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Inspire Policy Making with Territorial Evidence

T[4] – Territorial Trends in Technological Transformations

Applied Research

Final Report – Scientific Annex

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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)

1 The definition of technological transformation

Table A.1.1 Economy 4.0: Technology-driven transformation

General domains of 4.0 transformation	Technology invention domain	Technology production / adoption domain	
Transformation fields	***Transformation in technology markets***	***Transformation in manufacturing sectors***	***Transformation in services***
	Transformation in generation, appropriation and diffusion of new technologies	Transformation in organisation and connectivity of industrial and other business processes	Transformation due to new digital content creation and emerging of the platform economy
Economic transformation processes	Lower entry barriers in the technology market Winner takes all market Monopolistic competition (chances for small firms)	Industry 4.0 (Digitalisation of interconnected manufacturing environments, inter-company connectivity between suppliers and customers within the value chain)	Servitisation (Sharing economy, product-service economy and digital service economy)
Main actors involved in the transformations	Technology producing firms	Manufacturing firms (primary ICT' and 4.0 technologies' users)	On-line digital service providers (newcomers) New entrepreneurs responding to new demands
Economic effects	High profitability opportunities Higher gap in GDP distribution between profits and wages	Increase in efficiency through automation and interconnectivity New market niches	Emerging monopoly power due to network economies New market niches (new business activities widely spread across the economy, often self-employed)
Positive spatial economic effects	Increase in GDP and productivity in areas specialised in technology sectors High quality job creation	Increase in GDP and productivity in areas specialised in 'carrier' manufacturing sectors Job redesign and changing skill structure of the existing jobs	New business opportunities in both agglomerated and less developed areas Gig economy job opportunities Access to digital services in remote areas
Negative spatial economic effects	Too few leading regions Increased spatial polarisation in terms of technology production	Job losses in manufacturing production areas due to automation of routine and non-routine jobs Spatial polarisation of creative adopters	Displacement of traditional jobs and creation of gig jobs in urban areas Polarisation and casualization of work in urban areas 'A winner takes all' dynamics especially in knowledge economy areas

2 From conceptual definitions to empirical measurements: the logic

Transformation in the technology adoption domain calls for the identification, at regional level, of the two main technological transformations, Industry 4.0 and Servitisation.

These technological transformations are primarily a *sector-driven phenomenon*, and therefore call for a sector-driven approach. This statement does not refer to the trivial identification of Industry 4.0 transformation with the manufacturing sector, and of Servitisation transformation with the service sector; in fact, important spillover mechanisms are place across sectors within and/or across regions. More importantly, a sector-driven phenomenon refers to the differences among industries in terms of the inputs and technologies used as well as of the production structure; these elements strongly influence the profitability gains from technology adoption.

In particular, from a sectoral perspective, the potential gains and, thus, the probability of adoption can vary across sectors depending on the structure of the production process and, consequently, the intensity of use of specific inputs in the production process, whose use is especially advantageous in the new technological landscape.

In this respect, an important distinction can be made between sectors based on continuous vs a batch production process. Connectivity and interaction between parts, machines and people are capable to make the production system faster and more efficient and strengthen mass customization at peak levels. Robotisation of production processes takes place also in sectors characterised by continuous production systems (like the chemical and pharmaceutical industries); however, the increase in competitiveness and efficiency achieved in these sectors is expected to be more limited than in those characterised by batch production processes. In fact, the efficiency gains achievable by merging different production phases can be lower when production processes are already much integrated. Moreover, in sectors characterised by continuous production, the introduction of robotisation and automation require a limited reorganisation in the production chain with respect to what happens in the case of a batch production system.

Moreover sectors differ in the intensity of use of some key inputs, i.e. *key factor*, in a production process. According to Perez (2012), the *key factor* is that particular input factor which is affected at most in terms of cost abatement by the new technology. The intensity of the *key factor* makes the adoption of the new technologies rather appealing, rewarding and profitable. In the case of the 4.0 technological revolution, the *key factor* is the digital elaboration and transmission of big data, information, communication and texts. The degree of exploitation of such *key factor* differs among sectors, explaining the penetration level of the technologies and of the related transformations.

Based on these two intertwined critical elements – the production structure and the intensity of use of the *key factor* of economic sectors – sectors can conceptually be grouped into three main groups, as summarised in Figure A.1.1:

- technology sectors, representing those sectors where the new 4.0 technologies are mainly produced. Their market size depends on the rhythm of penetration of the new technology. They share a batch production structure and an intense use of *key factor* of the 4.0 technological revolution with the carrier sectors;
- carrier sectors, representing those sectors where the new 4.0 technologies are adopted, and partly also co-invented and/or produced. The high penetration rate of the technologies in these sectors depends on the intensive use of the *key factor* and on their batch production structure able to take full advantage of the technologies. They also represent the 'creative adopters' or 'user innovators', since they are adopters able to produce their own technologies and sell them on the market;
- induced sectors, representing those sectors that, because of their production structure, exploit the advantages of the technological change as a consequence of and complementary to the growth of the carrier sectors. Nonetheless, technological change can improve productivity also in these sectors.

