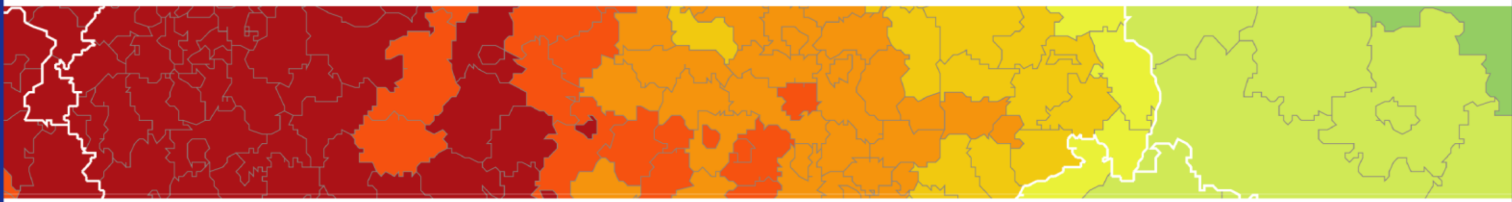
Co-financed by the European Regional Development Fund

Inspire Policy Making with Territorial Evidence



T^4 – Territorial Trends in Technological Transformations

Applied Research

Final Report

Final Report

This applied research activity is conducted within the framework of the ESPON 2020 Cooperation Programme.

The ESPON EGTC is the Single Beneficiary of the ESPON 2020 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.

This delivery does not necessarily reflect the opinion of the members of the ESPON 2020 Monitoring Committee.

Authors	**responsible for**
Politecnico di Milano (POLIMI) – Roberta Capello and Camilla Lenzi	Executive summary, Sections 1, 2, 3, 4, 5, 7 and 8
Technopolis Group (TG) – Reda Nausedaite and Jari Romanainen	Sections 6, 7 and 8
Technopolis Group (TG) – Olga Mikheeva, Karine Lanoix, Patrick Eparvier and Kincsö Izsak	Input for Section 6
Prof. Slavo Radosevic	Inputs for Section 1
MCRIT – Laura Noguera, Oriol Biosca, Rafa Rodrigo and Andreu Ulieu	Inputs for Section 6
University of Warsaw & EUROREG (UW – EUROREG) - Agnieszka Olechnicka and Maciej Smętkowski	Inputs for Section 6
Economics University in Bratislava (EUBA) - Miroslav Šipikal, Štefan Rehák, and Martina Džubáková	Inputs for Section 6

Advisory Group
Project Support Team: Marinko Ajduk, Wolfgang Pichler, Christine Wallez Cuevas
ESPON EGTC: Martin Gauk, György Alfoldy

Information on ESPON and its projects can be found on www.espon.eu.

The web site provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

Contact: info@espon.eu
ISBN: 978-2-919795-59-8

Final Report

T^4 – Territorial Trends in Technological Transformations

Version 06/07/2020

Disclaimer:
This document is a Final report.

The information contained herein is subject to change and does not commit the ESPON EGTC and the countries participating in the ESPON 2020 Cooperation Programme.

The final version of the report will be published as soon as approved.

Table of contents

Executive summary v

1 Introduction: aim of the project 1

2 Definition of 4.0 technological transformations 2

3 Where does 4.0 technological transformation take place? 5

3.1 Spatial trends of the 4.0 transformation in the technology invention domain 5

3.2 The 4.0 technological transformation in the technology adoption domain 9

3.2.1 4.0 technology adoption in manufacturing sectors 9

3.2.2 4.0 technology adoption in services 12

3.2.3 4.0 transforming regions 15

4 Economic impact of technological transformation 16

4.1 Impacts of 4.0 technology adoption on GDP growth 16

4.2 Impacts of 4.0 technology adoption on productivity growth 24

5 Social impact of technological transformation in the technology adoption domain 27

6 Main case study results 33

6.1 Estonia 33

6.2 France 36

6.3 Poland 38

6.4 Slovakia 40

6.5 Spain 42

6.6 Main common results from the case study analysis 44

7 Tailor-made policy recommendations 44

8 Recommendations for future research 47

9 References 48

10 List of Annexes 48

List of Maps

Map 3.1. Number of applicative recombinatorial 4.0 patents per 1,000 inhabitants w.r.t. ESPON countries' average, 2000-2009 6

Map 3.2. Number of applicative recombinatorial 4.0 patents per 1,000 inhabitants w.r.t. ESPON countries' average, 2010-2015 7

Map 3.3. Taxonomy of 4.0 inventing regions, 2010-2015 8

Map 3.4. Number of robots per employee in 'technology' manufacturing sectors w.r.t. ESPON countries' average, 2008-2016 10

Map 3.5. Number of robots per employee in 'carrier' manufacturing sectors w.r.t. ESPON countries' average, 2008-2016 10

Map 3.6. Number of robots per employee in 'induced' manufacturing sectors w.r.t. ESPON countries' average, 2008-2016 11

Map 3.7. Share of manufacturing firms developing and/or using 4.0 technologies, 2017 11

Map 3.8. Share of firms with online sales in 'technology' services w.r.t. ESPON countries' average, 2009-2016 13

Map 3.9. Share of firms with online sales in 'carrier' services w.r.t. ESPON countries' average, 2009-2016 13

Map 3.10. Share of firms with online sales in 'induced' services w.r.t. ESPON countries' average, 2009-2016 13

Map 3.11. Share of firms with online sales in transport services w.r.t. ESPON countries' average, 2009-2016 14

Map 3.12. 4.0 technological transformations in European regions, 2009-2016 16

Map 4.1. GDP per capita growth rate: comparison among regions characterised by different technological technological transformations, 2007-2012 18

Map 4.2. Impact of robot adoption in 'technology' manufacturing sectors on GDP per capita growth by type of technological transformation, 2013-2017 19

Map 4.3. Impact of robot adoption in 'induced' manufacturing sectors on GDP per capita growth rate by type of technological transformation, 2013-2017 19

Map 4.4. Impact of online sales adoption in 'induced' services on GDP per capita growth rate by type of technological transformation, 2013-2017 21

Map 4.5. Degree of adoption efficiency for different technological transformations, 2013-2017 23

Map 4.6. Impact of robot adoption in 'technology' manufacturing sectors on productivity growth by type of technological transformation, 2013-2017 25

Map 4.7. Impact of robot adoption in 'induced' manufacturing sectors on productivity growth by type of technological transformation, 2013-2017 26

Map 5.1. Impact of robot adoption in 'technology' manufacturing sectors on employment level by type of technological transformation, 2013-2018 28

Map 5.2. Impact of robot adoption in 'induced' manufacturing sectors on low-skill employment share by type of technological transformation, 2013-2018 29

Map 5.3. Impact of online sales in 'induced' services on low-skill employment share by type of technological transformation, 2013-2018 30

Map 5.4. Impact of robots adoption in 'technology' manufacturing sectors on high-skill employment share by type of technological transformation, 2013-2018 30

Map 5.5. Impact of robots adoption in 'induced' manufacturing sectors on high-skill employment share by type of technological transformation, 2013-2018 31

Map 5.6. Impact of online sales adoption in 'induced' services on high-skill employment share by type of technological transformation, 2013-2018 31

Map 5.7. Regional job creation and job displacement by skill level, 2013-2018 32

List of Figures

Figure 4.1. Impact of technology adoption on GDP per capita growth by type of technological transformation, comparison between 2007-2012 and 2013-2017 periods 18

Figure 4.2. Impact on GDP per capita by type of technological transformation and adoption intensity, 2007-2012 21

Figure 4.3. Impact of the adoption of different types of technology on productivity growth, comparison between 2007-2012 and 2013-2017 periods 25

Figure 4.4. Impact on productivity growth by type of technological transformation and adoption intensity, 2013-2017 27

List of Tables

Table 6.1. Summary and comparison of Estonia case studies 35

Table 6.2 Summary and comparison of France case studies 36

Table 6.3. Summary and comparison of Poland case studies 39

Table 6.4. Summary and comparison of Slovakia case studies 40

Table 6.5. Summary and comparison of Spain case studies 43

List of Boxes

Box 2.1. Definition of 4.0 technological transformations 4

Box 2.2. Expected impacts of the 4.0 technological transformation 5

Box 3.1. Spatial patterns in the technology invention domain 8

Box 3.2. Spatial patterns of 4.0 technologies adoption in manufacturing sectors 12

Box 3.4. Spatial patterns of 4.0 technologies adoption in services 15

Box 3.5. 4.0 technological transformations in European regions 16

Box 4.1. Results on the impacts of 4.0 technology adoption on GDP growth 24

Box 4.2. Impacts of 4.0 technology adoption on productivity growth 27

Box 5.1. Social effects of technological transformation 33

Abbreviations

3D	Three-dimensional
5G	5th Generation
AI	Artificial Inteligence
CPC	Cooperative Patent Classification
CPS	Cyber-Phisical System
DESI	Digital Economy and Society Index
EC	European Commission
EPO	European Patent Office
ERP	Enterprise Resource Planning
ESPON	European Territorial Observatory Network
ESPON EGTC	ESPON European Grouping of Territorial Cooperation
EU	European Union
EUBA	Economics University in Bratislava
FDI	Foreign Direct Investments
GDP	Gross Domestic Product
GPS	Global Positioning System
GPT	General Purpose Technologies
GVC	Global Value Chain
HEI	Higher Education Institution
ICT	Information and Communication Technologies
IFR	International Federatio of Robotics
IIOT	Industrial Internt of Things
IOT	Internet of Things
IPC	International Patent Classification
ISCO	International Standard Classification of Occupations
ISIC	International Standard Industrial Classification
LFS	Labour Force Survey
MS	Member State
NACE	Statistical Classification of Economic Activities in the European Community
NUTS	Nomenclature of Territorial Units for Statistics
O*NET	Occupational Information Network
OECD	Organisazion for Economic Cooperation and Development
P.C	Per capita
P2P	Peer-to-peer
PIIAC	Programme for the International Assessment of Adult Competencies
POLIMI	Politecnico di Milano
R&D	Research and Development
SBS	Structural Business Statistics
SDM	Spatial Durbin Model
SME	Small and Medium Enterprises
SOC	Standard Occupational Classification
TG	Technopolis Group
URL	Uniform Resource Locator
UW-EUROREG	University of Warsaw – EUROREG
W.R.T.	With respect to

Glossary

3.0 technologies	High-tech technologies according to EUROSTAT definition
4.0 technologies	Set of wide-ranging technological fields including: artificial intelligence, robotics, internet of things, autonomous vehicles, additive manufacturing, virtual reality, 3D printing, nano-technologies, biotechnology, energy storage with application such as smart home, smart transport, smart energy grids, intelligent robotics, smart factories
Application technologies	Final applications of 4.0 technologies in different parts of the economy (home, enterprises, infrastructure)
Applicative recombinatorial 4.0 inventions (i.e. patents)	Inventions (i.e. patents) that apply basic digital technologies to a specific domain of application
Automation	Process of substitution of human activities with machines
Best practice regions	Regions having both an adoption and an impact from technology adoption above the average of its respective transformation pattern
Carrier sectors	Group of sectors comprising the most visible and active users of digital solutions and automation
Core technologies	Building blocks upon which the 4.0 technologies are developed and are established ICT fields such as hardware, software and connectivity
Deskilling	Process of reduction of jobs' skill content
Digitalisation	Process of adoption of digital solutions
Digitalisation of traditional service	A process of supply of products and services on virtual markets via a website
Élite jobs	High-skill, high-wage jobs
Enabling technologies	Technologies that build upon and complement the core technologies, including AI, position determination, analytics
Gig jobs	Short-term (low value added) work
Gig-economy	A free market system where organizations and independent (freelance) workers engage in short-term (low value added) work arrangements
High adoption efficiency – high potential regions	Regions having a higher than average impact from technology adoption and a lower than average adoption rate of their respective transformation pattern.
Induced sectors	Group of sectors taking limited advantages from the technological revolution because of their specific production structure
Industry 4.0	A process of increasing digitalisation, robotisation and automation of the manufacturing environment, enriched with the creation of digital value chains to enable inputs from suppliers and customers, and between business partners, leading to smart factories
Low adoption efficiency – high potential regions	Regions having a lower than average impact from the adoption of technologies and a higher than average adoption rate of their respective transformation pattern
Low adoption potential regions	Regions having both an adoption and an impact from technology adoption below the average of their respective transformation pattern

Low tech regions	Regions with very limited 3.0 and 4.0 technology creation
New islands of innovation	Regions able to leapfrog on the 4.0 technological frontier even in absence of a strong knowledge base in 3.0 technologies
Niches of robotisation	Areas where technological transformation takes place only in selected niches of manufacturing activities
Polarisation of labour markets	Increase in the number of low-skill (low-wage) and high-skill (high-wage) jobs at detriment of mid-skill jobs
Robotisation	Process of adoption of robots substituting human activities
Robotisation of traditional manufacturing activities	A process of robot adoption in manufacturing activities
Servitisation	A process of creation of new digital markets through the supply of products and services via digital intermediaries.
Technological field	Sub-group of 4.0 technologies
Technological transformations	Structural changes taking place in the society, on how people work, communicate, express, inform and entertain themselves, and, finally, do business thanks to new 4.0 technologies.
Technology falling behind regions	Regions with a large knowledge base in 3.0 technologies and a limited one in 4.0 technologies
Technology invention domain	Analysis of the way in which a new idea is invented and commercialised in the market.
Technology invention's market	Market of technological ideas (captured through patents)
Technology leader regions	Regions leading the creation of both 3.0 and 4.0 technologies
Technology production / adoption domain	Analysis of the way in which a technology is produced and adopted in a market
Technology sectors	Group of sectors that actively produce 4.0 technologies
Upskilling	Process of upgrading and valorisation of jobs' skill content
User innovation/innovator	Innovation by intermediate or end users (respectively, firms and individual), rather than by suppliers (service proivers and/or manufacturers)

Executive summary

The labels ‘Industry 4.0’, ‘4^{th} technological revolution’, ‘4^{th} technological paradigm’ are all mentioned every day in newspapers, press, scientific journals and TV news. These labels are accompanied by disruptive visions of the drastic changes in society on how people work and communicate, express, inform and entertain themselves, and, finally, do business. Such changes are called technological transformations. Which technological transformations occur, where they take place, and with which socio-economic impacts are the subject matters of such a project. **An analysis like this is still missing in the literature**.

Which technological transformations does the project take into account?

The technological transformations taken into consideration are much broader than the ones usually labelled as Industry 4.0. They involve not only industry but also stretch to a variety of services and traditional sectors. They can be split into four different phenomena.

Structural changes occur first in the **technologicy invention domain**, i.e. the domain where new ideas are invented and commercialised in the market. In this domain, the structural changes in the nature of the technology affect the way in which the invention of a new technology can turn into a commercially viable technology. 4.0 technologies are obtained by re-using existing technological knowledge to produce new profitable products. A new app obtained with a traditional computer science knowledge can generate disproportionate gains to the inventor. Large profits are no longer obtained with huge R&D efforts, with deep consequences in the way the technology market works.

Profound transformations occur also in the **technology adoption domain**. The most common technological transformation in this domain is the **Industry 4.0**, a term that describes the increasing digitalisation, robotisation and automation of the manufacturing factory, enriched with the creation of digital value chains to merge inputs from suppliers and customers, and between business partners. Industry 4.0 is interpreted as new ways of organization and control over the entire value chain of the lifecycle of products. Industry 4.0 represents a deep and disruptive change in business operations, rather than a technology based improvement of production capabilities. Integrated, adapted, optimised, service-oriented and interoperable features of manufacturing process are correlated with algorithms; big data and high technologies change the design, manufacture, operation and service of products and production systems. Smart factories are based on cyber-physical systems (CPS), which comprise smart machines, storage systems, and production facilities, able to exchange information, initiate actions, and mutually control each other. Their interconnection via Internet, also termed as the Industrial Internet of Things (IIoT), generates technological leaps in engineering, manufacturing, material flow, and supply chain management.

A second technological transformation takes place in the field of service activities, and is labbed **Servitisation**. This term was coined at the end of the 1980s to identify a strategy put in place by manufacturing firms in developed countries to offer services together with the product, in order to compete with firms in developing countries. Large companies, such as IBM and Rolls Royce, had started to offer various services linked to their products. In the digital era, Servitisation widens to phenomena that are related to the creation of virtual markets. Servitisation, in fact, refers to the supply of products and services offered on virtual markets via digital intermediaries. Amazon, Uber, Ebay, Booking are some of the giants we are speaking about. Business-to-consumer and consumer-to-consumer transactions are made possible by intermediation services that organize a virtual market, on which firms sell their products via internet (business-to-consumer) or people share their goods once they do not use them (consumer-to-consumer transactions). It is in this field where the 'gig economy' – a free market system where organizations and independent (freelance) workers engage in short-term (low value added) work arrangements – takes place. Via Servitisation new (digital) markets are created. Large sharing platforms, managing billions of data concerning people's travels and availability of second houses so to match supply and demand of these spare resources, allow new services to be offered, and new businesses be developed. BlaBlaCar, Home Exchange or Love Home Swap are nowadays websites that allow an individual to offer his/her idle capacity. Thanks to such platforms, a free place in a car or unoccupied houses obtain a value through car-sharing or home-sharing services. With the creation of digital intermediary markets, the boundaries between products and services are redrawn. Services maintain a key role as value creators but no longer in contrast to manufacturing, and instead in a sort of 'symbiotic recoupling'. Digital markets allow an important shift from purchasing goods to using goods and paying for the utilization, the function or the utility customers extract from the product, e.g. by renting or leasing it. Moreover, digital markets enable companies to operate without owing the resources; in fact, Uber operates without owing a fleet of cars, Foodora or Justeat operate without having restaurant facilities. What intermediaries own is the data on suppliers and customers, enabling to match demand and supply rapidly with low transaction and search costs. The profits for intermediaries rely on the high speed, low transactions costs and low search costs, i.e. on selling an efficient and reliable intermediary service.

The first step of the transformation of Servitisation is the **digitalisation of traditional services**. This is a transformation associated to a process of digitalisation of the delivery of the service, and the product is bought thanks to the existence of the company website. All large fashion companies (e.g. Zara, Armani, Bata, Guivenchy, just to quote a few) in the retail sector have the possibility to sell online. The product sold is not new, the market is not new, but the delivery of the product at home is something new, and creates new value by enlarging the number of potential customers. With respect to the Servitisation, in which new markets are created, in this case markets existed already, but enlarged their size thanks to the network.

In the case of Industry 4.0, a first step in the technological transformation is **robotisation of traditional manufacturing activities.** This is a process in which a manufacturing firm introduces robots replacining blue collar workers, with heavy effects on the labour market; the difference with the smart factory is that the last one calls for drastic reorganization of the production system, while robotisation is a labour-saving technological progress, with limited economic gains.

Where do these technological transformations take place?

New inventions take place in core areas. However, unexpectectly, they are also registered in some peripheral areas, mentioned in the report as **new islands of innovation**. These areas, in fact, are able to leapfrog on the 4.0 technological frontier even in absence of a strong knowledge base in 3.0 technologies (i.e. hardaware, software, connectivity). Such islands of innovation are located both in relatively less innovative areas of leading countries (e.g. in France, UK, Sweden, the Netherlands and also one in Germany) but also in follower areas (e.g. the North-eastern and central regions of Italy, Norte in Portugal, Pays Basquos, Aragona and Asturias in Spain) and, even more importantly, in not only in capital regions of Eastern countries (e.g. Poland, Czech Republic, Slovenia, Romania). Interestingly enough, these islands of innovation are able achieve productivity growth advantages thanks to their creative capacity.

Industry 4.0 takes place in a few regions, located mainly in Southern Germany and Northern Italy. Regions characterised by this type of transformation are able to grasp both GDP and productivity growth, when robots are adopted.

Servitisation takes place especially in large city regions. Regions going through a Servitisation transformation reach the highest increase in GDP (with respect to all other transformations) through the adoption of online sales technologies. Instead, Servitisation transformation does not produce productivity growth advantages, whatever the technology adopted.

The **digitalisation of traditional services** is present mainly in Southern Italian regions, in some regions in Spain, in parts of the UK, in Baltic regions, in regions in Norway, in Northern Germany, and in part of the Netherlands. Regions going through this transformation achieve greater GDP growth (even if less than through Servitisation transformation) when online sales are introduced, while do not grasp any productivity growth advantage.

Robotisation of traditional manufacturing activities characterises most regions in Europe, especially regions in France, Poland, Central Italy, Hungary. Regions characterised by this type of transformation achieve GDP and productivity growth advantages, even if much more limited with respect to Industry 4.0 transformation regions, and only when its specific technology (robots) is adopted.

Niches of robotisation, where technological transformation takes place only thanks to manufacturing niche adopters, characterises regions that are located mainly in Eastern countries, Greece, part of Spain and a few regions in France. The advantages received by this type of transformation are very limited. It regards only a small amount of actors and firms, and a critical mass, necessary so to achieve an aggregate positive effect, is not reached.

Which socio-economic impacts do they generate, and where?

Each region is characterised by a prominent technological transformation. Each region obtains **the highest advantage from the adoption of the technology specific of its transformation**.

In all transformations, the strength of the impact varies according to the intensity of adoption. **In complex transformation patterns** (namely Servitisation and Industry 4.0) **the intensity of adoption matters**, winessing the existence of increasing returns and learning processes from technology adoption**.** Regions with a high intensity of adoption achieve higher advantages in terms of GDP than those with a low intensity of adoption. Instead, **simple transformations** (digitalisation of traditional service, robotisation of manufacturing activities and niches of robotisation) **register positive advantages from the adoption of their specific technologies, but at decreasing rates**; by increasing the adoption, the advantage obtained is positive but decreasing in magnitude.

