape burdens have a positive effect on innovation. Business Europe, the European Risk Forum and ERT (2016) also found that regulation can influence innovation priorities of

---

213 Annex to the Communication from the Commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions - Coordinated Plan on Artificial Intelligence (COM(2018) 795 final), https://ec.europa.eu/knowledge4policy/publication/coordinated-plan-artificial-intelligence-com2018-795-final_en.

214 Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC, *OJ* L 136/3, 29.5.2007, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02006R1907-20140410&from=EN.

215 Regulation (EC) No 1829/2003 of the European Parliament and of the Council of 22 September 2003 on genetically modified food and feed, *OJ* L 268, 18.10.2003, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32003R1829&from=en.

216 EU Regulation on the registration, evaluation, authorisation and restriction of chemicals.

companies and their willingness to devote substantial resources to R&D. They put together a repository of regulations stimulating innovation (such as innovation clause on food for specific population groups, sustainable mobility and waste policies) and many examples of regulations hampering innovation, such as favouring 5G innovation in telecom networks, Europe 2020 strategy initiative for a resource-efficient Europe, framework/access directives on the Telecom package and the, EU medical devices directive.

Medical/ Health care

According to a recent Accenture forecast (2018), AI in healthcare is will grow to reach US$6.6 billion by 2021, at an average 40 % annual growth rate (Accenture, 2018). The same report suggests that AI technology in the US will enable an industry savings opportunity of US$150 billion by 2026.

Global players and R&D investments

The report from CB Insights (2018) found that healthcare AI start-ups have raised US$4.3 billion across 576 deals between 2013-Q1 and 2018-Q4, thereby topping all other industries in AI deal activity in the private sector in the same period. Amongst its top applications, medical AI developments will revolutionize diagnostics, for which Google DeepMind's system is a pioneer example with the ability to diagnose sight-threatening eye diseases matching the accuracy of medical experts (CB Insights, 2018). As of 2017, firms in healthcare and biotech accounted for about 9 % of the total number of start-ups engaged in the field of AI (Roland Berger and Asgard, 2018).

In 2016 South Korea announced to invest 1 trillion won (US$840 million) to boost artificial intelligence in the country and in 2018, the government added a considerable volume of further 2.2 trillion won to its AI strategy, primarily focusing on three priority areas: medicine, national defence and public safety (Craglia et al.,2018).

Israel, coming third globally in terms of the number of AI start-ups within the country, has a governmental commitment as well to invest US$275 million in the field of health and medical sciences, for the digitalization of health data to foster AI projects (Roland Berger and Asgard, 2018).

Uptake of the technology from consumers' side

Based on the literature, it can be concluded that the speed of uptake of health care AI solutions largely depends on two major factors: 1) how accessible the technology will be for end consumers (how efficient producers and health sector players will be in reaching the target groups) and 2) to what extent consumers will trust the products. Current development news and the reviewed literature show promising signs in both dimensions, with a prospect for medical sector to be a trigger of AI market growth globally.

Transport (excluding autonomous vehicles)

Start-up firms are crucial drivers of AI developments and investments worldwide. Yet, a recent study by Roland Berger and Asgard (2018) finds that as of 2017, transportation sector accounted for only 3 % of the number of start-ups that confirmed to work in the field of AI, implying that the sector is not yet disrupted to a large extent by AI solutions.

Global players and R&D investments

While announced AI investment globally tend to be less specified with regards to industry or discipline, in Israel there is a clear national program promoting smart transportation with AI applications (Roland Berger and Asgard, 2018).

Households/ Consumer household products

Global players and R&D investments

Despite falling back of the US or China in terms of investment sizes, Japan and South Korea can be considered as strong global players in AI solutions in the field of consumer household products (Craglia et al., 2018), with several globally dominant private firms investing in the technology in both countries (e.g. LG Electronics).

Uptake of the technology from consumers' side

Consumer household goods represents a sector where AI solutions move in relatively rapidly, according to the latest Global Consumer Insights Survey of PwC (2018d). The extensive survey covered topics such as the receptiveness to adopting AI devices for shopping, the results of which first of all illustrate Asian countries' openness to buying and using AI devices (with China, Vietnam, Indonesia and Thailand at the top). At the same time, Brazil is also outstanding with the largest uptake potential. On the contrary, developed markets like the US, the UK of France exhibit relatively lower current and articulated future demand for these products: around 25 % of the sample replied positively to future plans to buy an AI device for shopping (PwC, 2018d).