Within each transformation pattern, the capacity to exploit technology adoption for growth is certainly not evenly distributed in space. **Best practices** – when high adoption couples with a high positive impact – tend to be located in Scandinavia, down to Northern France and Germany, till Northern Italy, while they are totally absent in Eastern countries. **Low adoption potential regions** – when both the adoption and the impact are low – are merely present in Eastern countries, in Greece, and some spots around Europe. **The high adoption efficiency regions**, where the impact is high but adoption is low, requires interventions on stimulating adoption, and concerns mainly France, Italy and Germany, while **the low adoption efficiency regions,** where adoption is high but the impact is low, calls for actions to increase technology adoption and exploitation. This situation characterises countries like UK, Spain and Ireland.

The adoption of 4.0 technologies definitely generates an impact on the labour market. Starting with the impact on the general employment level, **robots replace jobs when adopted in technology manufacturing sectors**. **The adoption of robots and online sales in service sectors does not seem to have a direct effect on employment levels**.

The general picture on employment level can however mask a heterogeneous impact of technology adoption on different groups of occupations. **The introduction of robots does replace low-skill jobs**. **The adoption of online sales, instead, generates an expansion of the share of low-skill jobs, suggesting a rapid expansion of gig-jobs**. This effect is pervasive across all regions, regardless their transformation pattern, highlighting complex intra-regional sectoral interdependencies. **The introduction of robots replaces also high-skill jobs**, **with an especially strong effect in** Industry 4.0 and robotisation patterns. The adoption of online sales, instead, generates an expansion also of the share of high-skill employment, **leading to the creation of élite jobs**. The concomitant enlargement of the low-skill and the high-skill segments, with a nil effect on total employment, erodes the share of middle-skill jobs, **a phenomenon known as polarisation of the labour market**. These disruptive effects are accompanied by a **lack of specialised workforce**, especially in the manufacturing sector, calling for a priority to speed on digital skills for both young people and adults by updating the Digital Education Action Plan, as suggested by the political guidelines for the European Commission 2019-2024.

Policy suggestions

In the end, adoption of 4.0 technologies is generally in its **very initial stage**. **Large potentialities for their exploitation still exist**. Policy measures should concentrate on: i) supporting especially lagging regions in the possibility to become new islands of innovation, creating and stimulating creativity; ii) supporting the existing technological transformation present in the region, through nation- and region-specific interventions, according to the 4.0 technological transformation profile of the region; iii) developing interventions balancing technological knowledge, new business opportunities and stimuli of new opportunities; iv) learning from best practices, using them as pilot cases and developing high adoption or adoption efficiency potential that exists; v) guaranteeing that Eastern countries are not be left behind in this process, so to avoid a further increase in regional disparities; vi) supporting education and training activities of young people; vii) launching new legislation for a coordinated European approach on the human and ethical implications of 4.0 technology applications.

1 Introduction: aim of the project

Since the beginning of the 2010s, the 4.0 technological revolution has taken place, resting on wide-ranging technological fields such as artificial intelligence, robotics, internet of things, autonomous vehicles, 3D printing, nano-technologies, biotechnology, energy storage, just to name a few of them (Brynjlfsson and McAfee, 2014; Schawb, 2016). The feeling of disruption of the present technological revolution is deep since, as it is usually the case, the outcome of an evolutionary trajectory is very difficult to be predicted. The profound uncertainty surrounding the development and adoption of emerging technologies leaves open a set of possible evolutions of the socio-economic technological transformations, where extreme and alternative, positive as well as negative, pictures of the future emerge. A positive vision of a worldwide interconnected, smart and automated society and production system, where routinized and low-skill jobs are replaced by machines, leaving to humankind the decision-making power of control over the machines, counterbalances a negative vision of a civilization brought close to a "near workless-world" (Rifkin, 1995).

What is sure is that the introduction of the 4.0 technologies entails profound transformations. These technological transformations – **defined and interpreted in this project as all 4.0 technology-driven socio-economic structural changes** – are expected to provide new growth opportunities. However, many of the consequences of these transformations are not yet clear. The spatial dimension of such transformations (where it takes place; under which local conditions; with what positive or negative socio-economic effects) is in the present literature either ignored, or treated in a fragmented way, dealing with specific issues, specific technologies, specific areas or specific European countries.

This project is a first effort to provide a **comprehensive and systematic picture of the technological transformations and of their intertwined regional / sectoral effects, which is still missing in the literature**. The project therefore delves into **the understanding of the technological transformations and of their socio-economic impacts**. This report contains the whole analysis developed on:

1. **a conceptual definition of technological transformations,** and the potential socio-economic changes that derive from them (Section 2);
2. a description of the **spatial trends of the technological transformation** (Section 3);
3. an analysis of **the economic and social impact of such transformation on European countries** (Sections 4 and 5);
4. an **in-depth analysis of the transformation and its impacts, through selected case** studies (Section 6);
5. **tailored-made policy recommendations** (Section 7);
6. **future research directions** (Section 8).

2 Definition of 4.0 technological transformations

The new 4.0 technologies create technological transformations in the economy and in the society, stemming from deep transformations occurring in the technology invention and adoption domains. The project defines the 4.0 technological transformations as specific structural socio-economic changes (technological patterns), in particular[1]:

- **the restructuring of the technology invention's market**. By this transformation in the technology invention domain, market opportunities can open to newcomers and to user innovators, generating new growth opportunitites to weaker regions;
- **Industry 4.0**. This is a label for the transformation in the adoption of 4.0 technologies in industries characterised by batch production. This transformation leads to the smart factory which is based on cyber-physical systems (CPS), comprising smart machines, storage systems, and production facilities, able to exchange information, initiate actions, and mutually control each other. Their interconnection via Internet, also termed as the Industrial Internet of Things (IIoT), generates technological leaps in engineering, manufacturing, material flow, and supply chain management.
- **Servitisation.** This transformation deals with the phenomena that are related to the creation of virtual markets thanks to digital intermediaries like Amazon, Uber, Ebay, Booking etc., leading to Internet of Things (IoT). Digital markets allow an important shift from purchasing goods to using goods and paying for the utilization, for the function or the utility they extract from the product. Moreover, digital markets enable companies to operate without owing the resources; in fact, Uber operates without owing a fleet of cars, Foodora or Justeat operate without having restaurant facilities. Consumers-to-consumer transactions are also part of Servitisation, made possible by intermediation services that organize a virtual market, on which people share their goods once they do not use them. Home sharing, car sharing, car-pooling all belong to what has been called a sharing economy.

Because of the presence of adopters not able to fully grasp the advantages of these transformations (sectors that do not base their production on batches and that do not need digital processes in their production, the so called 'induced' sectors in the literature and in this project), transformations may halt at a certain stage, and may give rise to different, and less radical, types of structural changes in the technology adoption domain, namely:

- **Robotisation of traditional manufacturing activities**, in the case of manufacturing sectors. By this process, a manufacturing firm introduces robots replacing blue collar workers, with heavy effects on the labour market; the difference with the smart factory (i.e. with Industry 4.0 transformation) is that the last one calls for drastic reorganization of the production system, while robotisation is a labour-saving technological progress, with limited economic gains.
- **Digitalisation of traditional services**, in services. This represents a process of digitalisation of the delivery of the service, and the product is bought thanks to the existence of the company website. The product sold is not new, the market is not new, but the delivery of the product at home is something new.

[1] Table A.1.1 in Annex synthesises the transformation processes and their effects.

The technology invention's market – representing the market where new ideas are created and sold – goes through a deep transformation. New ideas are nowadays obtained by re-combining pieces of basic technologies, obtaining new applications like autonomous driving, vehicle fleet navigation devices, intelligent energy distribution networks, intelligent transport networks, intelligent lighting and heating systems, to provide a few examples, all made possible by the application of digital and communication devices (EPO, 2017). New digital outpus are nowadays often recombinations, or mash-up, of previous ones, and call for talents and creativity as the main inputs. The production of these new digital outpus is characterised by a marginal cost that tends to zero, with the consequence of a market with enormous profit margins, super star compensation, disproportionate rewards to the top performers in each market achievable in a very limited time. However, while the winner-takes-all-economics is the source of enormous profitability gains, there is no automatic ceiling to the number of markets (for digital goods) that can be created, enlarging business opportunities to everybody, icluding a myriad of new agile and innovative firms that penetrate the market (Rullani and Rullani, 2018). On their turn, large traditional incumbents have the possibility to cross the boundaries across sectors, leveraging their customer base, infrastructure or technology (Schwab, 2017). Telecommunication and digital platform providers moved into heathcare or automotive segments, with new and vast profitability gains.

The changes in the technology invention's market provoke: i) a **geographical concentration of core and basic technologies in the leading innovative areas of Europe**, as a consequence of large multinational companies controlling the market of core software, hardware and transmission technologies, as well as those of enabling technologies that call for a geographic concentration of activities, exploiting cumulated knowledge and economies of scale in R&D; ii) **new invention opportunities in less developed and peripheral regions** can be expected being the main assets required to enter the technology markets nowadays easily accessible, i.e. talents and creativity rather than massive RD labs; iii) **new islands of innovation**, i.e. regions in which little innovation was developed in the 3.0 technologcal revolution (i.e. ICT revolution), and instead where 4.0 innovation takes place, leapfrogging previous technologies thanks to zero marginal costs and low entry barriers in the market.

The production, adoption and use of 4.0 technologies bring with themselves transformations. The degree and type of transformations depend on the actors present in the areas. In particular, the **transformations are sector-specific, since they differ according to the role sectors play in the production and adoption of such technologies.** In this respect, three types of sectors can be identified[2]:

- **the 'technology' sectors can be defined as that group of sectors that produce 4.0 technologies.** The 'technology' sector includes computer and electronic product

[2] This distinction between 'technology', 'carrier' and 'induced' sectors apply to both manufacturing sectors and to services.

manufacturing, telecommunications, data processing, hosting, and related services, other information services, and computer systems design and associated services;

- **the 'carrier' sectors include those sectors that are the most visible and active users of digital solutions and automation**. The high adoption rate driven by the great advantages foreseen leads firms belonging to the 'carrier' sector to be creative and become innovators themselves, frequently by applying open innovation business models based on co-design and co-creation of new technologies[3] For example, around 80 per cent of the installed robots in the world are in the automotive, computers and electronic equipment, and electrical appliances sectors. At the same time, the automotive sector is a major producer of robots, for both its own and for commercial purposes. Alternatively, high-tech sectors such as aeronautics and vehicles are among the primary users of artificial intelligence patents. On-line digital platforms are new business models which start to dominate digital services sectors and drive 4.0 technology production / adoption;
- **the 'induced' sectors represent sectors which take limited advantages from the technological revolution because of their specific production structure**. Because of their structural characteristics, in fact, these sectors are likely to enjoy lower advantages from the technological revolution. In these sectors, a total information-intensive system based on remote production machine interconnection through digital platforms does not fit the continuous production processes of such sectors. At the same time, reorganisation costs of production and management within firms to achieve efficiency gains are not contained. These sectors go through a process of robotisation and automation of some phases of the production. The efficiency advantages exist, but to a more limited extent.

Box 2.1. Definition of 4.0 technological transformations

The 4.0 technological transformation encompasses all structural changes in the economy and society that originate from the invention, production and adoption of 4.0 technologies. Four main types of technological transformation are envisaged in this project:

- **the reconfiguration of the technology invention's market**, through the opening of market opportunities to newcomers and to user innovators, due to the recombinatorial nature of 4.0 technologies;
- **Industry 4.0**, i.e. smart factories where integrated, adapted, optimised, service-oriented and interoperable features of manufacturing process are correlated with algorithms; big data and high technologies change the design, manufacture, operation and service of products and production systems;
- **Servitisation**, i.e. the supply of services made possible thanks to the creation of virtual markets, like Amazon, Uber, Ebay, Booking etc…
- **Robotisation of traditional manufacturing activities**, i.e. a process in which a manufacturing firm introduces robots replacing blue collar workers, with heavy effects on the labour market; the difference with the smart factory is that the last one calls for drastic reorganization of the production system, while robotisation is a labour-saving technological progress, with limited economic gains.
- **Digitalisation of traditional services**, i.e. a process of digitalisation of the delivery of the service, and the product is bought thanks to the existence of the company website. The product sold is not new, the market is not new, but the delivery of the product at home is something new.

Technological transformation takes place in those regions specialised in sectors creating, producing and / or adopting 4.0 technologies, according to the degree of adoption of such technologies.

[3]https://www.espon.eu/sites/default/files/attachments/Policy%20Brief%20-%20Digital%20Innovation%20in%20Urban%20Environments.pdf, last visited 15/06/2020.

The technological transformations foreseen above generate **socio-economic impacts**. Overall, **economic effects** are expected, mainly in the form of an increase in **economic efficiency through automatisation and interconnectivity** but also **highly skewed market concentration in services with uncertain efficiency effects**. The digitalisation of traditional manufacturing processes and services leads to the creation of new market niches responding to new demands in traditional or digitilised ways (care, health, education, coaching, creative activities, organic food, etc.). New business activities widely spread across the economy (often self-employed). Technological opportunities may lead to concentration of technology commercialisation capacities, but they can induce the institutional resistance and regulation of new monopolies.

The 4.0 technology transformation generates also **social effects**. Polarisation of wages and income distribution is a foreseable outcome of the disproportionate rewards of large digital intermediaries controlling the new digital markets, and the freelancers offering on-demand services subject to gig-wages, often with no social protection rules. New poor are created by the spatially uneven distribution of digital equipments; offline businesses have in fact much more limited possibility to compete with new digital ones. It is the case of traditional travel agencies suffering from the presence of giants like Booking.com or even BlaBlaCar, Home Exchange or Love Home Swap through which people can share travels to the same destination, or exchange unutilised houses. New social inequalities emerge, penalising elderly people and non-digital native population for their limited access to digital services. But especially, the **labour market will be highly affected by such technological transformations**. Job displacement, creation of gig-jobs, profound changes in skill composition, polarisation of jobs in high and low level ones are all effects that are expected to take place. These will be the subject matter of this project.

Box 2.2. Expected impacts of the 4.0 technological transformation

The technological transformations impose a number of impacts in the economy and society including:

I. generation of profitability gains for 4.0 technology inventors;
II. promotion of new market opportunities both for new digital service providers and inventors of new creative applications;
III. generation of efficiency gains for adopters;
IV. new social inequalities for specific categories of people;
V. creation of élite and gig jobs.

Given the sector-specific nature of the transformation, **the actual outcomes will be shaped by the rate of 4.0 technology adoption and the sectoral specialisation of the regions.**

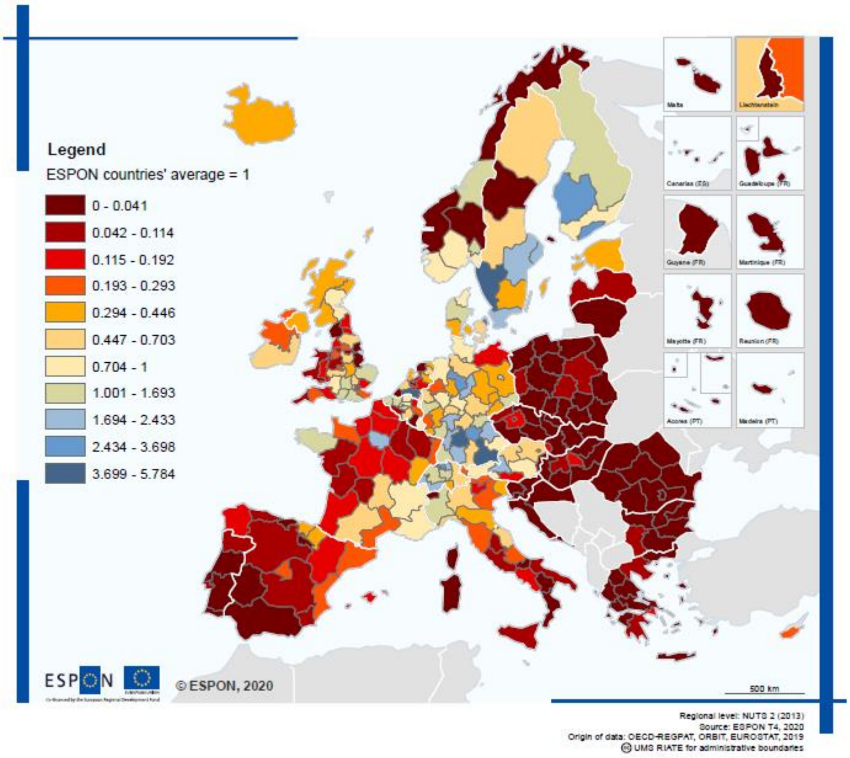
3 Where does 4.0 technological transformation take place?

3.1 Spatial trends of the 4.0 transformation in the technology invention domain

The present technological transformation has an intrinsic recombinatorial nature. The share of applicative recombinatorial 4.0 patents (i.e. patents that apply basic digital technologies to a specific domain of application) has outpaced the share of basic digital technology patents (hardware, software and connectivity).

If one maps the 4.0 intensity of recombinatorial 4.0 patents that target a specific application, like smart homes, alarm systems, intelligent lighting and heating, consumer robotics, autonomous vehicles, intelligent retail and healthcare systems, autonomous office systems, smart offices, just to mention some application domains, **a particular spatial pattern emerges** (Map 3.1).[4] In particular, **recombinatorial inventions targeting specific applications are diffused also in regions traditionally considered as less knowledge and patent intensive**. In countries where 4.0 technology are invented (i.e. Germany, France, UK, Sweden, Netherlands, Finland and Switzerland) almost all regions do contribute (and not negligibly) to the production of recombinatorial 4.0 patents with a specific application. Several regions are located in advanced areas of countries which are followers in terms of 4.0 technologies' invention (e.g. Italy, Spain and Belgium). Some interesting areas emerge also in Eastern countries such as in Poland, Czech Republic and Hungary and in the Baltics (notably Estonia) and are generally regions hosting the capital city or second tier cities within the national context (Map 3.1).[5]

Map 3.1. Number of applicative recombinatorial 4.0 patents per 1,000 inhabitants w.r.t. ESPON countries' average, 2000-2009



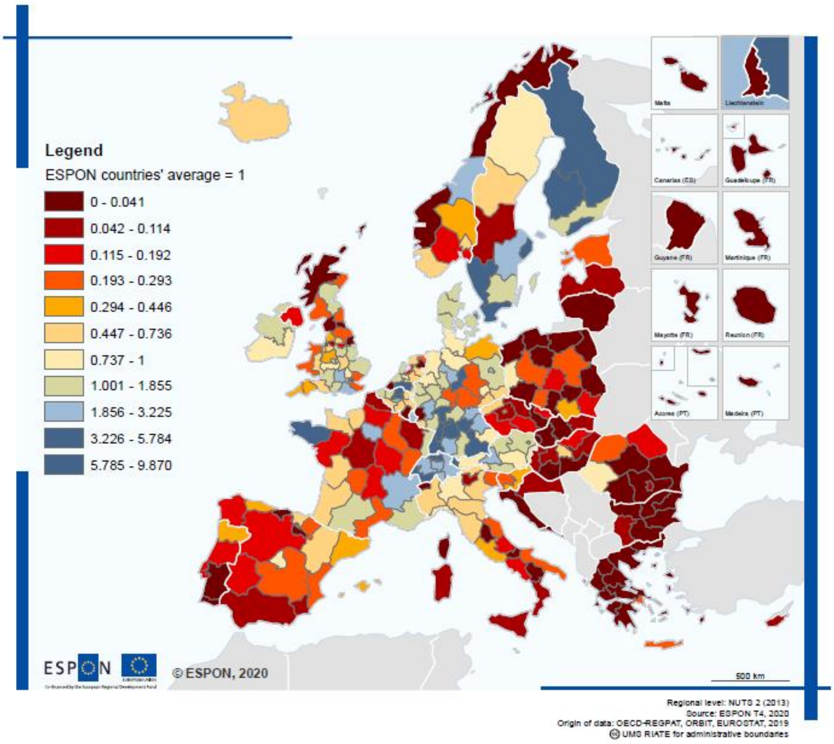
Over time these trends have consolidated. Map 3.2 displays the intensity of recombinatorial 4.0 patents per 1,000 inhabitants in European NUTS 2 regions in the period 2010-2015 (yearly average value) that target a specific application. By comparing Map 3.1 with Map 3.2, one can

[4] In maps 3.1 and 3.2, patent intensity is presented with respect to the ESPON countries' average.

[5] A focus on smart transport and energy inventions is reported in Maps A.3.3 – A.3.6, Section 3 in Annex. The main trends in smart transport technologies are similar to the general case (Maps 3.1 and 3.2), while smart energy technologies show a more balanced trend over space and in time with respect to smart transport technologies.

observe **a diffusive trend for such inventions and the spreading of new technological opportunities**, also in areas traditionally considered as weak in terms of technology creation**.**

Map 3.2. Number of applicative recombinatorial 4.0 patents per 1,000 inhabitants w.r.t. ESPON countries' average, 2010-2015



By crossing patent specialisation and patent intensity in the invention of both 4.0 and 3.0 technologies[6], a **taxonomy of 4.0 inventing regions** is obtained (Map 3.3), showing the existence of:

- **low tech regions**, i.e. regions creating neither 3.0 nor 4.0 technologies;
- **technology falling behind regions**, regions leading the creation of 3.0 technologies but not 4.0 technologies;
- **new islands of innovation,** i.e. regions leading the creation of 4.0 technologies with little if not nil experience in 3.0 technologies;
- **technology leader regions**, i.e. regions leading the creation of both 3.0 and 4.0 technologies.

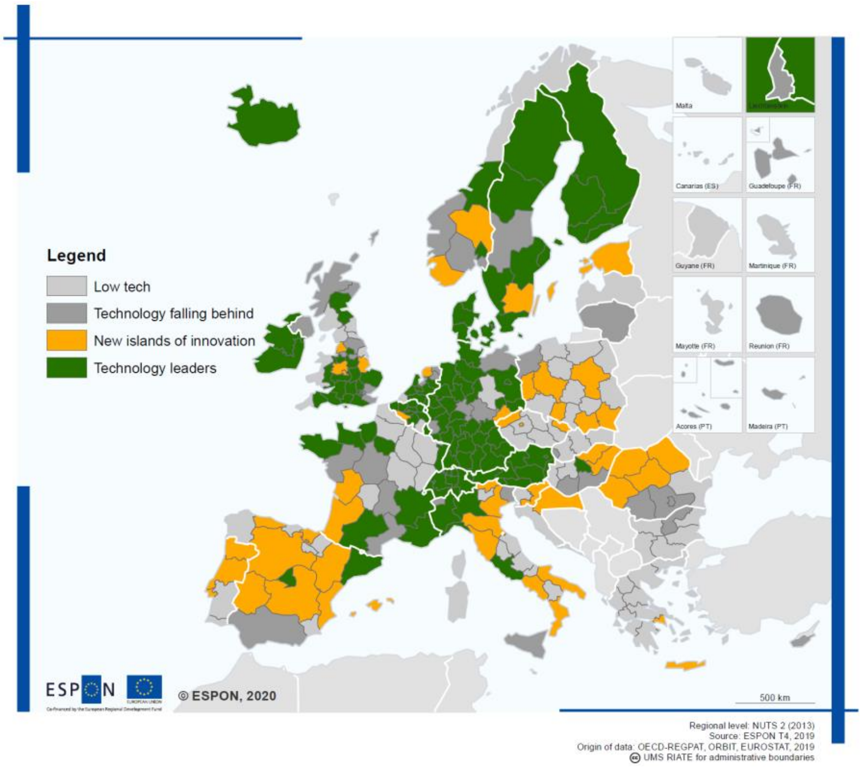
Map 3.3. shows that:

- **the degree of knowledge cumulativeness is pretty high** as most of high performing regions in 4.0 technologies exploit an existing edge in 3.0, accumulated in previous times, or an existing attitude and openness towards new technological developments in 3.0 fields. These regions are mostly located in leading countries (e.g. Germany, Scandinavian countries, France, the UK, Switzerland, Netherlands) and in advanced areas of follower countries (e.g. Italy and Spain);

[6] For the methodology, see Annex, Section 3.3.

- more interestingly, there are **regions able to leapfrog on the 4.0 technological frontier even in absence of a strong knowledge base in previous 3.0 technologies** (i.e. hardware, software, connectivity). These regions are the **new islands of innovation**. Interestingly, these areas are located both in relatively less innovative areas of technologically leading countries (e.g. in France, UK, Sweden, the Netherlands and also one in Germany) but also in technologically follower countries (e.g. the area traditionally known as Third Italy, Norte in Portugal, Pays Basquos, Aragona and Asturias in Spain). Even more importantly, one can find islands of innovation in Eastern countries and not only in capital regions (e.g. Poland, Czech Republic, Slovenia, Romania). Some are located in weak or intermediate areas of follower countries (e.g. in Central Spain and Southern Italy) but also in laggard regions in Eastern Europe (e.g. Czech Republic, Romania, Hungary). This confirms the possible rise of new islands of innovation in 'technologically virgin' areas;
- finally, **a lot of regions are excluded from substantial inventing efforts in the development of 4.0 technologies**. This result highlights both the difficulties in unlocking a pre-existing technological gap but also of missing the opportunities of 4.0 technologies and losing the edge achieved in 3.0 technologies.

Map 3.3. Taxonomy of 4.0 inventing regions, 2010-2015



Box 3.1. Spatial patterns in the technology invention domain

- Applicative recombinatorial 4.0 inventions dominate the present 4.0 technological revolution.
- These application inventions are spreading in space offering **new invention opportunities to newcomer regions**.
- **Opportunities exist for new islands of innovation**.
- **Nearly half of European regions are unable to participate to the process of invention of 4.0 technologies**.

3.2 The 4.0 technological transformation in the technology adoption domain

3.2.1 4.0 technology adoption in manufacturing sectors

In order to map technological transformations, an analysis of the intensity of adoption of 4.0 technologies[7] at the sector/regional level is required. For the manufacturing sectors, two indicators of technology adoption have been taken into account: i) **the purchase of robots** in **manufacturing sectors** (i.e. the number of robots per employee in manufacturing sectors) and ii) **the intensity of 4.0 technological transformation of manufacturing firms** (measured as firms referencing 4.0 technology development and/or adoption on their websites).[8]

Starting with **robot adoption** (Maps 3.4 to 3.6), their intensity remarkably varies across countries and sectors:

- **robot adoption in 'technology' manufacturing sectors** (Map 3.4) concentrates in a block of countries. Within these national trends, diffusion is pervasive also in regions that are not 'technology' advanced regions (e.g. Southern Italy, Northern Germany).
- **Robot adoption in 'carrier' manufacturing sectors** (Map 3.5) shows a remarkable presence in Germany and Sweden; other areas experience a moderate decrease with respect to robots in the 'technology' sectors (e.g. Italy). Importantly, other countries exhibit a positive increase either because of a stronger specialisation in these sectors (e.g. Belgium and Spain) or because of the introduction of robots by multinationals operating in these sectors (Czech Republic and Slovakia).
- **Robot adoption in 'induced' manufacturing sectors** (Map 3.6) is highly concentrated in Scandinavian countries, Germany, Italy, Austria, Belgium, the Netherlands and Spain. Within these general national trends, adoption is relatively homogenous across regions.

The **intensity of 4.0 technological transformation of manufacturing firms** (measured through the share of firms developing and/or using 4.0 technologies) offers additional insights on the intensity of 4.0 technologies adoption in manufacturing, as shown in Map 3.7.[9]

Two important messages can be derived. First, **there are sharp differences across countries signalling the relevance of national digital infrastructure (broadband network)**. In this respect, the usual gap of Southern and Eastern countries is confirmed. Second, **within countries, the role of capital and urbanised regions clearly stands out**. This is evident not only in highly digitalised countries as France or Germany, but also for less digitalised countries as Spain, Italy and Czech Republic. The first result is rather consistent with those stemming from the analysis of robot adoption; the second result, instead, may indicate that **cities are the primarily location choice of 4.0 digital businesses because of the co-occurrence of multiple favourable conditions to 4.0 technology adoption in highly urbanised areas**.

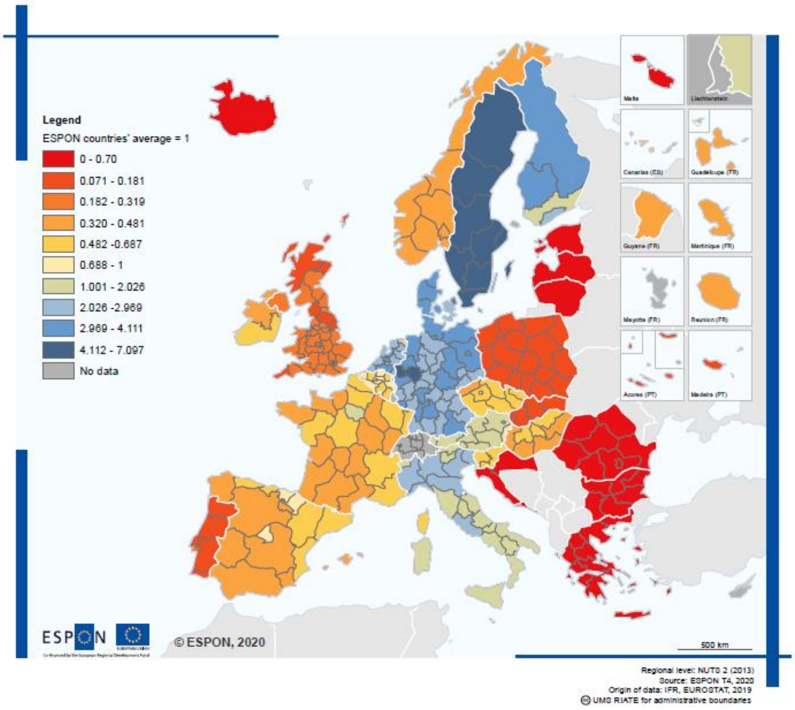
---

[7] In 4.0 technologies, the distinction between adoption and production of technologies is no longer so evident. Adopters in 'technology' and 'carrier' sectors can also be producers of their technologies. For sake of simplicity, we refer to adoption.

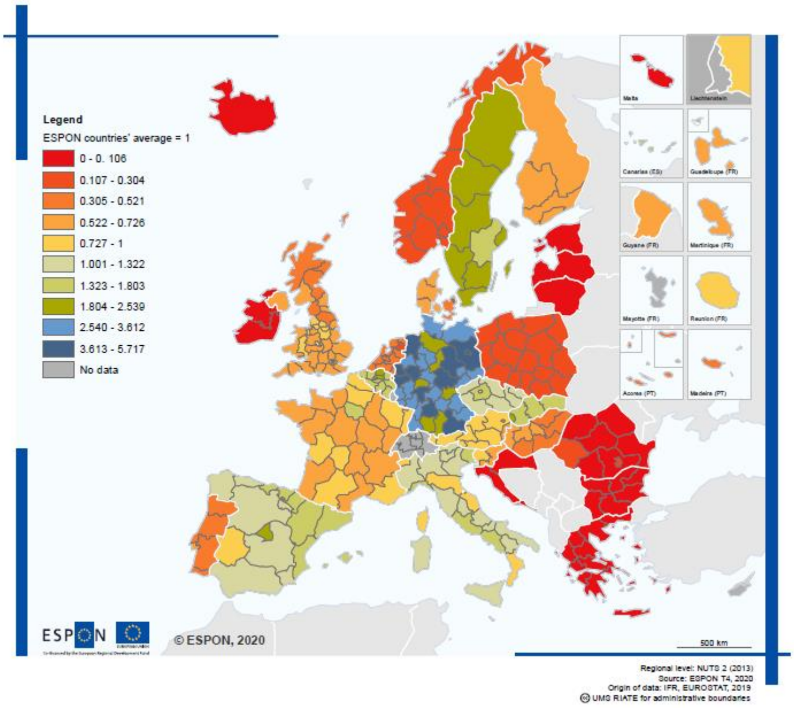
[8] Data and methods used to develop these indicators are presented in Section 5 in the Scientific Annex.

[9] Section 5.2 in the Scientific Annex lists selected examples of regional firms who have taken up digital technologies and describe what they have done so far and how they promote this on their websites.

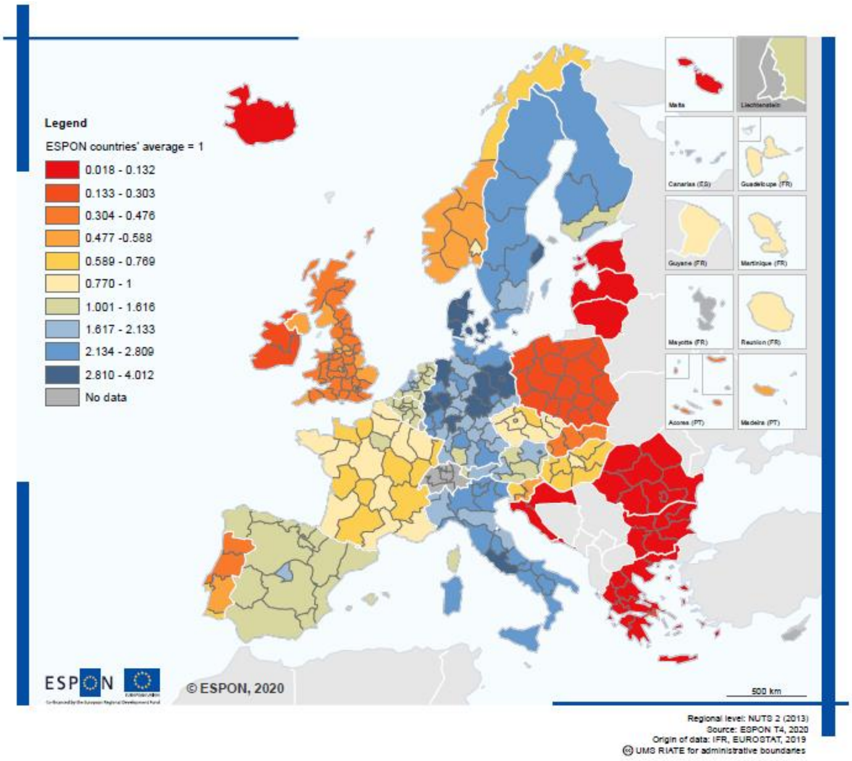
Map 3.4. Number of robots per employee in 'technology' manufacturing sectors w.r.t. ESPON countries' average, 2008-2016



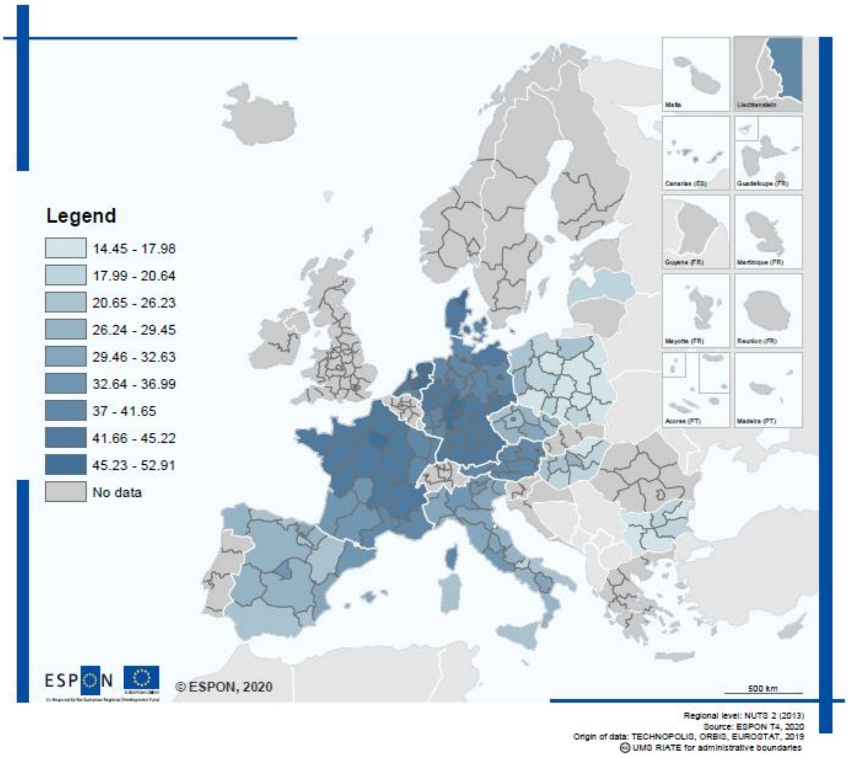
Map 3.5. Number of robots per employee in 'carrier' manufacturing sectors w.r.t. ESPON countries' average, 2008-2016



Map 3.6. Number of robots per employee in 'induced' manufacturing sectors w.r.t. ESPON countries' average, 2008-2016



Map 3.7. Share of manufacturing firms developing and/or using 4.0 technologies, 2017



Box 3.2. Spatial patterns of 4.0 technologies adoption in manufacturing sectors

- The **adoption of robots is affected by national institutional and regulatory conditions**.
- Only **Germany and Italy are strong adopters**.
- **When countries adopt, the adoption is overall pervasive across regions**.
- Firms' adoption of 4.0 technologies is affected by **national digital infrastructural and regulatory conditions**.
- Within countries, **4.0 digitalisation intensity is higher in capital and urbanised regions**.

3.2.2 4.0 technology adoption in services

The intensity of online sales, measured as the share of firms with at least 1% of turnover from online sales, is the indicator of adoption of 4.0 technologies in services; this indicator is also used in DESI as to monitor the integration of digital technology by enterprises.[10] **The adoption of 4.0 technologies in services present important country effects** (Maps 3.8 to 3.11), suggesting **the importance of the national broadband infrastructure to support technology diffusion**.[11] The diffusion is rather robust to sectoral differences, albeit with specificities in each group of sectors. In fact:

- **online sales in 'technology' services (e.g. IT services)** are especially high in Germany, Scandinavian countries[12], Ireland, the UK, and Czech Republic. New, however, is the relatively good performance of some regions in Poland, Bulgaria, Portugal and Greece, especially in light of the overall weak performance. Most of them, however, are not capital regions (Map 3.8);
- **online sales in 'carrier' services (e.g. retail, administrative services, technical services)** are more prominent in Scandinavian countries, Ireland, the UK, Belgium, Luxembourg and the Netherlands as well as of Czech Republic. Germany has a relatively good positioning but loses the edge shown with respect to previous indicators (Map 3.9);
- **online sales in 'induced' services** (e.g. transport, real estate, accomodation) are diffused also in Southern European regions, also in countries like Portugal and Italy, that do not exhibit a strong performance as a whole (Map 3.10). A focus on transport and storage firms shows that some advanced countries like Italy, Spain and Finland are still lagging behind in terms of adoption of online sales in this specifc sector (Map 3.11). Awareness of this delay in the transport services is particularly relevant when new initiatives aimed at the development and/or integration of various forms of transport services accessible on demand has to come to the implementation stage. A relevant example in this respect is the MAAS initiative;[13]

---

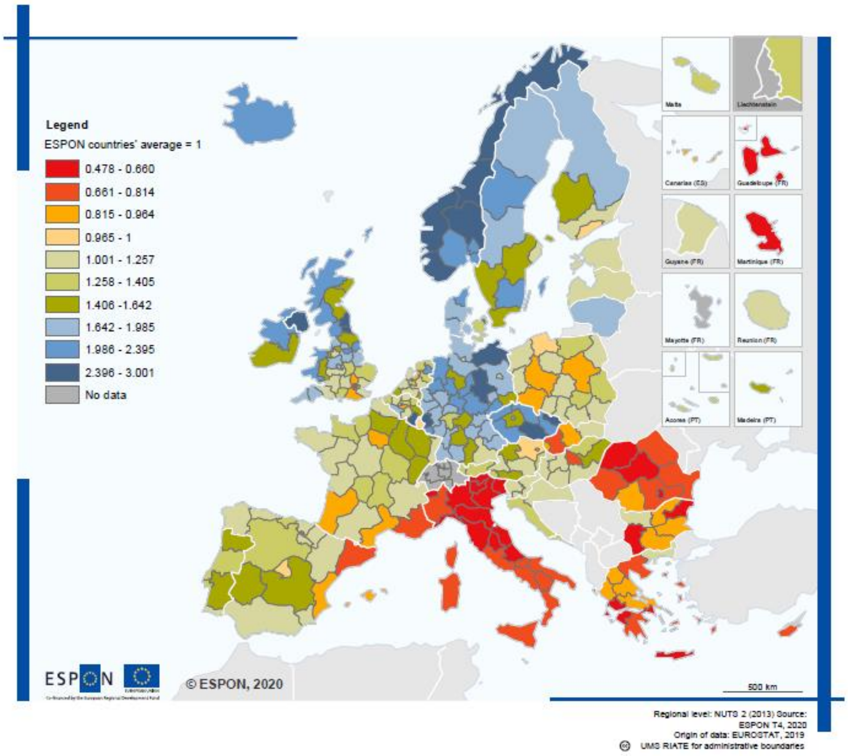
[10] https://ec.europa.eu/digital-single-market/en/integration-digital-technology, luuuuuuuuuuuuuuuuuuuuast visited on 15/06/2020.

[11] In maps 3.8 to 3.10, the intensity of adoption is presented with respect to the ESPON countries' average.

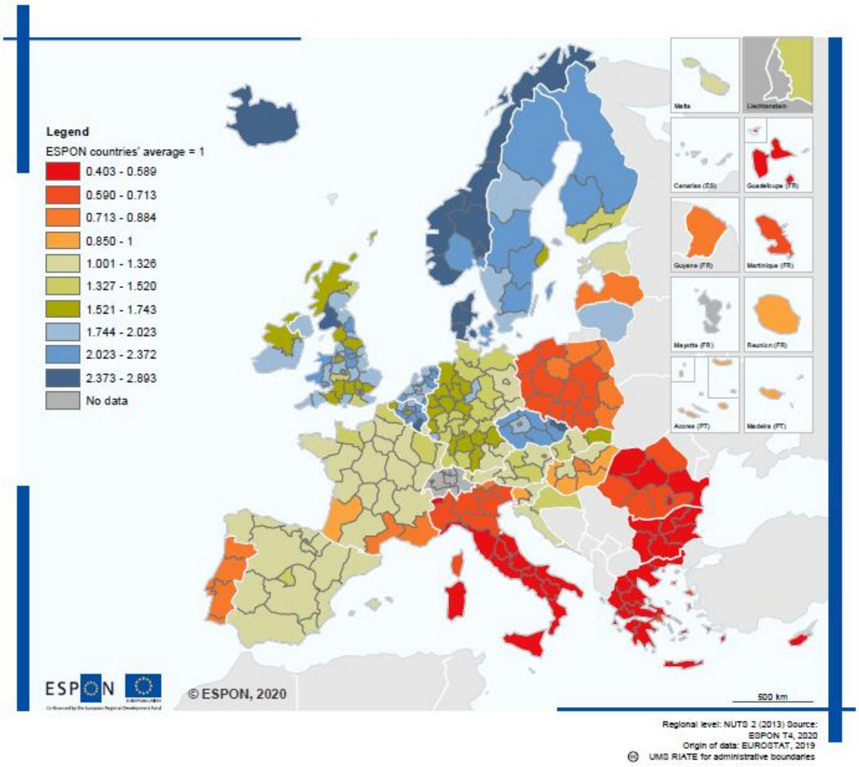
[12] The high performance of Scandinavian countries in terms of digitalisation is also acknowledged in several studies. An illustrative example is available at http://norden.diva-portal.org/smash/get/diva2:1295022/FULLTEXT01.pdf, last visited on 15/06/2020.

[13] https://maas-alliance.eu/, last visited 15/06/2020.