At home, a smart thermostat can reduce energy bills by up to 25 % by analysing the habits of the people who live in the house and adjusting the temperature accordingly (European Commission, 2018c). Therefore, an ethical, secure and cutting-edge AI made in Europe leading to cost-saving is expected to have a huge update in the households sector.

Hobby/ Entertainment

Global players and R&D investments

Japan and South Korea are relevant countries with regards to AI solutions in the field of hobby or entertainment products (Craglia et al., 2018), with several globally dominant private firms investing in the technology in both countries (e.g. LG Electronics, Naver, KT, SKT).

Summary of announced investment in AI

Table 9 presents a selection of announced, relevant public investments worldwide in 2017-2018, coupled by some remarkable private investments in the field. While several countries have developed dedicated national robotics and AI strategies already (not presented here), most of the announced investment plans are not allocated to specific industries, rather offer a general development budget for the field of robotics and AI in the countries.

Table 9: Selected announced public and private investments in robotics and AI

Country	Leader of the investment strategy	Type of investment	Investment volume	Key investment goals	Date of announcement
US	DARPA	public	US$2 billion	to overcome the perceived limitations of AI technologies	2018 Sep
France	government	public	US$1.8 billion until 2022	plans to make private companies publicly release their data for use in AI, to support research firms	2018 Mar
South Korea	government	public	2.2 trillion won	to develop scientific training, application development, public funding infrastructure	2018 May
Israel	government	public	US$275 million	digitalization of health data to foster AI projects	2018
Singapore	government	public	US$150 million until 2022	to enhance AI capabilities	2017 May
Canada	government and research institutes	public	125 million CAN dollar until 2022	to enhance AI research infrastructure	2017
Australia	government	public	29.9 million AU dollar until 2022	to support AI developments, to increase the supply of AI talent	2018 May
India	government think-tank	public	'significant public investment' (planned, not announced)	to improve social inclusiveness of AI technologies	2018 Jun
UK	government and private companies (Global Brain, Chrysalix)	public-private	US$200 million	to build AI tech incubators, to fund academic research	2018 Apr
Germany	Amazon	private	US$1.5 million	to build a new research center next to a Max Planck Institute AI campus (Tübingen, DE)	2017 Oct
South Korea	private companies (Samsung, LG Electronics, SKT, KT, Naver, Hyundai Motor)	private	3 billion won each company	to support a high-profile research center	2016

Note: ordered by announced investment volume, vertically grouped by type of investment.

Sources: Roland Berger and Asgard (2018); Craglia et al. (2018); An Overview of National AI Strategies from https://medium.com/politics-ai/an-overview-of-national-ai-strategies-2a70ec6edfd; https://qz.com/1264673/ai-is-the-new-space-race-heres-what-the-biggest-countries-are-doing/

In summary, there is information on future planned public sector investment for AI as a whole. The main competitors for EU are China and the US. Very little information is available on levels of private investment that are planned. In terms of breakdown by the four markets, some information was found for the medical sector R&D level. The most reliable information identified in the distribution of AI start-ups by industry in Europe, although most of them (35 %) are categorised as general/cross-sectoral. Overall, the Commission communications emphasise that an adequate safety and liability framework guaranteeing a high level of safety and effective redress mechanisms for victims in case of damages is essential for building trust in AI that will also influence the uptake level. On the take-up of AI by consumers, there is little if any information available, except that the Commission is setting up the Digital Innovation Hubs to accelerate uptake of AI in the wider economy, in particular by SMEs.

QA-01-19-611-EN-N

Robotics is a wide and multi-faceted domain, which crosses boundaries between many economics sectors and legal disciplines. The perception of a need for some kind of Europe-wide legal framework to accompany the development of robotic and artificial intelligence (AI) technologies is growing. A harmonised EU regulatory framework concerning specifically liability and insurance regarding robotics and AI could provide greater legal certainty and promote trust. It could also stimulate greater research and development activity by producers and increase the speed of uptake of these two new emerging technologies by consumers, resulting in a possible positive impact in terms of GDP. Research suggests that, by 2030, EU GDP could be 0.04 % higher than it would otherwise be under the current regulatory framework.

This is a publication of the European Added Value Unit
EPRS | European Parliamentary Research Service

PDF ISBN 978-92-846-5184-9 | doi:10.2861/522252 | QA-01-19-611-EN-N