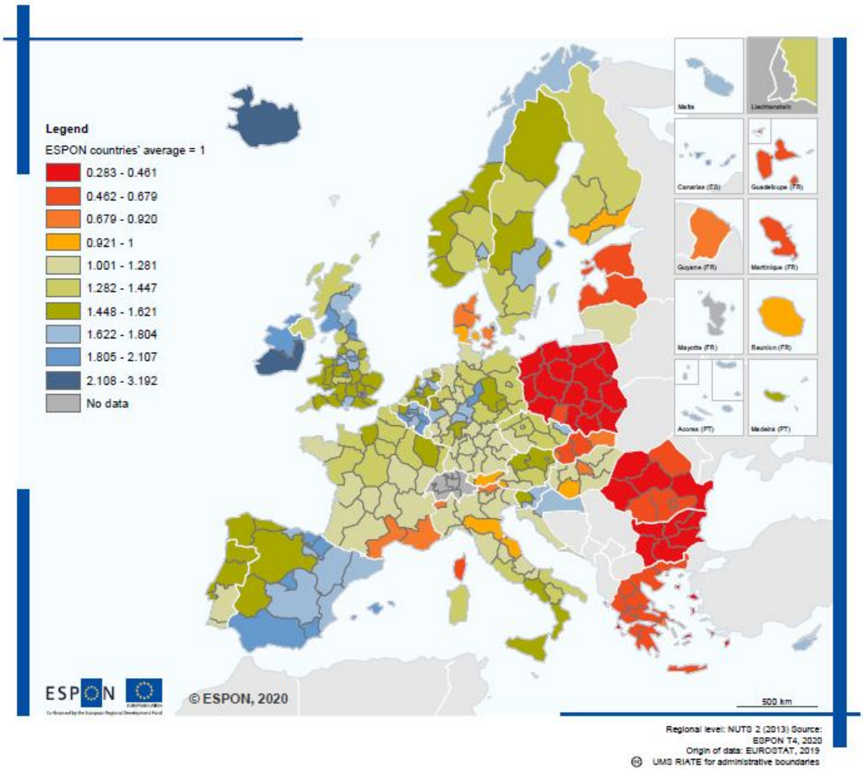
Map 3.8. Share of firms with online sales in 'technology' services w.r.t. ESPON countries' average, 2009-2016



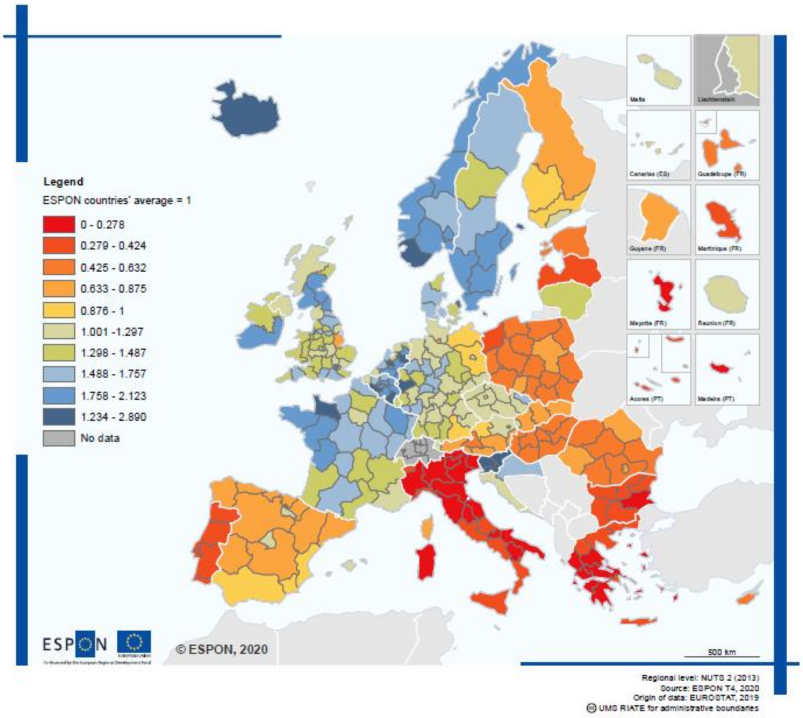
Map 3.9. Share of firms with online sales in 'carrier' services w.r.t. ESPON countries' average, 2009-2016



Map 3.10. Share of firms with online sales in 'induced' services w.r.t. ESPON countries' average, 2009-2016



Map 3.11. Share of firms with online sales in transport services w.r.t. ESPON countries' average, 2009-2016



- similar to what observed for robot adoption in manufacturing sectors, **regional sectoral specialisation and regional sectoral adoption do not always overlap**. Most of relatively peripheral regions in countries like Spain, France or the UK show relatively high levels of online sales in all types of services with weak or nil specialisation in some of them. Conversely, capital regions in Eastern countries like Slovakia, Hungary, Romania, and Bulgaria, highly specialised in all the three types of services do not show any prominence in terms of online sales, regarless the type of service considered. These situations represent interesting *peculiar cases. High penetration rates in de-specialised areas represent success stories; low penetration rates in regions with high specialisation signal areas of strong potential for 4.0 technological adoption.*

Box 3.3. Spatial patterns of 4.0 technologies adoption in services

- **The adoption of 4.0 technologies in services is country-specific, which makes us think that the general national conditions in terms of digital infrastructure (broadband diffusion) and regulatory conditions matter**.
- Adopting countries show **similar adoption patterns in all types of services**, albeit with different intensity.
- Within adopting countries, **adoption is overall pervasive across regions**.
- **A high adoption in specific services in a region does not always reflect a high presence of those services in the region**. High penetration rates in de-specialised areas represent success stories in adoption; low penetration rates in regions with high specialisation signal areas of strong potential for 4.0 technological adoption.

3.2.3 4.0 transforming regions

Through a statistical analysis, presented in Annex 7 of the scientific report, the technological transformation prevailing in each region is highlighted on the basis of the sectors present in the region, and of the degree of adoption of 4.0 technologies useful for the specifc predominant sector. In particular:

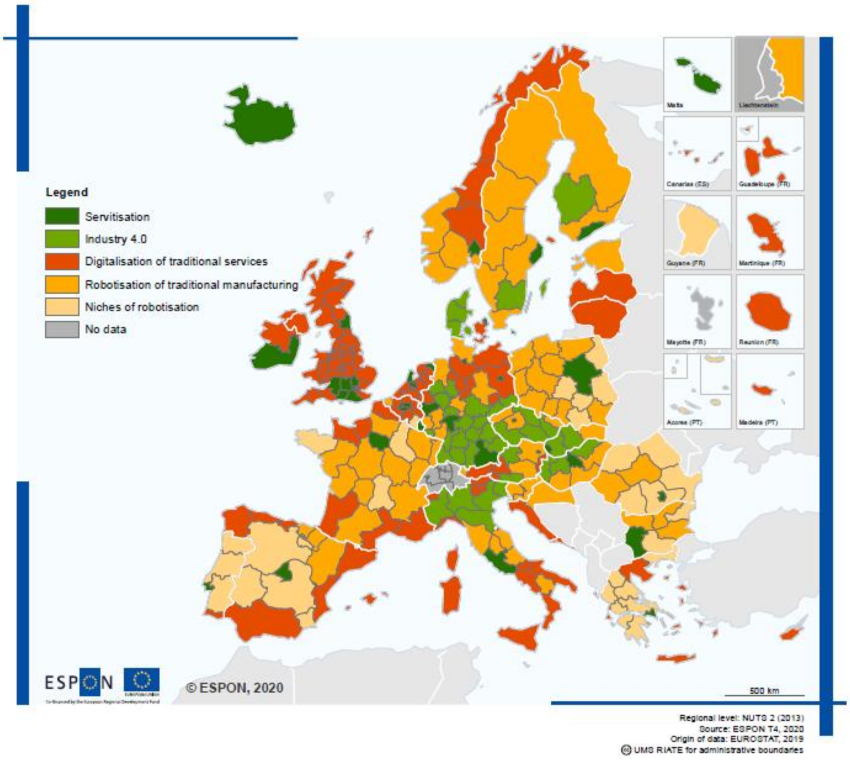
- **Servitisation** is assumed to take place when ‘technology’ or ‘carrier’ services are predomimant in the region and associated with a high adoption of the technologies specific of these services (online sales in ‘technology’ or ‘carrier’ services);
- **Industry 4.0** is expected to take place when ‘technology’ or ‘carrier’ manufacturing sectors are predomimant in the region associated with a high adoption of the technologies specific of these sectors (robots in ‘technology’ or ‘carrier’ manufacturing sectors);
- **digitalisation of traditional service** is assumed to take place when ‘induced’ services are predomimant in the region with a high adoption of the technologies specific of these services (online sales in ‘induced’ services);
- ‘**robotisation of traditional manufacturing’** is expected to take place when ‘induced’ manufacturing sectors are predomimant in the region with a high adoption of the technologies specific of these sectors (robots in ‘induced’ manufacturing sectors).

The technological transformations are identified in Map 3.12[14]:

- **Servitisation** takes place in a few number of regions, especially large city regions, characterised by a high penetration of digitalisation in service and a high entrepreneurial capacity. This last feature highlights the creative ability in exploiting such new technologies for new business models (Map 3.12, dark green regions).;
- **Industry 4.0** is present in a few number, located mainly in Southern Germany and Northern Italy (Map 3.12, light green regions);
- **digitalisation of traditional service** is the most populated among the different groups. These regions are mainly Southern Italy regions, some regions in Spain, parts of the UK (with the exception of London and its surroundings), Baltic regions, regions in Norway, Northern Germany, part of the Netherlands (Map 3.12, red regions);
- **robotisation of traditional manufacturing**, a transformation present in several regions in Europe, especially in France, Poland, Central Italy, Hungary (Map 3.11, orange regions);

[14] See Section 7 in Annex for the methodology and results of the cluster analysis.

Map 3.12. 4.0 technological transformations in European regions, 2009-2016



- **niches of robotisation.** This case was not foreseen conceptually in Section 2, and is the result of the empirical analysis. In this case, transformation takes place intensively but only in a few manufacturing firms in the region. This situation is present mainly in Eastern countries, Greece, part of Spain and a few regions in France. These regions show a very low adoption, and a specialisation in very small 'induced' manufacturing sectors. These areas are characterised by a very high risk of job automation (Map 3.11, yellow regions).

We expect the different technological transformations to have different impacts on the local economy and society. This is the subject matter of Sections 4 and 5.

Box 3.4. 4.0 technological transformations in European regions

- **Servitisation** takes place especially in large city regions,
- **Industry 4.0** takes place in a few regions in Europe, located mainly in Germany and in Northern Italy;
- **digitalisation of traditional service** is a diffused phenomenon, taking place in peripheral regions, in the UK (with the exception of London and its sorroundings), Baltic countries, Norway, Northern Germany, part of the Netherlands;
- **robotisation of traditional manufacturing** is diffused in several regions in Europe; especially France, Poland, Central Italy, Hungary register relatively high adoption of robots in 'induced' sectors;
- **still many regions in Europe have a limited transformation**, mainly because **they experience only niches of robotisation**. These regions are mainly in Eastern countries, but also in Greece, part of Spain and a few regions in France. They show a very low adoption, a specialisation in very tiny manufacturing sectors, and, last but not least, have a very high risk of job automation.

4 Economic impact of technological transformation

4.1 Impacts of 4.0 technology adoption on GDP growth

High expectations exist about the economic and social effects of the adoption of 4.0 technologies. In this section, we present the results of the economic impact, leaving to the next section the social impact on the labour market.

The impact is a rather complex element to measure, since it depends on the type of sectors involved (and therefore on the type of transformation), on the type of technology adopted, on the capacity of the regions to exploit the technology, and on the period of time. Last but not least, the impact can be measured on different aspects of the economy, namely GDP or productivity growth and can vary over time. What follows takes all these elements explicitly into account, since **only by analysing all of them one can interpret the complex transformation process**. The analysis is carried out for two different periods of time, the crisis period (2007-2012) and the recovery one (2013-2017) with the explanatory variables of technology adoption referring to the previous three year period. Through the use of an econometric model, the impact of different types of 4.0 technologies (i.e. robots and online sales in the different 'technology', 'carrier' and 'induced' manufacturing sectors and services) on GDP growth is obtained, after controlling for different additional conditions that can influence GDP growth.

Map 4.1 presents the **GDP per capita growth rate in regions characterised by different technological transformations** in the period 2007-2012. After controlling for many other explanatory factors, the map shows us that **the highest GDP per capita growth is registered in the most complex and articulated technological transformations**, namely the Servitisation and the Industry 4.0 ones. Regions where the adoption is limited to niche of excellence (niches of robotisation) are characterised by the lowest rates of GDP per capita growth.

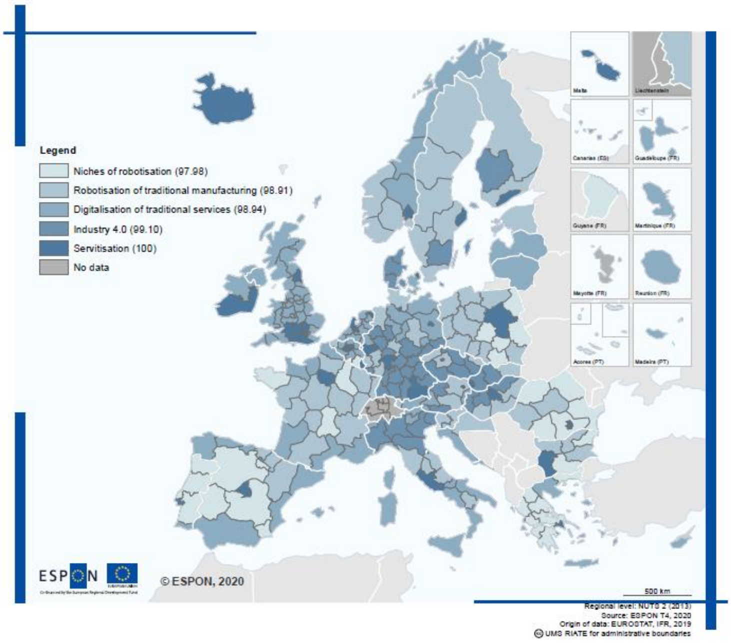
This difference tends to disappear over time (Figure A.8.1, Section 8 in Annex). This can be the result of an increase in adoption, or in a learning process on how to exploit the technologies. The interesting following step is therefore to directly link the GDP performace to the adoption of 4.0 technologies. **To which extent does GDP growth depend on the adoption of 4.0 technologies?**

The adoption impact is definitely positive (Table A.8.3). **A higher increase in robots' and online sales' adoption generates an increase in GDP growth rate**.[15] In the case of Industry 4.0 transformation, the adoption of advanced (automation) technologies (e.g. intelligent robots, IIoT, just to name a few of them), which represent very advanced process innovations, can lead to a considerable expansion of markets by realising mass customisation (i.e. the personalisation of products for many different users). In the case of the Servitisation transformation, new markets are created and existing ones can expand by connecting to and/or through the operation of intermediary platforms. For example, BlaBlaCar has created a market for a idle resource, i.e. free seats on car. Virtual marketplaces such as Amazon or Alibaba allow vendors connecting to the marketplace to reach unprecedented market size and customer base.

---

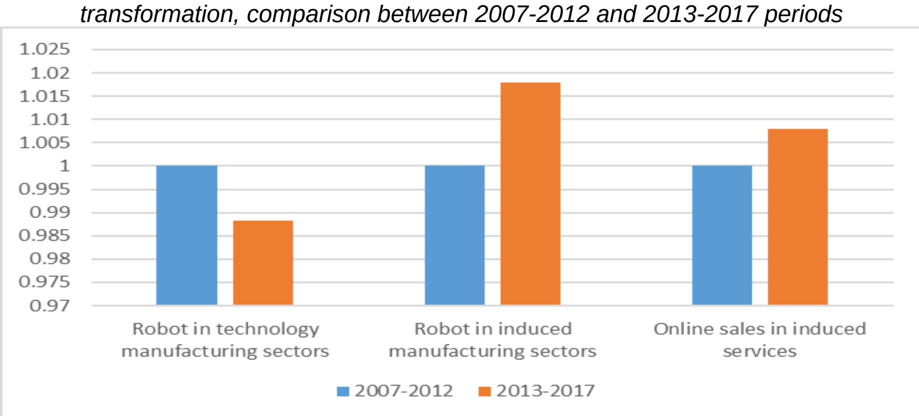
[15] Since the 'technology' sectors and the 'carrier' sectors are linked to the same technological transformations, the impact analysis is run only utilising the 'technology' sectors.

Map 4.1. GDP per capita growth rate: comparison among regions characterised by different technological technological transformations, 2007-2012



Over time, the impact of adoption slightly changes, decreasing for technologies that require a more complex adoption, like the reorganization of a production process in a smart factory, or the launch of a new digital service market, and increasing for technologies that need a simpler adoption, like the simple substitution of a human role with a robot, or the launch of online sales for a company. Greater advantages from adoption characterise more complex transformations with respect to simpler ones (Figure 4.1).

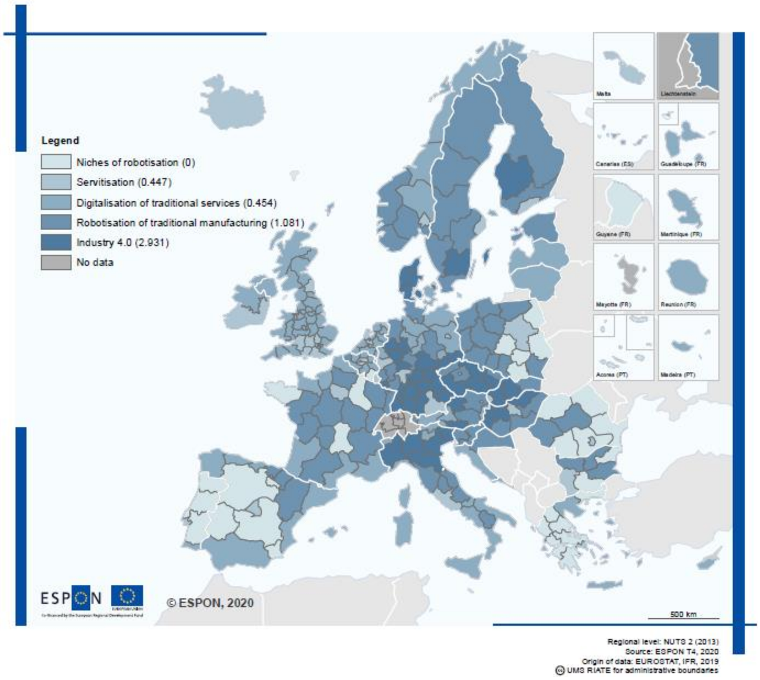
Figure 4.1. Impact of technology adoption on GDP per capita growth by type of technological transformation, comparison between 2007-2012 and 2013-2017 periods



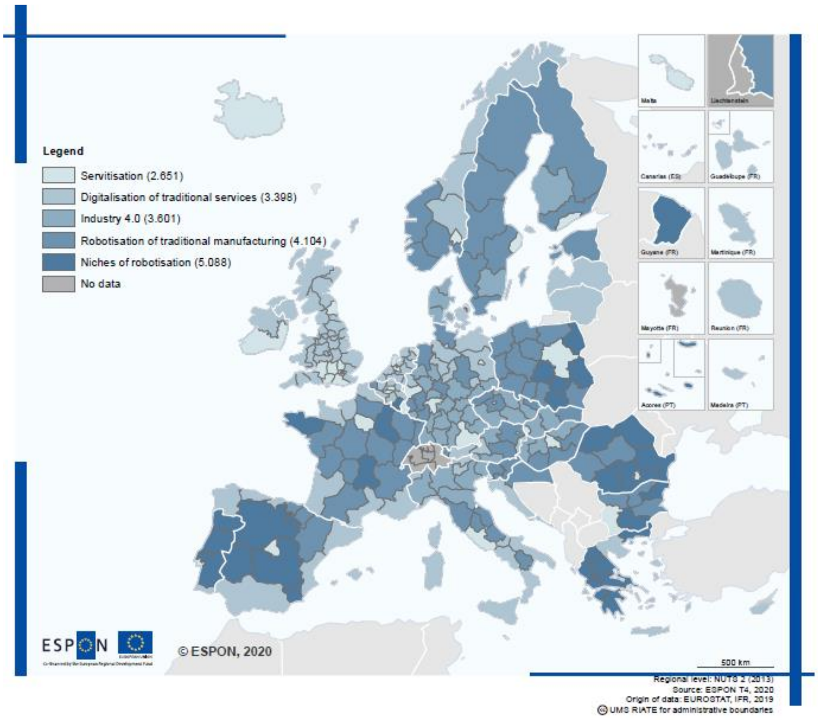
The positive impact is however expected to be differentiated across technological transformations. In fact, scale advantages or the need of a certain critical mass in technology adoption can exist and can affect the impact.

For what concerns the adoption of robots in ‘technology’ sectors, (Map 4.2), the results witness that **the impact on GDP growth is the highest in Industry 4.0 regions** followed, in terms of intensity, **by regions characterised by robotisation of traditional manufacturing**, by digitalisation of traditional service and by those that go through a **Servitisation**.

Map 4.2. Impact of robot adoption in 'technology' manufacturing sectors on GDP per capita growth by type of technological transformation, 2013-2017



Map 4.3. Impact of robot adoption in 'induced' manufacturing sectors on GDP per capita growth rate by type of technological transformation, 2013-2017



Regions with niches of robotisation do not register any impact. This result suggests that indeed scale advantages are at place and the achievement of a certain critical mass is nedeed in order to benefit from robot adoption in technology sectors. Over time, **the impact of robots on GDP per capita growth increases only in Industry 4.0 regions**, while it remains constant in the other transformations (Figure A.8.2, Section 8 in Annex). **This result indicates that the advantages of adoption increase over time when the adoption regards the specific technology on which the regional technological transformation is based**.

The results differ when looking at the **impact of robots in 'induced' sectors on GDP per capita growth** in the period 2013-2017 (Map 4.3). In this case, **the highest impacts on GDP per capita growth are registered in regions with niches of robotisation and in regions with robotisation of traditional manufacturing**, while both the Industry 4.0 regions and the Servitisation regions obtain from the adoption of such technology the lowest impact on GDP per capita growth. By reversing the spatial trends of the impact with respect to Map 4.2, the main message is that **regions are able to obtain the highest advantage from the adoption of the technology specific of their transformation**: this simply means that regions specialised in Industry 4.0 get the highest gains from such transformation, while those specialised in Servitisation gains the most from this type of transformation.

This message is reinforced in Map 4.4, where the impact of online sales in 'induced' sectors on GDP per capita growth is presented. In other words, this map represents the impact on GDP growth obtained from the introduction of simple technologies like online sales through companies' websites. **The map clearly shows that online sales' adoption generates its highest positive impacts in terms of GDP per capita growth in regions characterised by digitalisation of traditional services** and, to a lesser extent, in regions where Servitisation takes place. In all other regions characterised by other technological transformations, the impact is nil, suggesting that the advantages obtained from adoption do not spill over to other regions specialised in other sectors and experiencing other technological transformations. Interestingly enough, the spatial trends presented in Maps 4.3 and 4.4. remain constant over time (Figures A.8.3 and A.8.4, Section 8 in Annex).

The main result from the analysis is that the impact of technology adoption on GDP per capita growth in a region is the highest when adoption refers to the technology specific of the transformation that characterises a region.

Within the same region, the impact varies according to the adoption level of the technology. Figure 4.2 presents the impact on GDP per capita growth in the different types of technological transformations for different levels of adoption intensity. **In complex transformation types** (i.e. Servitisation and Industry 4.0) **regions with a high intensity of adoption achieve higher advantages in terms of GDP per capita growth than those with a low intensity of adoption**, **suggesting the existence of increasing returns from technology adoption and transformation**. Instead, **simple transformations** (i.e. digitalisation of traditional service, robotisation of manufacturing and niches of manufacturing robotisation) **register positive advantages from their technologies, but at decreasing rates**. In fact, in these technological transformations types, regions characterised by a high adoption rate show indeed a lower GDP per capita growth than those that have a lower adoption rate (Figure 4.2, Figure A.8.5 for the period 2013-2017).

Map 4.4. Impact of online sales adoption in 'induced' services on GDP per capita growth rate by type of technological transformation, 2013-2017

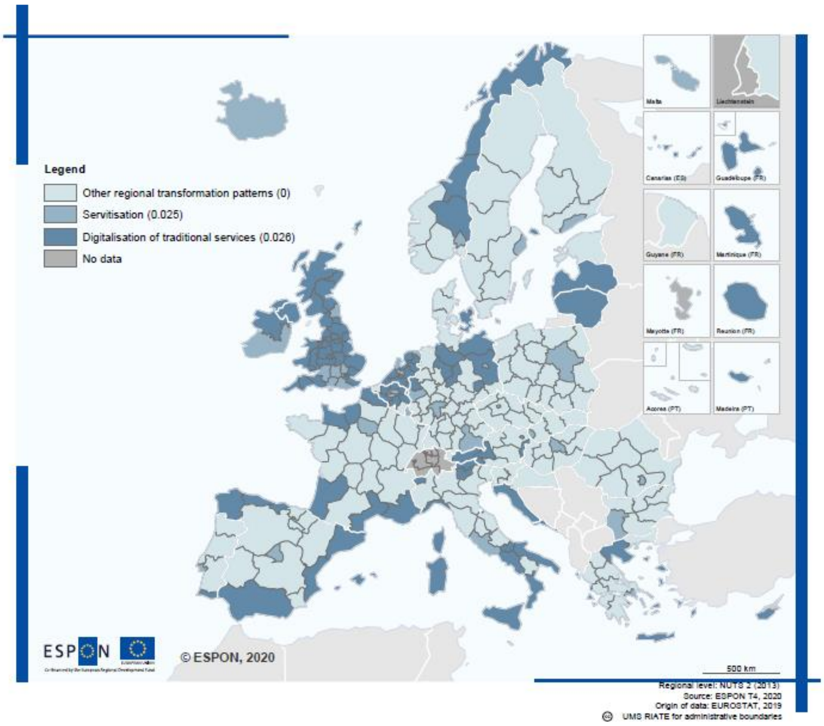
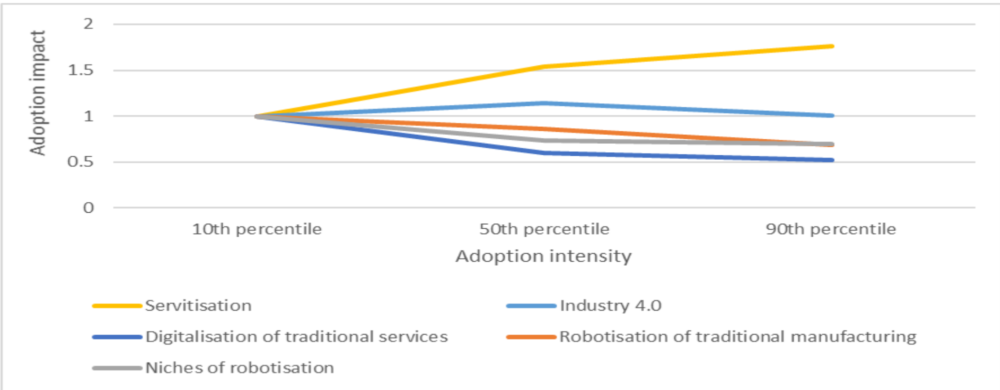


Figure 4.2. Impact on GDP per capita by type of technological transformation and adoption intensity, 2007-2012



Within each transformation, the degree of adoption efficiency is certainly not evenly distributed. In particular, within each type pf technological transformation regions can be classified as:

- **low adoption potential regions**, when regions have both an adoption and an impact below the average of their respective transformation pattern. A scarce adoption potential exists in these regions;
- **low adoption efficiency – high potential regions**, when the higher than average adoption rate characterising the region is not reflected in an efficient use of the technology, which produces a lower than average impact. A high potential exists of

increasing the advantages in these regions through a more efficient use of the technology adopted;

- **high adoption efficiency – high potential regions**, when the limited adoption in regions is compensated by a very efficient use of the technology, which produces a higher than average impact. A high potential exists of increasing the advantages in these regions through an increase in adoption;

best practice regions, when a higher than average adoption is associated to a higher than average impact.

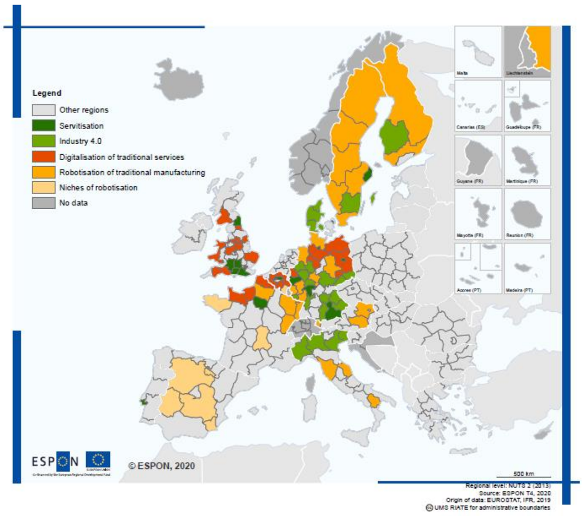
Map 4.5 displays **the degree of adoption efficiency for regions with different technological transformations**. Each colour represents a specific transformation type, as in Map 3.11. When reading the results by type of adoption efficiency, several interesting messages are provided by this map. **Best practices tend to be located in Scandinavian countries, down to Northern France and Germany, till Northern Italy**, while they are totally absent in Eastern countries (Map 4.5a). The other extreme case, **the low adoption potential case**, **is merely present in Eastern countries, in Greece, and some spots around Europe** (Map 4.5b). **The other two cases are in a limited number**, witnessing that the adoption of the specific transformation's technology in most cases leads to advantages. However, some exceptions exist, and are extremely interesting from a normative point of view, since they call for different kinds of policy inverventions. **The high adoption efficiency case, where policy interventions should focus on increasing adoption, concerns mainly France, Italy and Germany** (Map 4.5c), while **the low adoption efficiency, where normative actions should focus on increasing technology exploitation, characterises UK, Spain and Ireland** (Map 4.5d).

When reading the results by technological transformation, interesting results emerge too. **The Servitisation transformation shows a few cases of best practices concentrated in the North of Europe**, in particular in the area of London, Stockholm, in Germany (Frankfurt am Main and Munich) and in Portugal (Lisbon). **Low potential regions are instead concentrated in all capital cities of Eastern European countries** (Bratislava, Pragua, Warsaw, Budapest, Bucarest) and **in the Italian capital city region** (Rome). **A high adoption efficiency** is registered in Helsinki and Athens, where a high adoption potential exists, being extremely efficient in exploting the technologies they have adopted. Finally, **Spain, Ireland and Belgium register a low adoption efficiency**; they have a high potential in better exploiting their adopted technologies.

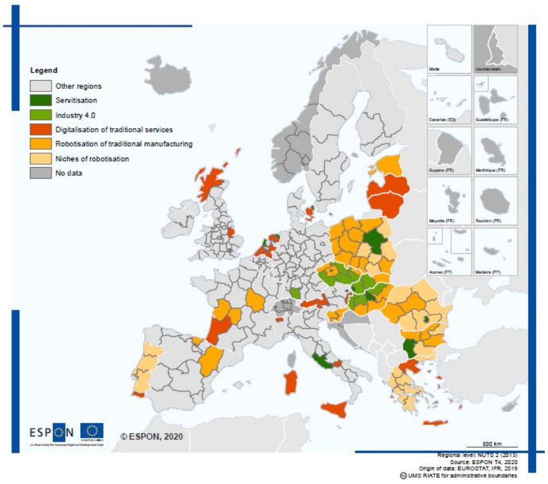
Within the Industry 4.0 pattern, best practice regions are in a high number, and are more spread around Europe than in the case of the Servitisation pattern (Map 4.5). **Best practices are present in Scandianavian countries** (Danmark, Sweden and Finland), **but also in Sourthern Germany and in Northern Italy**. **Low adoption potential regions are in a limited number and concentrated in the Eastern countries**. **High adoption efficiency cases are concentrated in Italy and Germany** where high potential for growth exists. **Low adoption efficiency cases almost do not exist**, witnessing that when advanced robotisation of manufacturing sectors takes place, firms know how to get advantage from the adoption.

Map 4.5. Degree of adoption efficiency for different technological transformations, 2013-2017

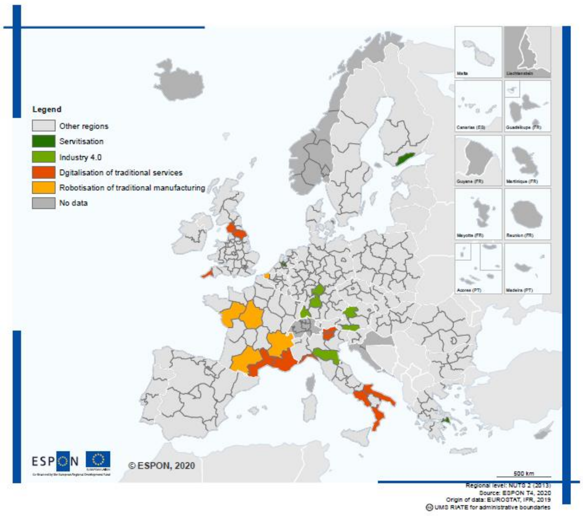
Panel (a) Best practices



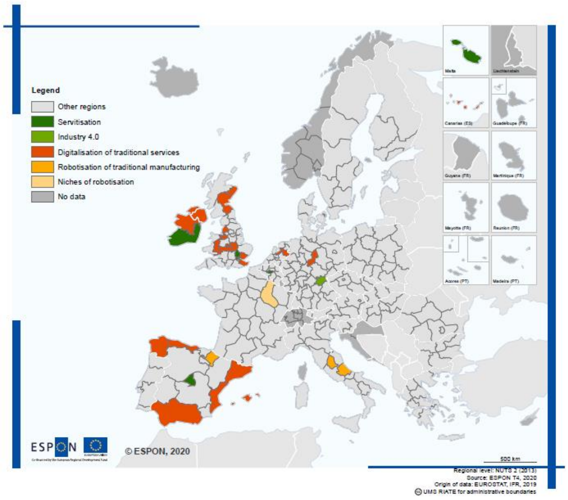
Panel (b) Low adoption potential regions



Panel (c) high adoption efficiency – high potential regions



Panel (d) low adoption efficiency – high potential regions



Within the pattern of digitalisation of traditional service, best practices are registered quite in a number in the UK, North of France, Benelux and Eastern Germany, while they are totally absent in Southern and Eastern Europe (Map 4.5). Low adoption efficiency characterises Spain, UK and Northern Ireland, where high potential exists in better exploiting the already adopted technologies. **In some Southern Italian and Southern French regions, high potential exists in that these regions display a very efficient use of their limited adoption**. Instead, **low potential adoption regions are sparcely diffused all over Europe**, except in Eastern countries where, however, this transformation pattern is not present.

Within the pattern of robotisation of traditional manufacturing sectors, best practice are spread around Europe, with the exception of Eastern Countries (Map 4.5). They are present in Scandinavian countries, in Germany and Northern France. **Eastern countries instead fall into the category of low adoption potential, with low adoption and low impact, together with some regions in Spain and France**. **High adoption efficiency regions are**

concerntrated in France, while low adoption efficiency are in a very few cases, and located in Southern Italy and Spain.

Within the pattern of niches of robotisation, best practices are present in Spain and France, while the low adoption case is restricted to Eastern countries and Portugal. **Low and high adoption efficiency cases do not really exist, showing that when these niche adoptions take place**, advantages are definitely achieved.

Box 4.1. Results on the impacts of 4.0 technology adoption on GDP growth

- The **highest GDP p.c. growth is registered in the most complex and articulated technological transformations**. Regions where the adoption is limited to niche of excellence are characterised by the lowest GDP growth;
- **GDP growth is definitely positively associated to adoption**. A higher increase in robots' (both in 'induced' and 'technology' sectors) and in online sales' adoption generates an increase in GDP growth rate;
- over time, the impact of adoption slightly decreases for technologies that require a more complex adoption, and increases for technologies that need a simpler adoption. This result suggests that **a learning process is required to adopters on how to exploit simple technologies in a strategic way**.
- **The adoption impact in a region is higher when the adoption relates to the technology specific of the transformation that characterises that region**;
- **in complex transformation patterns, an increasing intensity of adoption is associated with an increasing impact in terms of GDP growth.** Instead, **simple transformations register a negative association between adoption intensity and impact**;
- **the degree of adoption efficiency is certainly not evenly distributed**. **Best practices tend to be located in Scandinavia, down to Northern France and Germany, till Northern Italy**. They are totally absent in Eastern countries. Low adoption potential regions are merely present in Eastern countries, in Greece, and some spots around Europe. The high adoption efficiency regions, where policy interventions should focus on increasing adoption, concerns mainly France, Italy and Germany, while the low adoption efficiency regions, where normative actions should focus on increasing technology exploitation, characterises UK, Spain and Ireland.

4.2 Impacts of 4.0 technology adoption on productivity growth

In this section, **the impact of technology adoption on productivity growth** is presented. Expectations on productivity increases because of the spread of the new technologies in the economy are high, given the slugging performance of many European countries.[16] **The first message is that while robot adoption increases productivity growth, online sales do not impact on such performance** (Figure 4.3).

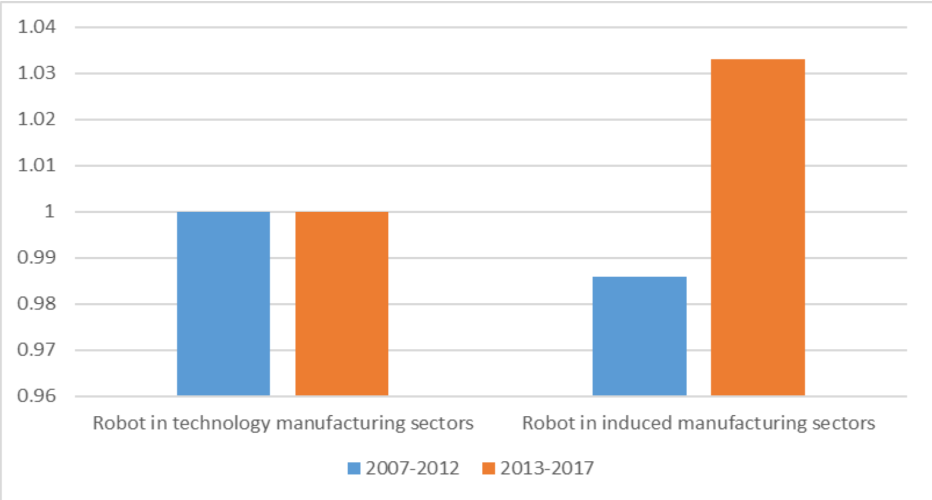
The impact of robots in 'technology' sectors is rather concentrated in space. **Map 4.6 shows that the advantages in terms of productivity take place only in the two transformation patterns that pertain to the manufacturing sectors**.

The highest impact on productivity growth is registered in the Industry 4.0 regions, while also regions with a robotisation of their traditional manufacturing activities are able to grasp productivity gains. New product and service development systems that can be made possible and personalised. These innovation trends lead to an increasing personalisation of products and in extreme cases to individual products, i.e. to a *batch size production*, abating production

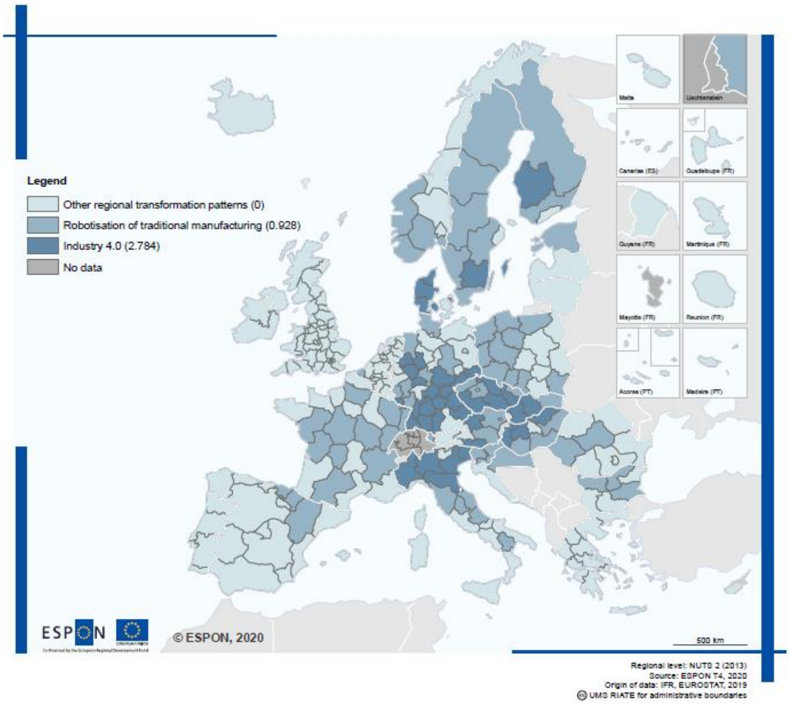
[16]https://sciencebusiness.net/viewpoint/viewpoint-why-productivity-going-down-when-technology-accelerating, last visited 15/06/2020.

costs and increasing productivity. Moreover, the integration of intelligent (cyber-physical) solutions in the production system allow greater automation and, thus, productivity advantages. In fact, these technologies allow embedding enhanced data extraction solutions in production equipment as to collect and monitor data on different process parameters (e.g. plant logistics processes, quality management and the testing of products). In short, the new technologies enable the standardisation (i.e. routinisation) of experience-based ad tacit knowledge intensive tasks and represent important sources of efficiency gains for those firms willing to switch to the new business models.

Figure 4.3. Impact of the adoption of different types of technology on productivity growth, comparison between 2007-2012 and 2013-2017 periods



Map 4.6. Impact of robot adoption in 'technology' manufacturing sectors on productivity growth by type of technological transformation, 2013-2017

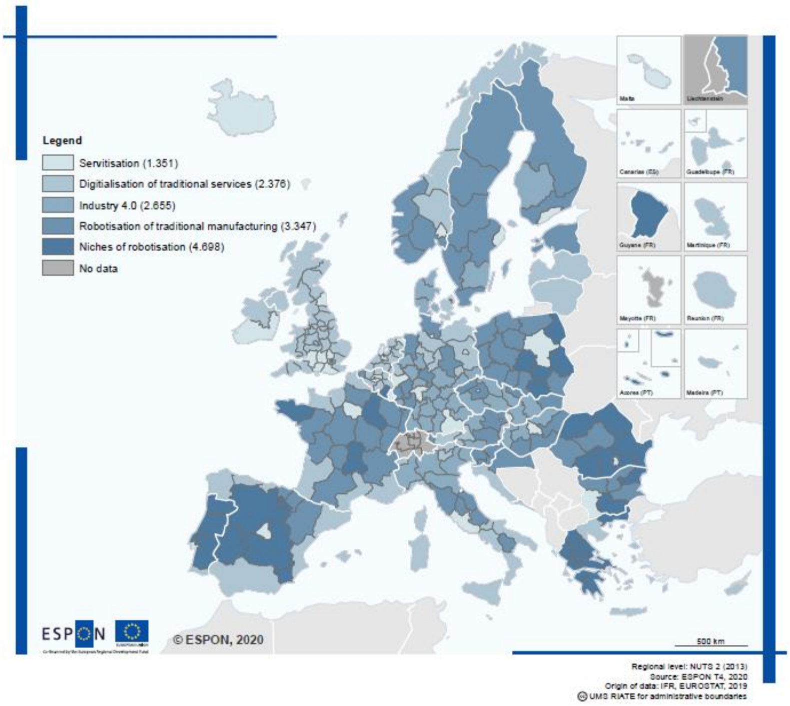


Interestingly enough, the complex transformation in manufacturing (Industry 4.0) registers an increase of productivity advantages over time, while the simple robotisation of traditional manufacturing sectors registers a decrease. This message is important, since it underlines that **complex transformations are those that in the long run pay off the most** (Figure A.8.6, Section 8 in Annex).

The productivity advantages, however, remain confined in the regions adopting the technologies, and no productivity gains are registered by other regions characterised by different technological transformations. No productivity gains are instead generated by transformations related to services. Even the niche adoption pattern is unable to increase productivity growth, and this suggests that **niche adoptions are not enough to generate productivity advantages, and that a critical mass of adopters is required in the region to register such greater performance**.

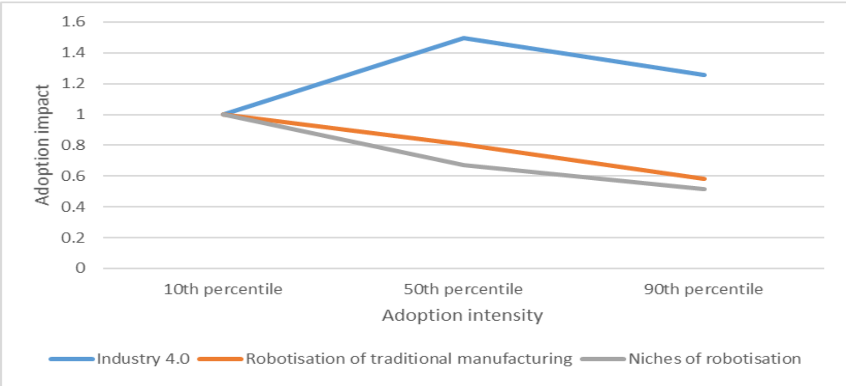
In the case of robots adoption in 'induced' sectors, **the impact on productivity growth pervades all patterns of transformation, showing that productivity advantages are achieved also by other sectors**. Map 4.7 displays such an impact by type of technological transformation. Being robots in 'induced' sectors less complex technologies, their adoption calls for simpler transformations, more easily leading to an increase in productivity growth. **Niches of robotisation**, as well as **robotisation of traditional manufacturing sectors register in fact the highest increase in productivity growth**, followed by Industry 4.0 regions. Last, but not least, digitalisation of traditional services and Servitisation transformations obtain a decisive productivity growth, even if less pronounced.

Map 4.7. Impact of robot adoption in 'induced' manufacturing sectors on productivity growth by type of technological transformation, 2013-2017



Looking at the relationship between the impact and the intensity of adoption, Figure 4.4 shows that only the more complex transformation registers an increase in the impact for higher adoption rates. In fact, although the trend in an inverted U-shaped curve, in the Industry 4.0 transformation pattern, **the most intense adopters of robot in 'technology' sectors achieve higher productivity growth gains than the least adopters**. This is not the case of the robots' adoption in 'induced' sectors, that decrease their positive effects on productivity growth while increasing the intensity of adoption. **Decreasing returns to adoption intensity therefore characterise the simplest transformations**, namely niches of robotisation, and robotisation of traditional manufacturing sectors (see also Figure A.8.8, Section 8 in Annex for the period 2007-2012).

Figure 4.4. Impact on productivity growth by type of technological transformation and adoption intensity, 2013-2017



Box 4.2. Impacts of 4.0 technology adoption on productivity growth

- **Impacts on productivity growth differ across technology**. Only robot adoption increases productivity growth, while online sales do not impact on such performance;
- **the impact of robots in 'technology' sectors is concentrated in manufacturing transformation regions.** Industry 4.0 regional pattern registers the highest impact. Also regions with a robotisation of their traditional manufacturing activities are able to grasp productivity gains;
- **the achievements of productivity growth advantages are more difficult to be grasped with respect to GDP growth advantages**, as they take place mostly in the sectors strongly related to the use of the technology, and with limited spillovers to other sectors. **Adoption in minority niches is not enough to generate productivity advantages**, and **a critical mass of adopters is required** in the region to register such greater performance;
- being less complex technologies to use and exploit, **the adoption of robots in 'induced' sectors register an increase in productivity growth everywhere, and especially in simple technological transformation patterns**;
- **decreasing returns to adoption intensity characterise the simplest transformations**, while the increase in adoption increases the productivity advantages in Industry 4.0 regions.

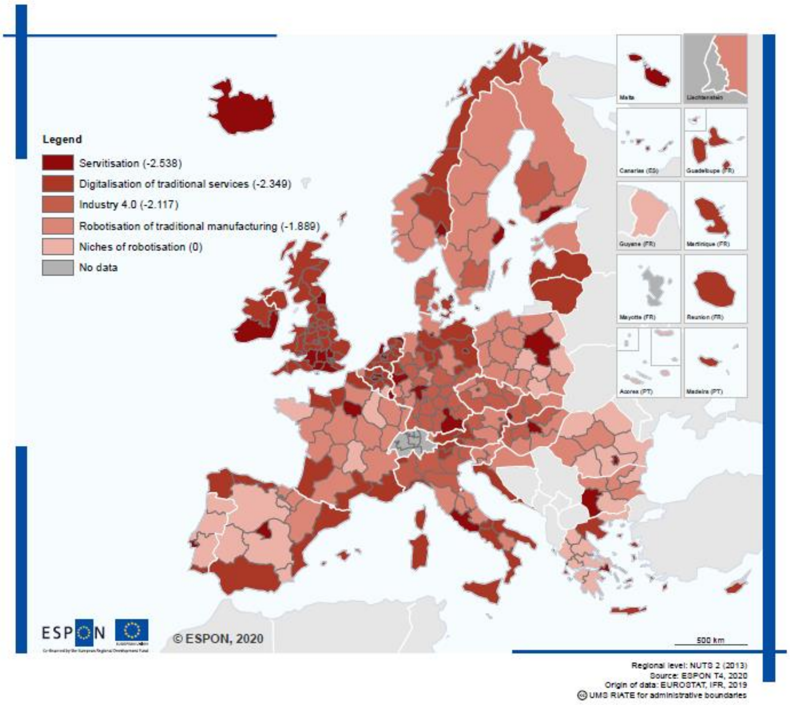
5 Social impact of technological transformation in the technology adoption domain

This section presents **the impact of technology adoption on the labour market obtained through the estimation of new appropriate econometric models**. Starting with the impact of technology adoption on the employment level, it seems that only **the adoption of robots in 'technology' sectors generates a negative impact on employment level** in both periods and regardless the transformation pattern taken into consideration, suggesting that **robots replace**

jobs when adopted in technology manufacturing sectors (Map 5.1 and Figure A.9.1, in Section 9 in Annex). **The adoption of robots and online sales in all other sectors does not seem to have a direct effect on employment levels**, in general.

This apparently unexpected result may be the outcome of several concomitant and opposite mechanisms taking place in regions: for example some occupations are more likely to be replaced than others by the new technologies. The adoption of new technologies can be especially harmful for some occupations and leave unaffected others; at the same time, new occupations can emerge and contribute to increase general employment levels. As a final outcome, the total employment level can be unaltered but this general picture can mask an heterogeneous impact of technology adoption on different groups of occupations. An important concern is, therefore, **what categories of jobs are more likely to be replaced and/or created by the introduction of robots and the Servitisation and/or digitalisation of traditional services**. In fact, 4.0 technologies differ from previous ones in their capacity to substitute not simply routine manual and cognitive jobs but also non-routine ones.[17] This important issue has been analysed by examining the impact of technology adoption on the share of employment in low-skill occupations and in high-skill occupations.

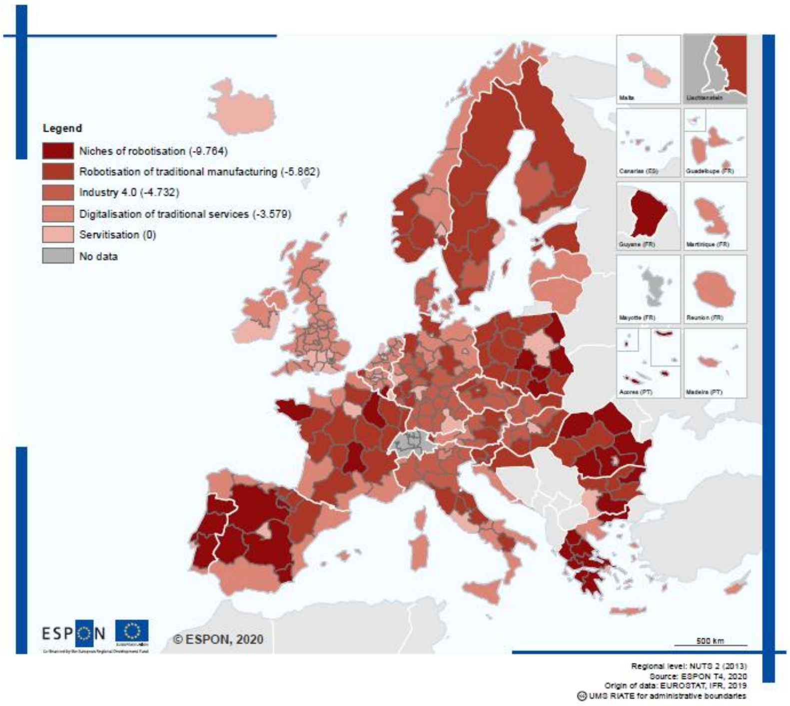
Map 5.1. Impact of robot adoption in 'technology' manufacturing sectors on employment level by type of technological transformation, 2013-2018



[17] For additional details see: http://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf, http://www3.weforum.org/docs/WEF_FOW_Reskilling_Revolution.pdf, http://www3.weforum.org/docs/WEF_Technology_and_Innovation_The_Next_Economic_Growth_Engine.pdf, https://www.eurofound.europa.eu/sites/default/files/ef_publication/field_ef_document/fomeef18002en.pdf, last visited 15/05/2020.

Starting with low-skill employment, opposite effects are at place when considering the adoption of robots and the implementation of online sales, regardless the period of time examined. **The introduction of robots in 'induced' sectors does displace low-skill jobs**. This effect is especially strong in manufacturing-related transformations, i.e. in Industry 4.0 and robotisation patterns (Map 5.2 and Figure A.9.2 in Section 9 in Annex). **The adoption of online sales, instead, generates an expansion of the share of low-skill jobs, a phenomenon commonly known as the rapid expansion of gig-jobs** (Map 5.3 and Figure A.9.3 in Section 9 in Annex). **This effect is pervasive across all regions, regardless their transformation pattern, highlighting complex intra-regional sectoral interdependencies**.

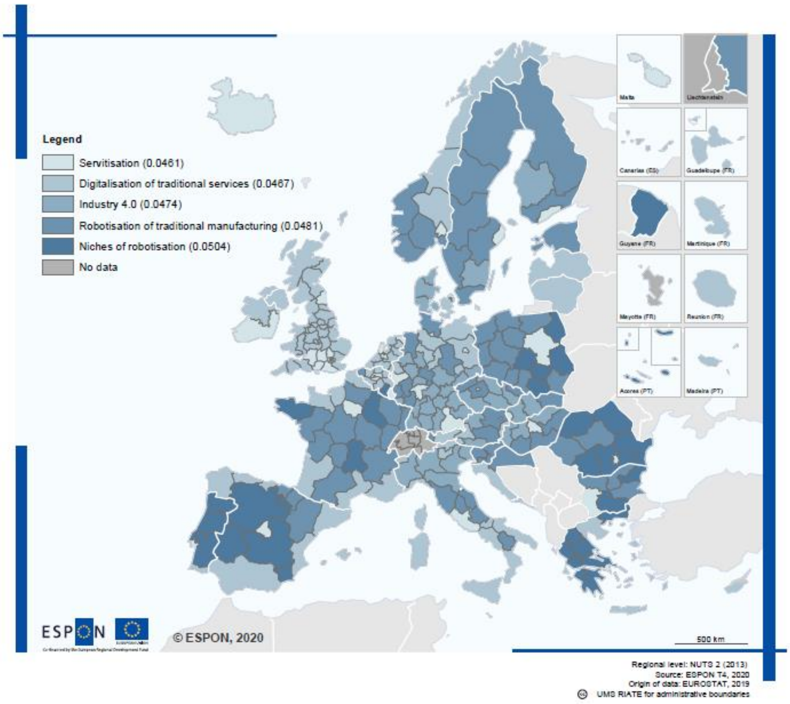
Map 5.2. Impact of robot adoption in 'induced' manufacturing sectors on low-skill employment share by type of technological transformation, 2013-2018



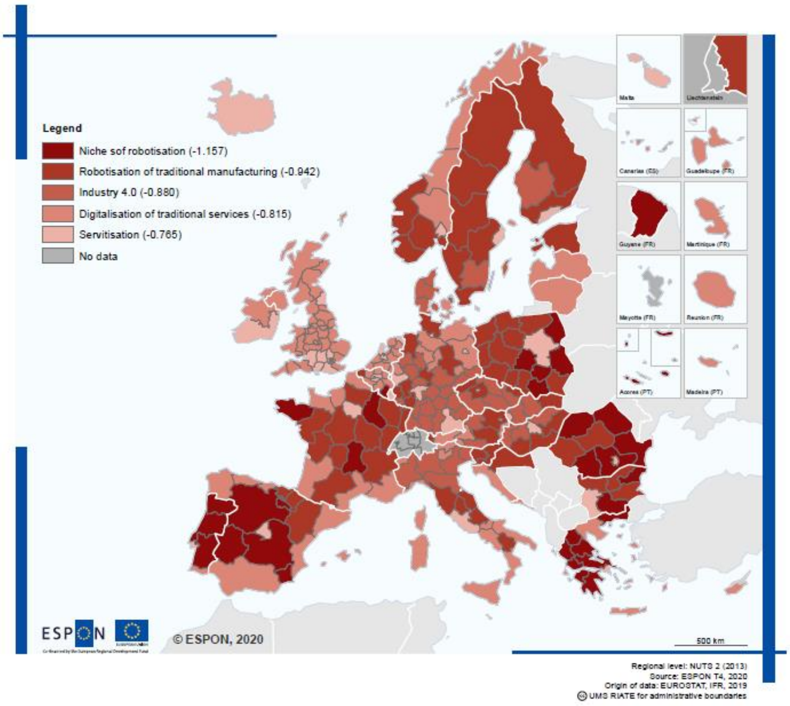
In the case of high-skill employment as well, opposite effects are at place when considering the adoption of robots and the implementation of online sales, regardless the period of time examined. **The introduction of robots in both 'technology' and 'induced' sectors displays also high-skill jobs**, **with an especially strong effect in manufacturing-related transformations**, i.e. in Industry 4.0 and robotisation patterns (Maps 5.4 and 5.5 and Figures A.9.4 and A.9.5 in Section 9 in Annex). This result confirms the potential of the new technologies to substitute also jobs that require a high level of skills and competencies and which are less routinised.

The adoption of online sales, instead, generates an expansion also of the share of high-skill employment, **leading to creation of élite jobs** (Map 5.6 and Figure A.9.6 in Section 9 in Annex). Coupled with an expansion of the share of low-skill employment and a nil effect on total employment, **this result highlights that the concomitant enlargement of the low-skill and the high-skill segments (i.e. gig jobs and élite jobs) comes at detriment of middle-skill jobs, a phenomenon commonly known as polarisation.**

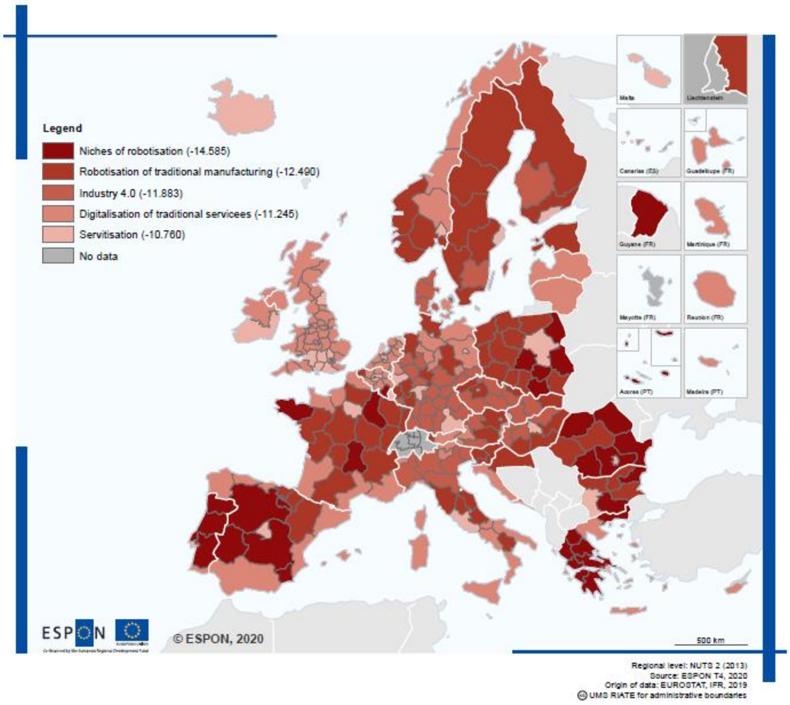
Map 5.3. Impact of online sales in 'induced' services on low-skill employment share by type of technological transformation, 2013-2018



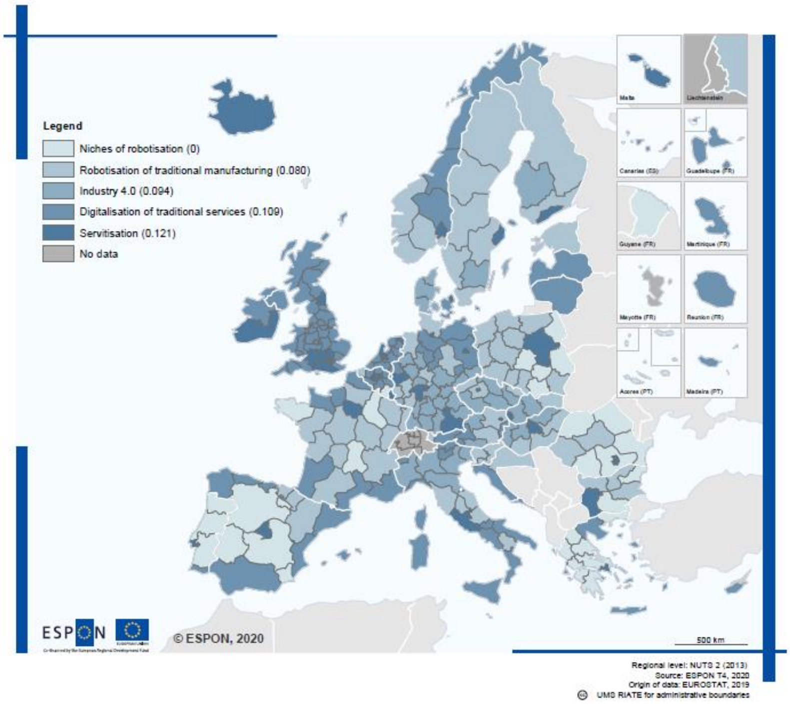
Map 5.4. Impact of robots adoption in 'technology' manufacturing sectors on high-skill employment share by type of technological transformation, 2013-2018



Map 5.5. Impact of robots adoption in 'induced' manufacturing sectors on high-skill employment share by type of technological transformation, 2013-2018



Map 5.6. Impact of online sales adoption in 'induced' services on high-skill employment share by type of technological transformation, 2013-2018

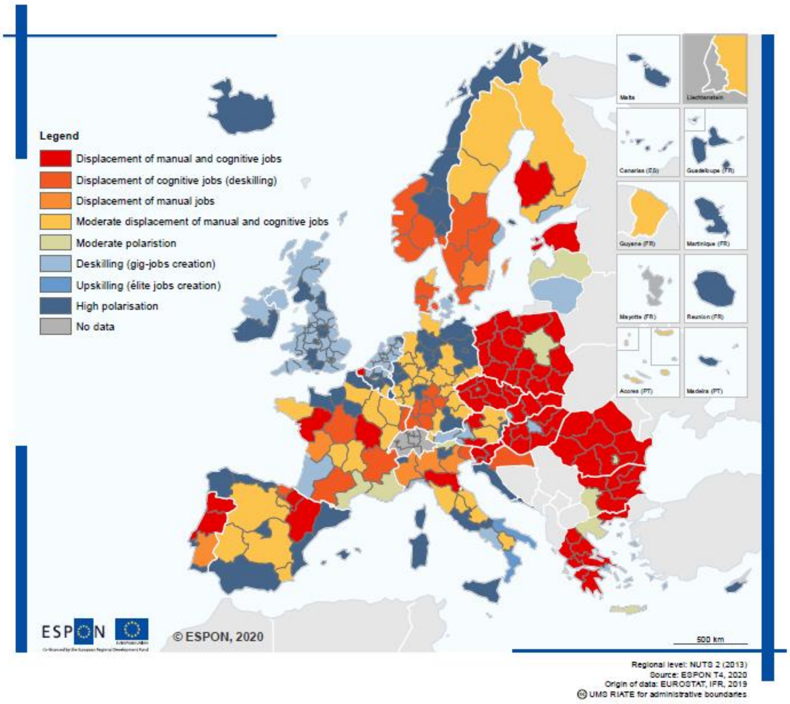


Across regions belonging to the same technological transformation type, **the adoption of the technology specific to each transformation type does not generate the same impacts on low-skill and high-skill employment; such impacts may vary according to the intensity of technology adoption**. Map 5.7 classifies regions by the intensity of displacement and creation of both low- and high-skill jobs, imposing to each region the prevailing effect related to its type of technological transformation.[18] For what concerns **manufacturing-related transformation patterns,** regions show different processes in the labour market, namely:

- **displacement of manual routine jobs**, when the displacement of low-skill jobs is above the group average and that of the high-skill job is below the group average. Regions of this type are primarily concentrated in Northern Italy and some sparce regions in France, Portugal and Sweden;
- **displacement of cognitive non-routine jobs (deskilling)**, when the displacement of high-skill jobs is above the average and that of the low-skill job is below the group average. This effect is rather rare and happens mainly in France, Germany, Denmark and Sweden;
- **displacement of manual and cognitive (routine and non-routine) jobs**, when the displacement of low-skill jobs is above the group average and that of the high-skill job is above the group average. This situation characterises primarily Eastern countries, parts of Greece, Portugal, Emilia Romagna in Italy and some sparce regions in France and Scandinavian countries;
- **moderate displacement**, when the displacement of low- and high-skill jobs is below the group average. Regions of this kind are primarily concentrated in France, Germany, central Italy, central Spain and Scandinavian countries.

For what concerns **service-related transformation patterns**, Map 5.7 shows regions characterised by:

Map 5.7. Regional job creation and job displacement by skill level, 2013-2018



- **deskilling (gig-job creation)**, when the creation of low-skill jobs is above the group average and that of the high-skill job is below the group average. Regions of this type

---

[18] Map A.9.1 and Map A.9.2 in Section 9 of the Scientific report represent regional creation and displacement, respectively for high-skill and low-skill jobs.

are primarily concentrated in UK, the Netherlands, Belgium and the Scandinavian capital regions. In these regions the creation of a gig-economy is clearly at place, and can lead to a generalised impoverishment of skills of the labour force and to deskilling;

- **upskilling (élite-job creation)**, when the creation of high-skill jobs is above the average but that of the low-skill job is below the group average. Two such regions exists in Southern Italy, in which a general upskiling process seems at place;
- **high polarisation**, when the creation of low- and high-skill job is above the group average. Regions of this type are primarily concentrated in Germany, Southern Italy and some sparce regions in France, costal and Northern Spain, UK, Belgium. In this case, **polarisation of the labour market is taking place**, by squeezing the share of middle-skill jobs and by expanding both low- and high-skill ones;
- **moderate polarisation**, when the creation of low- and high-skill jobs are below the group average. Regions with such a dynamic in their labour markets are some sparce regions in France, Greece, and some capital regions in Eastern countries (Bulgaria, Romania, Poland and Latvia).

The overall picture is rather fragmented but some general conclusions can be achieved:

- in **service-based transformation patterns**, the prevailing outcome is **one of either deskilling and high creation of gig-jobs or polarisation**; upskilling is unfrequent and only a few regions experience limited impacts, primarily capital regions in Eastern countries;
- in **manufacturing-based transformation patterns**, high displacement of jobs (regardelss the skill level) is taking place in Eastern regions. In the other cases, high displacement affects either low-skill jobs or high-skill ones. In western countries, however, the largest group is composed of regions with low displacement of jobs.

These results are further analysed in greater details in the analysis of case studies, presented in the next section.

Box 5.1. Social effects of technological transformation

- **Only the adoption of robots in 'technology' sectors generates a negative impact on employment level.** The adoption of the other types of technologies does not seem to have a direct effect on employment levels, in general.
- **Robots replace both low- and high-skill jobs.**
- **The adoption of online sales increases the share of low-skill jobs, i.e. gig-jobs, as well as of high-skill jobs; i.e. élite jobs.** This process compresses middle-skill jobs, leading to polarisation in the job market.
- **Élite jobs' creation takes place in a much more limited number of cases with respect to the gig-job phenomenon.**
- **The effects of robot adoption figure prominently in manufacturing-based transformation patterns,** while the **effects of online sales adoption are pervasive across all transformation patterns.**
- **The effects of online sales adoption have a positive effect on employment, and thus GDP, but not on productivity.**

6 Main case study results

6.1 Estonia

The Estonian case examines the metal-processing sector of the Northern region and the wood-processing sector of the Southern region. These two case studies therefore tackle a manufacturing related transformation, one in an 'induced' sector (metal-processing) the other in a ‘carrier’ sector (wood-processing). Furthermore, there have been no explicit policies targeting digitalisation in the analysed sectors and digitalisation agenda in Estonia, being ICT treated as a horizontal issue (Table 6.1).[19]

When examining 4.0 technology adoption, Estonian sectors use digital technologies from foreign suppliers and **there is little evidence that Estonian 4.0 technologies are in wide-spread use**; however, Estonian businesses are manufacturing 4.0 technologies for international markets. Furthermore, **the demand for higher technological standards is also driven by foreign and not local customers**. In terms of types of technologies being adopted, the wood-processing sector in the Southern region and metal-processing sector of the Northern region have adopted ERP systems, digital supply chain systems, digitised machinery and production lines and some robots. However, **the metal-processing sector has been less successful in the wider adoption of such practices unlike the wood-processing sector which has achieved a larger share of more digitally advanced firms**.

The regional preconditions do not play a significant role when determining 4.0 technology adoption. On the surface, the Northern region shows stronger potential for 4.0 technology adoption with a robust digital infrastructure supported by the presence of foreign-owned large manufacturing corporations. The Northern region has a significantly better developed information/knowledge infrastructure (trade fairs, seminars, conferences) and an ICT cluster located in the Northern region is also actively promoting 4.0 technology adoption. Despite this, **the analysed metal-processing sector has traditionally been a rather low value-added sector without significant signs of 4.0 technology adoption, focusing primarily on the local market**. On the other hand, the Southern region is an example of how remote areas can use digitalisation to boost international competitiveness. The wood-processing sector shows better 4.0 technology adoption results because the mainly internationally-driven demand for goods requires businesses in the sector to adopt the latest technologies to compete in the international market. The established wood-processing cluster in the Southern region has been very successful in facilitating digitalisation and gaining a good position on international markets (especially in Nordic countries) with firms exporting finished goods with higher value-added. Wood-processing also has a positive spillover effects onto related sectors (i.e. manufacture of furniture, wood-based biofuel).

The introduction of 4.0 technologies has also resulted in a growing demand for high-skill workforce, particularly people with sufficient ICT and sector-related competences. **This places the pressure on HEIs, especially universities of applied science to produce managers with sector-specific digital competences**. However, it is currently the case that student graduates are not interested in employment in either the metal-processing or wood-processing sectors, even if employment is linked to digital skill use.

---

[19] For detailed results of all case studies, see the case study Annexes A and B.

Overall, the adoption of new 4.0 technologies is much stronger in the Southern wood-processing sector and this has translated into an increase in high-performing and digitally advanced firms and higher value-added finished goods when compared to the metal-processing sector in the North. Furthermore, while the internationalisation is benefitting the wood-processing sector, in the Northern region it has been a source of growing divide between large subsidiaries of foreign manufacturing companies (favouring digitalisation) and local SMEs (non-digitalising). The developments in the wood-processing sector related to digitisation and automation echo the general pattern of business dynamics and productivity trends in Estonia and many other Eastern European countries: micro-enterprises, low productivity and low R&D intensity, shortage of skills even for less advanced/more manual jobs, and therefore lower value-added. In addition, exports are dominated by semi-finished goods. This is a typical structural problem of Eastern European transition economies, which integrated into the Western European production chains mainly as subcontractors or host countries of foreign-owned assembly lines. Within this context, the proximity of Estonia to the Scandinavian markets and the ability of Estonian wood-processing sector to upgrade the standards and develop its own industrial capacities is a good success story.

Table 6.1. Summary and comparison of Estonia case studies

<table>
<tr><td>Analysed sectors</td><td>Metal-processing sector in the Northern region</td><td>Wood-processing sector in the Southern region</td></tr>
<tr><td>Key drivers</td><td>The metal-processing sector is characterised by low value-added businesses that are generally not adaptive towards 4.0 technologies. Adoption of 4.0 technologies is primarily the interest of large companies that are utilising digital supply chain systems, digitalised machinery and production lines.</td><td>International demand for Estonian wood-processing businesses necessitates adoption of new technologies to maintain competitiveness. Furthermore, businesses in the sector primarily adopt foreign made 4.0 solutions. Businesses are primarily interested in digital supply chain systems, digitalised machinery and production lines.</td></tr>
<tr><td rowspan="2">Key barriers</td><td colspan="2">Student graduates show less interest in more traditional sectors even if such employment opportunities are aligned with digital technologies. There is a lack of policy support for 4.0 technologies adoption. While digitalisation agenda in Estonia treats ICT as a horizontal issue no specific linkages with Industry 4.0 are notable. Local manufacturers either are unable to supply 4.0 technologies or are more interested in international markets.</td></tr>
<tr><td>SMEs in the metal-processing sector lack capacity or willingness to adopt 4.0 technologies.</td><td>Concerns expressed about 4.0 technologies negatively impacting employment (loss of jobs due to automation).</td></tr>
<tr><td>Key impacts</td><td>Because of low interest in 4.0 technologies, there are few identifiable impacts. Large companies see growing demand for high-skill workforce, particularly with ICT competences.</td><td>In wood-processing sector there has been a growth in innovative higher value-added businesses that employ 4.0 technologies. These have allowed wood-processing businesses to enter international markets. The introduction of 4.0 technologies is driving the demand for high-skill workforce.</td></tr>
<tr><td>Key messages</td><td>The metal-processing sector in the Northern region would benefit from facilitating linkages between businesses. This would create within-sector demand for SMEs to digitalise and the spill-over effects from larger international (more digitalising) companies to SMEs would reduce the gap between local and international businesses.</td><td>In wood-processing sector 4.0 technologies allowed establishing competitive positions in international markets and show potential for spill-over effect to related sectors. However, technology transformation creates a higher risk of job losses due to automation. Thus, adoption of 4.0 technologies has to go together with training programmes to reduce unemployment risk.</td></tr>
</table>

6.2 France

The Pays de la Loire region[20] is the third-ranked manufacturing region in France, with productive capacity structured around a core network of medium-sized companies. Auvergne – Rhône-Alpes region is the first French region in terms of manufacturing jobs and boasts a diverse business environment with strengths for Industry 4.0 and high R&D expenditure. Both regions are benefitting from "French Fab" label which is an instrument designed to promote business activities among students and graduates and is designed to be a complete support system for manufacturing companies, SMEs and mid-caps, in terms of innovation and digitalisation (Table 6.2).

Table 6.2 Summary and comparison of France case studies

Analysed sectors	High-tech sectors in the Pays de la Loire	Automotive sector in Auvergne–Rhône-Alpes region
Key drivers	Strong policy support for Industry 4.0 nationally and regionally. Notable is the French Fab label – an instrument designed to support and promote excellence that has been awarded to both regions.	
	Regional focus on local value chains and locally produced solutions to drive Industry 4.0. Furthermore, high-tech sectors benefit from robust R&D infrastructure and favourable conditions for the creation of start-ups.	The strongest enablers for the 4.0 technology adoption are the Transpolis lab dedicated to urban mobility, and Pavin - a platform dedicated to smart vehicles.
Key barriers	Pays de la Loire region is experiencing a skills+ shortage in the workforce which is limiting companies in their development projects.	Auvergne–Rhône-Alpes region faces concerns related to the ICT skill gap in the workforce, particularly evident in SMEs. Furthermore, the SMEs show considerably less interest in 4.0 technology adoption, despite existence of support measures targeting SMEs.
Key impacts	High-tech companies have reported an increase in revenues after the adoption of 4.0 technologies. The regional value chain means that regional businesses both drive the demand for 4.0 technologies as well as provide the supply. It also enables a more focused approach towards region-wide technology transfer.	In Auvergne – Rhône-Alpes companies work with education institutions to develop curricula to support 4.0 technologies. A division is forming between large companies that are adopting 4.0 innovations and SMEs that lack interest in technological transformation, despite the existence of regional support measures for SMEs.
Key messages	Pays de la Loire is an example of how high-tech sectors can benefit from technology development that is grounded within the regional territory making the supply of 4.0 technologies close to regional companies.	Auvergne-Rhône Alpes is on track for regional companies to achieve strong European market position as a result of technological transformation. However, the region still faces concerns regarding SMEs that are not as interested in 4.0 technologies.

The high-tech sector of Pays de la Loire benefits from the strong culture of business collaboration which creates a regional value chain and allow for a self-sufficient regional Industry 4.0 to emerge. It is one of the only regions in France that has all the solution providers in its territory. It should be noted that compared to other European regions the degree of regional specialisation in manufacturing 'carrier' sector is rather high in the Pays de la Loire region. The same applies to the degree of regional specialisation in manufacturing 'induced'

---

[20] This region is part of the initiative Regions in industrial transition, https://ec.europa.eu/regional_policy/en/information/publications/factsheets/2018/pilot-action-regions-in-industrial-transition, last visited 02/07/2020.

sector. On the other hand, this is less the case in the manufacturing ‘technology sector’ (see maps A.4.1, to A.4.3).The high-tech sectors further benefit from the networking of regional Techno campuses - shared R&D platforms that develop 4.0 technologies engaging in transfer of knowledge to the various regional actors. **The region is also regarded for its favourable conditions for the creation of start-ups, with many training courses in electronics, computer and information technology. However, ICT skill shortage among the workforce is becoming apparent and an increasing issue for high-tech industries**. **The Auvergne – Rhône-Alpes region also demonstrates a good level of cooperation among actors**. The strongest enablers for the 4.0 technology adoption in the automotive sector in Auvergne – Rhône-Alpes region are the Transpolis lab dedicated to urban mobility, and Pavin - a platform dedicated to smart vehicles. **The automotive sector has become increasingly important in the region, and is one of the main manufacturing employers. However, there is a shortage of employees with sufficient skills in ICT – particularly evident among SMEs which are starting to lag behind in terms of digitalisation**.

Expected impact of introducing new technologies in the Pays de la Loire region primarily concern competitiveness and attractiveness. **Importantly, high-tech businesses that introduced 4.0 technologies have reported an increase in their turnover in the following years**. Furthermore, the focus on regional value chain means that **digital transformation generates the development of new software, application or website development projects. This also results in businesses adopting 4.0 technologies are raising the demand for employees with high-tech skills with particular interest in research engineers**.

As for the automotive sector in Auvergne-Rhône-Alpes region **there are signs of growing division between large companies that are forging ahead in the adoption of 4.0 technologies and the SMEs which are lagging behind**. The regional economy has enough technology producers and measures to support SMEs in the process of adopting 4.0 technologies. However, while large companies are often interested in introducing the latest solutions to remain competitive, SMEs are less keen on adopting new technologies or innovating in general.

During the period 2008-2016, the Rhône-Alpes Region displayed a stronger specialisation in ‘technology’ manufacturing sectors with regard to the European average and a lower specialisation in ‘induced’ manufacturing sectors. As for services, both Rhône-Alpes and Auvergne were under-specialised in ‘technology’ and in ‘induced’ sectors (see Maps A.4.1. to A.4.6.). The introduction of 4.0 technologies often necessitated adopting firms to open new employment positions involving skills (i.e. additive manufacturing, robotics) that are currently in shortage. **Training programmes have been made available and local companies work with education institutions to develop new curricula**.

Overall Pays de la Loire is an example of how 4.0 technology development can be grounded within the regional territory making the supply of 4.0 technologies close to regional companies.

This leads to a more coherent approach to region-wide adoption of 4.0 technologies. As for Auvergne-Rhône-Alpes, the supporting actions aimed at automotive, transport and logistics sector should enable regional companies achieve strong European market position. **The future outlook of 4.0 technologies concerns SMEs which have been the slower adopters of new technologies**. It is expected that the large scale adoption of 4.0 technologies will create the market pressure making digitalisation a priority for regional SMEs concerned. The successful integration of SMEs will further strengthen the regional value-chain.

6.3 Poland

The Warsaw metropolis is a highly developed service region, increasingly oriented at foreign customers in business services. The economy of the Warsaw capital city region is primarily based on services and current technological transformation leads to further servitisation that combines digitalisation in service and a high entrepreneurial capacity (Mao 3.12). **The 'technology' sector engages in the development and application of ICT solutions based on big data and cloud computing, and to a lesser extent AI**. Comparatively, **the Podkarpackie Voivodship is a poorly developed manufacturing-agricultural region that nevertheless displays a significant export potential from several strong high-tech branches that have introduced 4.0 technologies to varying intensity**. This is evident when observing the fact that Podkarpackie is among the regios where a growth of new technological opportunities can be observed in the years 2010-15 when compared to 2000-2009 (Maps 3.1 and 3.2). New technologies are implemented (and to a lesser degree developed) in the manufacturing sector - mainly in aviation and automotive industries, where digital production plans, 3D-printing, inventory management or augmented reality are used. However, it should be noted that for both regions the links between academia and business are not well developed leading to lessened knowledge transfer and decreased capacity to accurately meet business demand for high-skill workforce (Table 6.3).

The regions display differences in the source of 4.0 technologies. In Warsaw the local demand drives the growth of local providers supplying relevant solutions. This has facilitated the growth of the advanced business services sector which is further driven by the development of the start-up ecosystem active in Industry 4.0. However, despite positive results, **Industry 4.0 in Warsaw (and Poland in general) is still facing challenges in wide-spread adoption. The main obstacles for implementation of innovations in enterprises sector include not only lack of basic knowledge but the strong national economy where businesses experience growth even without adopting innovation**. Thus, it becomes a challenge to incentivise such businesses to look into 4.0 technologies.

A consequence of growing 4.0 technology adoption is the demand for high-skill employees. In Warsaw this demand is being met through upskilling which has been noted as an important part of introducing 4.0 technology driven jobs. **Upskilling takes place mostly in enterprises, particularly SMEs, for which gaining new competences is crucial to improve their market position.** This process is mainly driven by private sector initiatives.

Table 6.3. Summary and comparison of Poland case studies

Analysed sectors	Advanced business services in the Warsaw region	Aeronautic and automotive sector in the Podkarpackie Voivodship
Key drivers	At the regional level, the Regional Smart Specialisation Strategies, while not directly mentioning Industry 4.0, support emergence of Industry 4.0 as part of horizontal dimension.	
	Warsaw is characterised by both a healthy demand from local businesses for demand for 4.0 technologies that is supported primarily through local supply from the start-up ecosystem active in Industry 4.0. Notably, there is a lesser presence of foreign-developed 4.0 technologies when compared to Podkarpackie and the high local demand is generating a positive effect on the growth of innovative SMEs. There is also a high supply of high-skill workforce to meet the demand for Industry 4.0 employment.	In Podkarpackie, the introduction of 4.0 technologies is driven more by internationalisation, both in terms of international supply as well as the of adopting international practices related to Industry 4.0 to maintain competitiveness. Furthermore, the introduction of 4.0 technologies is being viewed as a solution for the employment issues that are a growing concern for the sector.
Key barriers	Long-term issues of small collaborative efforts between businesses and HEIs which hinders knowledge transfer.	
	The main obstacles for emergence of Industry 4.0 is the strong national economy which has resulted in good economic indicators for businesses regardless of the level of technological innovation. Thus, businesses do not see the incentive to invest in adopting 4.0 technologies.	While interest and willingness to adopt 4.0 technologies is more common among foreign-owned companies or Polish-owned companies involved in international value chains, local SMEs show significantly less interest in the opportunities offered by 4.0 technologies.
Key impacts	There has been an observable increase in the number of employees in high-tech sectors in particular in the ICT sector. The process of upskilling is more evident primarily as in-house training programmes which are particularly evident in SMEs.	New technological solutions are expected to increase productivity and resolve problems associated with labour shortage. Industry 4.0 related employment is seeing increasing demand for high-skill staff with competences matching the needs of digital economy. There has been growth in collaboration with HEIs to facilitate curricula relevant to Industry 4.0. The actors introducing 4.0 technologies have also seen success in attracting specialists from outside the region.
Key messages	The future of 4.0 technologies relies on continued efforts to maintain the local supply of 4.0 technologies and high-skill workforce. Upskilling initiatives are a way to address the potential negative impact on employees. However, these are currently most evident as private initiatives, rather than publically supported ones.	The future of 4.0 technologies is particularly linked to the labour market. While Industry 4.0 is viewed as a solution to labour shortage, the introduction of 4.0 technologies needs to be performed in parallel to training. This will allow maintaining the current workforce while modernising the regional sector.

In Podkarpackie, businesses face a lack of local supply of locally produced 4.0 technologies and have to rely on international markets; overall, the region's science potential is not sufficient to develop 4.0 technologies on its own. However, **Podkarpackie region has had success in attracting students or graduates from outside the region to both supply the high-skill employment positions as well as introduce new technology suppliers**. Furthermore, Podkarpackie has seen positive evidence in the development of the SMEs through linkages with international companies as well as cluster initiatives. This internationalisation is evident in the automotive sector. **New 4.0 technology solutions allow enterprises to meet international demand and expand their operations into global value chains**. Those companies that fail to adapt in time risk the loss of the global subcontractor position. Industry 4.0 related employment faces increasing demand for high-skill staff with competences matching the needs of digital economy. Notably Podkarpackie faces greater risk of insufficient high-skill workforce which may delay or impede the positive effects of the technological transformation.

Overall, the future of 4.0 technologies is particularly linked to the labour market. In both regions industry expects that introduction of larger automation will help address problems with general staff shortages. However, this is also linked to uncertainty regarding the long-term perspective and potential negative impacts on the labour market (reduction of low-skill jobs resulting in unemployment growth). Thus, 4.0 technologies need to be introduced in parallel to training, upskilling initiatives to still maintain the existing employees rather than risk losing them in a labour market that is already characterised by a shortage of workers.

6.4 Slovakia

Bratislava is among the most developed regions of the EU, with high GDP per capita; however, it features very low innovation activity compared to regions with similar economic performance in other countries. The Eastern Slovakia region is the second largest region in Slovakia in terms of size and population and the most underdeveloped region. **The Bratislava region is characterised by concentration of branches of large international companies that are the primary drivers of 4.0 technology adoption**. On the opposite side, **Eastern Slovakia has a smaller number of internationally owned companies as well as low technological and educational level and limited innovation capacities**. Thus, considering that internationalisation is a key driving force for 4.0 technologies adoption, their deployment is rather different between the two regions (Table 6.4).

Table 6.4. Summary and comparison of Slovakia case studies

Analysed sectors	Automotive sector in Bratislava region	Transport and logistics sector in Eastern Slovakia region
Key drivers	Internationalisation is the primary driver of technological transformation. For Bratislava, the automotive sector features a concentration of international companies that are the main drivers in introducing 4.0 technologies in Bratislava-based plants.	For Eastern Slovakia, the adoption of 4.0 technologies is more reactive, based in changing demand from international customers. Businesses have to adapt to evolving international pressure or risk losing market position.
Key barriers	The supply of 4.0 technologies is external ti the region as none of the relevant solutions (for the analysed sectors) are developed in the country. Lack of high-skill workforce is also felt thought to a lesser extent in Bratislava. Lastly, there is no policy support for Industry 4.0 in either region.	
Key impacts	In the automotive sector, 4.0 technologies are focused on production aspects in order to maintain competitiveness. 4.0 technologies are recognised as being essential for further growth in productivity, efficiency and savings. Furthermore, the automotive sector has a significant impact on its supply sectors. Because of technological transformation there has been a growing need for ICT specialists. Companies have been investing in in-house training to improve the skills of their employees to match the needs of 4.0 technologies.	For the logistics and transport sector, Industry 4.0 has primarily allowed to expand into new, international markets and enter international value chains. This has resulted in higher demand for workers.
Key messages	Internationalisation will continue to play a major part in technological transformation. In the automotive sector businesses expect further growth on the demand for digital skills such as in maintenance of new technologies or in the integration of information systems. There is a reliance on international 4.0 solutions but the sector would benefit from growth of locally produced 4.0 technologies which is regarded as an advantage by international companies.	Growing integration into international supply chains will continue to play a leading role for Industry 4.0 in the sector. The challenges facing the sector are primarily connected to demand for employees with sufficient ICT skills. There are also opportunities linked to supporting emergence of local 4.0 technology providers which are generally regarded as an added strength to businesses that can benefit from more readily-available, regionally-produced solutions.

The automotive sector in Bratislava has been experiencing an intense introduction of 4.0 technologies. Their primary usage is connected to robotics and automation processes in production. The vast majority of technologies are purchased from technology providers that are large multinational corporations. **As for the Eastern Slovakia region, the adoption rate of 4.0 technologies in the transportation and logistics sector is rather low with businesses mostly utilising ready-to-use technologies from international suppliers**. Companies in the Eastern Slovakia are mainly responding to the changing customer needs or regulation in the logistics and transport industry.

For both regions, the emergence of Industry 4.0 is hampered by the fact that none of or relevant 4.0 technologies are manufactured regionally. Furthermore, **a common feature of both regions is the lack of sufficient skills among the workforce to meet the demand in the analysed sectors**. While digital skills are higher in Bratislava, the automotive industry is still experiencing shortages for Industry 4.0 related employment. For Eastern Slovakia, the problem is further hampered by the drain of qualified workforce.

The economic transformation made possible by 4.0 technologies is strongly influenced by the structure of the sector. Because the automotive sector in the Bratislava region has a very high share of internationally-owned plants, the transformation is driven by demands from the parent company. Currently, this translates into a focus on production aspects (more flexible production, smooth and more accurate production, higher ICT skills) with the aim of maintaining competitiveness with other plants within the company. **The key factor is the quality of the workforce and especially its ICT skills. Companies are investing heavily in ICT education and in-house training to improve the skills of their employees**. Conversely, **in Eastern Slovakia the logistics and transport sector see new market opportunities**. **By adopting 4.0 technologies, regional companies have gained the capacity to expand the customer base outside Slovakia and at a higher level of value chain**. However, **the greater extent of transformation is likewise hampered by lack of ICT specialists**.

It is recognised in both the automotive and the transport and logistics sectors that 4.0 technologies are essential for further growth in productivity and 4.0 technologies are a key area for additional efficiency, savings and quality. When considering spill-over effects, the different impact in both regions results mainly from the fact that while automotive is the ‘carrier’ sector, logistics is an ‘induced’ sector. Thus, there is no evidence that introducing 4.0 technologies in the logistics sector impacted other sectors. However, **the automotive industry has a significant impact on its supply sectors**. However, the high deployment of robots in the ‘carrier’ sector in the Bratislava region, one of the highest in Central and Eastern Europe (Map 3.5), was not transformed into the deployment of robots in the ‘induced’ or in the ‘technology’ sectors. In both cases, mainly because they contain a small share of FDI, which is located in the ‘carrier’ sector and rather forms a kind of dual economy in the region without significant spillovers to other sectors. Overall, Bratislava’s automotive sector as well as transport and logistics sector of Eastern Slovakia are **an example of how Industry 4.0 is driven by**

internationalisation. The demand for 4.0 technologies in both regions is primarily satisfied through international sources. **For the automotive sector, 4.0 technologies are introduced as part of the agenda driven by multinational companies aiming to maintain competitiveness. For the transport and logistics sector, 4.0 technologies allow entering more advanced value chains and expand the international market**.

The development of Industry 4.0 is expected to continue along the existing path. In both sectors, businesses expect further growth on the demand for digital skills such as in maintenance of new technologies or in the integration of information systems. This will result in a demand for new on the job trainings and potential changes in formal educational system. However, **support should be given towards an emergence of local 4.0 technology providers which are generally regarded as an added strength to businesses that can benefit from more readily-available, regionally-produced solutions**. The case of automotive sector suggests opportunities linked to a more robust local supply of 4.0 technologies which is considered an advantage by international companies. **Strengthening local development (and local supply) of 4.0 technologies would have a positive effect on adopting sectors. Such providers are still lacking in both regions**.

6.5 Spain

Catalonia has a well developed business environment composed of a broad network of family-run SMEs in mature sectors, combined with a number of large multinational firms. **A significant part of services is connected to tourism supported by ICT companies primarily concentrated in Barcelona. The Canarias economy has a strong orientation towards services which represent over three quarters of both GDP and employment**. In the Canary Islands, tourism is the main source of income and job creation. Digitalisation is driven by the ICT sector which is composed mainly of small and micro-sized businesses with a tendency to specialise in the tourism sector. In both regions, the tourism sector has adopted technological solutions such as online booking, e-marketing, etc. that primarily support effective use of data (both for tourists and providers) (Table 6.5).

Both regions have established public support programmes and initiatives that help the implementation of 4.0 technologies in the tourism sector. **Tourism strategic plans and programmes highlight the importance of the digitalisation of the sector for achieving these principles**. The ICT sector is seen as an important enabler of digitalisation with actions in both regions to support wider ICT solution adoption by tourism businesses. In Catalonia, this is seen in the Tourism & ICT cluster while in Canarias there is ICT Demonstration Centre for Tourism Innovation, both based on public and private sector collaboration. Furthermore, in both regions, the **education programmes related to tourism are under transformation for introducing ICT skills**. Despite these efforts, **the tourism sector in both regions is still characterised by a workforce with insufficient ICT skills and growing demand for ICT competences**.

Table 6.5. Summary and comparison of Spain case studies

Analysed sectors	Tourism sector in Catalonia	Tourism sector in the Canarias
Key drivers	The drivers for 4.0 technology adoption come from public support programmes and initiatives that help the implementation of 4.0 technologies in the tourism sector. The ICT sector further supports digitalisation of the tourism sector with actions facilitating this. In Catalonia, this is seen in the Tourism & ICT cluster while in Canarias there is ICT Demonstration Centre for Tourism Innovation,	
	In Catalonia, to meet the demand for ICT-skilled employees, training offers are created around innovation, digital transformation and digital marketing applied to tourism.	Canarias established the Valley Canarias, an innovation hub specialised in digital training, which is introducing training programmes related to digitalisation in tourism.
Key barriers	Growing demand in the tourism sector for new ICT skilled-employees continues to be an issue, despite growing number of training opportunities. Global tourism trends play a particularly important part as well (i.e. widespread increase of online booking platforms). This presents an international dimension where the tourism sector has to adapt to the changing trends to maintain competitiveness.	
Key impacts	4.0 technologies contribute towards emergence of new professional occupations in the tourism sector linked to ICT skills. However, growing digitalisation is also showcasing the importance of employment positions where technologies cannot offer direct solution (i.e. customer relations).	
	In Catalonia big data is being utilised to increase the knowledge of traveller flows and behaviour.	In Canarias, the introduction of big data is being used for better tourism promotion, personalised recommendations and tourism experiences in the islands.
Key messages	The regions benefit from locally developed 4.0 solutions, creating linkages between the ICT and the tourism sector. Furthermore, both regions have public initiatives that specifically link ICT and tourism sectors. The introduction of 4.0 technologies is expected to generate new employment opportunities concerning the monitoring, analysis or use of data. This will continue to strengthen the linkage between the tourism and ICT sector and further necessitate both training programmes and introduction of ICT curricula at the education system.	

With tourism considered a strategically important sector for the economies in both regions and the focus on local ICT initiatives targeting the tourism sector it is unsurprising that the introduction of **4.0 technologies is generating more economic activity and new job opportunities**. **This transformation is responsible for the emergence of new professional occupations in the tourism sector that are linked to ICT skills and both regions have seen growth in the digital competences of the workforce**. Despite this, **training programmes are a necessity to meet the demand in the tourism sector for IT-skilled employees**. In Catalonia, new training offers are created around innovation, digital transformation and digital marketing applied to tourism. In Canarias, the Valley Canarias, an innovation hub specialised in digital training, is also introducing training programmes related to digitalisation in tourism.

One of the drivers for 4.0 technologies is the widespread increase of online booking platforms which has changed the relationships between the sector and tourists. Changes in consumption patterns have translated in new business models emerging that are intrinsically connected to 4.0 technology usage. The digitalisation in the tourism sector has contributed to spread of P2P economy, especially in Catalonia. **The region is now looking into collecting, analysing and exploiting big data to increase the knowledge of traveller flows and behaviour to support the tourism sector in the region**. For example, Barcelona has analysed the international tourist consumption patterns through their credit card payments to analyse the expenses across the city. The use of big data in the case of Canarias is mainly used for better tourism promotion, personalised recommendations and tourism experiences in the islands.

Overall both regions benefit from public initiatives that create linkages between the local ICT and tourism sectors, facilitating the adoption of locally developed 4.0 solutions. **While the introduction of 4.0 technologies is expected to replace some traditional occupations in the sector it will also generate new employment opportunities concerning the monitoring, analysis or use of data**. Due to 4.0 technologies the tourism sector is expected to experience general growth in productivity and competitiveness. In relation to training in Catalonia, universities and research centres are working to promote digitalisation, prioritising implementation of 4.0 technologies in the sector. Thus, collaboration between the sector and universities will become more relevant in the forthcoming years.

6.6 Main common results from the case study analysis

The development of 4.0 technologies is highly differentiated among regions within the same country. This holds for both advanced and less advanced countries, and highlights the fact that **the process is not only due to national and institutional elements**.

Two main drivers emerge for the adoption of 4.0 technologies in the regions. The first is the r**egional sectoral specialisation backed up by regional suppliers for 4.0 technologies**. This facilitates regional/national Industry 4.0 value chains.

The second main driver is **internationalisation**, which emerges as either presence of international companies operating in the region (4.0 technology adoption is driven by decisions from the parent company) or presence of regional companies entering international markets (4.0 technology adoption is driven by market demand, pressure to adopt latest solutions in order to maintain competitiveness). This facilitates international Industry 4.0 value chains.

However, specific regional aspects affect the adoption rate in Industry 4.0 presenting new challenges. In particular, the **lack of specialised workforce is** common to all regions, especially in the manufacturing sectors. At the same time, **in less developed regions 4.0 technologies are commonly viewed as solutions to already on-going labour shortages**. While **in more developed regions 4.0 technologies are more commonly associated with increased efficiency, quality and revenues**.

In the end, adoption of 4.0 technologies is generally in its **very initial stage**. **Large potentialities for their exploitation still exist**.

7 Tailor-made policy recommendations

A technological transformation is definitely underway, and cannot be avoided. In front of such technology push, regions have to cope with the socio-economic transformations that accompany the technological revolution. The sooner territories decide to cope with such transformations, the better; learning processes are at work, even for simple technologies and transformations. They require time to generate the expected positive impacts. Moreover, a late adoption does not prevent from the costs of adoption and instead generates risks for territories of lock in a laggard position.

Policies, at both regional and urban level, have to support such transformation. Some lessons have been learnt from the results of the research, that can be helpful to suggest some policy recommendations.

1) The technological features of the 4.0 technological transformation are profoundly different in nature with respect to the 3.0 one. The innovative element does not lie in new basic technologies, as in the case of 3.0 technologies, but in a creative recombination of basic ones. This aspect opens the possibilities to obtain profits not only for incumbents and large firms, but for small and new firms, located also in laggard regions. Experimentation in the design of new policies, particularly in education and skills development are important for guaranteeing creative talents to emerge and for providing all actors and territories the chance to exploit market opportunities. **Policy measures should concentrate on supporting especially laggard regions the possibility to become the new islands of innovation, creating and stimulating the necessary creativity to occur**. In this sense, the launch of training programmes for professionals and entrepreneurs with relevant background is important, so to avoid outdated skills and competences in new 4.0 technologies (see Section 10 in Annex).

2) Much of the 4.0 technological transformation and penetration depends on the sectoral specialisation of the region. Each sector is, in fact, influenced by a particular technological transformation, by making use of and get advantages from specific 4.0 technologies. **Policies necessarily have to be tailored to the technological transformation present in the region**.

3) Complex technology transformations call for a blending between technological scaling up, experiment and utilisation of cutting-edge technologies, and business ideas in order to be exploited to achieve efficiency gains. **Policies have to be balanced among technological knowledge, new business opportunities and stimuli of new opportunities**.

4) Within the same transformation patterns, regions strongly differ in terms of adoption efficiency. This holds for both advanced and less advanced countries, and highlights the fact that the process does not only depend on national and institutional elements. In general, when there is a high adoption penetration, advantages take place. However, **a large potential exists for such technologies to display their effects in some areas, either because of unexploited technology adoption, or because of unexploited technology adoption efficiency**. These two situations call for completely different policy measures. **The first case requires soft policies (through best practice examples), able to support a better use of the existing technologies, the second case incentives for further adoption**.

5) As in the previous technological revolution, capital or large cities are the drivers of the technological transformation. Instead, differently from the past, the traditional dichotomy rich and technologically leading countries vs. poor and technologically lagging behind countries is no longer true. Countries like Italy is a major driver of technology adoption in the manufacturing

sector, together with Germany, while France is a leading country in the 4.0 technological transformation in the services. The impression is that national digital infrastructural and regulatory conditions have strongly influenced the national trend of adoption: **the degree of technological transformation, therefore, shapes, and is shaped by, institutional and policy contexts**.

6) The impact in a region is higher when the adoption relates to the technology typical of the transformation that characterises that region. This result is in line with all previous innovation processes, and with the recent Smart Specialisation Strategy adopted by the European Commission for the present programming period, which claims that a "one size fits all" policy is impossible to be designed for regions. This is also valid for the 4.0 technological transformation. **Policies are called to have a region-specific nature, according to the 4.0 technological transformation profile of the region**.

7) Best practices exist for each transformation. **Policies have to make the best use of such situations, and exploit them as pilot cases**. An efficient way to transfer the know-how from best practices, especially in the public sphere, is through **cooperation agreements among local institutions**. The "Oulu declaration cooperation on Digital Transformation and Smart Growth" is a good example in such respect.

8) **Policies should guarantee that Eastern countries are not left behind in this process**. This would be a mistake that all Europe would in the long run pay in terms of integration and cohesion. However, as the policy review has shown (see Section 11 in Annex), the aims of the existing policy measures are rarely those of overcoming adoption barriers in lagging regions**. 4.0 technologies should instead be interpreted as an effective way to solve underperformance of regions, and policy measures should be developed in such direction**.[21]

9) **Policies to support simple technology transformations (e.g. digitalisation of traditional services) should not only concentrate their attention to hard and soft infrastructure**. They rather should intervene so to develop a strategic adoption of new services to achieve new efficiency levels. This is especially true for the public sector, where **the support to adoption of 4.0 technologies should be oriented not to the pure digitalisation of traditional services, but should also solve needs of citizens, with a human (rather than technological) perspective**.

10) The impact on the labour market is present, and complex. Displacement of jobs is a trend in manufacturing related transformation, while creation of more gig than élite jobs characterises service-related transformations. Moreover, all case studies mention the lack of the right skills in the labour market. **Education and training policies – in the form of increase intake in HEI to**

---

[21] This conclusion well aligns with those from the EC (https://ec.europa.eu/regional_policy/sources/docgener/brochure/Industrial_transition_no_region_left_behind_en.pdf, lst visited 15/06/2020).

ensure future supply of Industry 4.0 professionals, of cooperation between universities and sectors in the design of curricula, of attraction of professionals from best practice regions and countries – are necessary actions to be undertaken. The priority should be to speed on digital skills for both young people and adults by updating the Digital Education Action Plan, as suggested by the political guidelines for the European Commission 2019-2024 (van der Leyen, 2019), in close alignment with existing inivitatives such as the European Institute of Technology strategy for the 2021-2027 period.[22]

11) The **substitution of jobs with technology calls for legislation for a coordinated European approach on the human and ethical implications of Artificial Intelligence**. In this respect, the proposal of the new President of the European Commissioner, Ursula von der Leyen, to develop a **new Digital Services Act** to upgrade liability and safety rules for digital platforms, services and products, **and achieve a Digital Single Market,** is well taken.

8 Recommendations for future research

The present research has requested large conceptual and data efforts. A conceptualisation of a complex phenomenon has been undertaken, and a large effort to analyse the effects of such complex phenomenon through the collection of new data – estimated when missing at regional level – has been applied. However, in both fields (data and analysis) still some work can be developed. **We suggest here recommendations for future research in both fields**.

For what concerns data, an effort should be made to obtain **technological adoption data at regional and sectoral level**. Our analysis has in fact shown that both dimensions, the sectoral and the regional ones, are necessary in order to grasp the complex phenomenon of the 4.0 technological transformation. The effort of Eurostat to produce DESI at national level should be definitely carried out also at regional and urban level if one really wants to monitor the phenomenon of 4.0 technological transformation.

Another important type of data that is still missing relates to **occupation at sectoral and regional level**. The existing European Labour Survey is unfortunately insufficient to produce data at 2-digit ISCO code at sectoral regional level. This type of information is fundamental to go more indepth in the effects of such technologies on the labour market.

From the conceptual point of view, a more indepth analysis should be developed on how the **positive and negative effects of technological transformation propagates through sectoral interdependence**, an aspect that was impossible to treat in this project. Moreover, this project focused its analysis on the private sectors. The public sector is a totally different case, since its technological transformation is independent from profitability gains and instead driven by efficiency and wellbeing of citizens. **An analysis of the public sector on its own would be**

22
https://ec.europa.eu/commission/presscorner/detail/en/ip_19_3849?utm_campaign=58cad4cb73a6a3222e021bde&utm_content=5d2739ed9c1b6f0001688b1c&utm_medium=smarpshare&utm_source=linkedin, last visited 15/06/2020.

important. Last, but not least, a more thorough analysis of the territorial elements behind best pratices of each transformation would be an additional step forward with respect to the present analysis.

9 References

BCG - The Boston Consulting Group (2015) Industry 4.0. The future of productivity and growth in manufacturing industry, April, available at https://www.bcg.com/it-it/publications/2015/engineered_products_project_business_industry_4_future_productivity_growth_manufacturing_industries.aspx, last visited on 6/3/2019

EPO (2017) Patents and the Fourth Industrial Revolution. The inventions behind digital transformation, European Patent Office, December

Evans P. and Gawer A. (2016) The Rise of the Platform Enterprise: A Global Survey, The Center for Global Enterprise

Freeman C. and C. Perez (1988) “Structural Crises of Adjustment, Business Cycles and Investment Behaviour”, in G.Dosi et al. eds. Technical Change and Economic Theory, London: Francis Pinter, p. 38-6

Perez, C (2012) Technology Revolutions and Financial Capital, Edward Elgar, Cheltenam, UK

Rullani F. and Rullani E. (2018), Dentro la Rivoluzione Digitale, Giappichelli Editore, Chieri (Torino)

Srnicek, Nick (2017) *Platform Capitalism*, Polity

Valenduc G. (2018) “Technological revolutions and societal transitions”, The Foresight Brief, #04 – April 2018, The European Trade Union Institute (ETUI), available at https://www.etui.org/Publications2/Foresight-briefs/Technological-revolutions-and-societal-transitions, last visited 6/3/2019

Van der Leyen U. (2019), My agenda for Europe. Political guidelines for the next European Commission 2019-2024, European Union, https://ec.europa.eu/commission/sites/beta-political/files/political-guidelines-next-commission_en.pdf

10 List of Annexes

Annex 1: Scientific report

Annex 2: Case studies – Annex A

Annex 3: Case studies – Annex B

ESPON 2020 – More information

ESPON EGTC
4 rue Erasme, L-1468 Luxembourg - Grand Duchy of Luxembourg
Phone: +352 20 600 280
Email: **info@espon.eu**
www.espon.eu, **Twitter**, **LinkedIn**, **YouTube**

The ESPON EGTC is the Single Beneficiary of the ESPON 2020 Cooperation Programme. The Single Operation within the programme is implemented by the ESPON EGTC and co-financed by the European Regional Development Fund, the EU Member States and the Partner States, Iceland, Liechtenstein, Norway and Switzerland.