Figure A.2.1. Logic and methodological steps

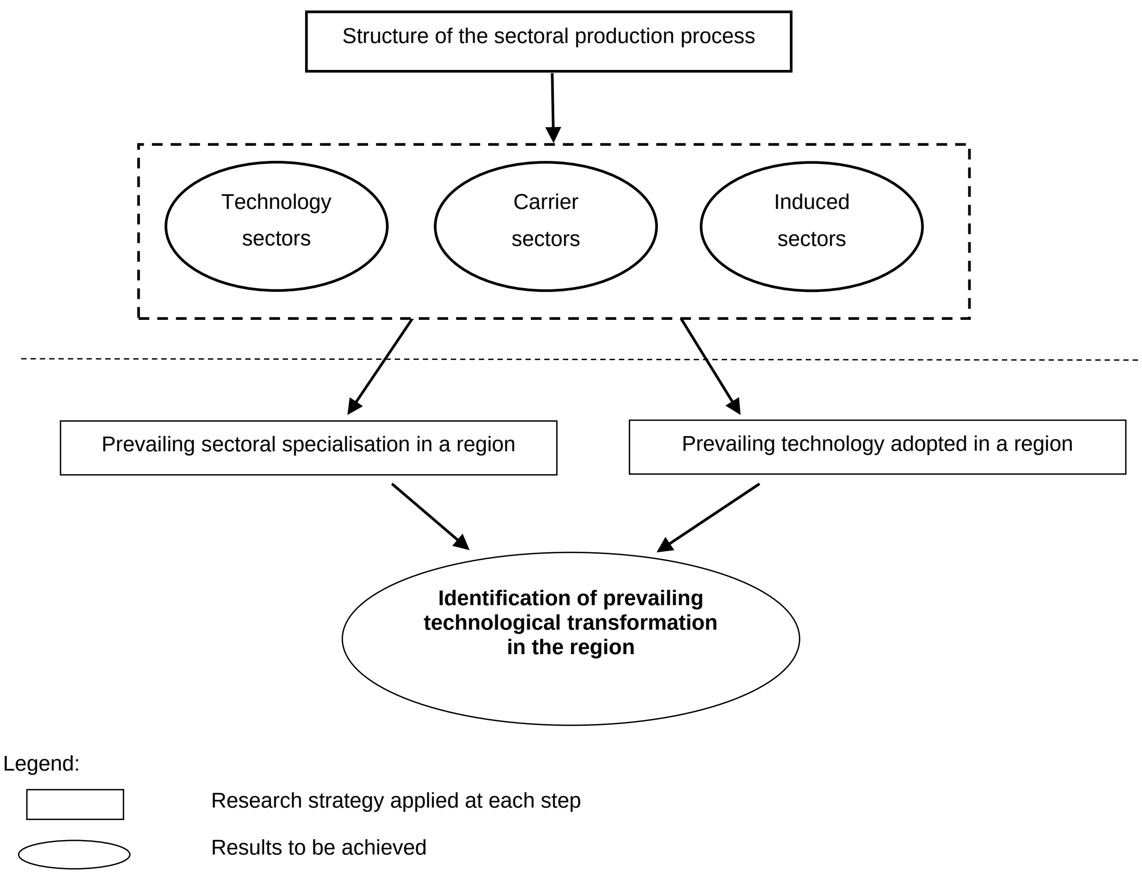


Table A.2..1 presents the characteristics that are associated to the groups of sectors in the manufacturing and in the service industries. Technology and carrier manufacturing sectors share similar characteristics, and, accordingly, are grouped together. They are identified as those sectors having typically a batch production where 4.0 robotisation and automation technologies are fully applied. Induced manufacturing sectors are instead characterised by continuous production and/or limited use of the *key factor*, i.e. digital communication and transmission systems. In the service sector, technology and carrier sectors are those sectors where new digital service are created and digital technologies deployed at large scale. In the service induced sectors, instead, the prevailing characteristic is that of a digitalisation of the service delivery.

Table A.2.1. Manufacturing and service sectors: critical elements behind the distinction into technology / carrier and induced sectors

	Manufacturing sectors	**Service sectors**
Technology / carrier sectors	Batch production Intense use of digital communication and transmission	New digital service creation
Induced sectors	Continuous production Limited use of digital communication systems	Digitalisation of service delivery

A sector-driven approach is vital for the identification of the presence of a certain technological transformation, but not enough to understand the prevailing transformation in regional economies. The same sector can in fact go through a transformation in a region and not in another, according to the local profitability of the technology adoption. This statement is easily comprehensible when the profitability of a technology is measured in terms of opportunity cost, like for example labour cost over cost of the investment in fixed capital. The same firm can find more convenient to adopt the technology only in those regions with high labour costs, producing instead with the traditional technology in other regions.

In this respect, the first step is to identify the presence and relevance of the three different sectors in each region, i.e. the regional sectoral specialisation, which highlights the potential presence of a technological transformation (Figure A.2.1). The sectoral specialisation is in fact a first necessary but not sufficient condition to signal the existence of a technological transformation. For this phenomenon to occur, the presence of sectors has to be accompanied with a high degree of adoption of 4.0 technologies in the three – technology, carrier and induced – sectors. Neither adoption, however, is a generic process; rather, it is highly dependent on the characteristics of the sector involved and is therefore differentiated for service and manufacturing as well as between technology, carrier and induced sectors within service and manufacturing, respectively.

Because the different sectors can coexist in regions, with different degree of specialisation and adoption intensity, a second important step is understanding the prevailing sectoral specialisation and technology adoption patterns of each region. Therefore, by combining the dominant regional sectoral specialisation and technological adoption, it is possible to identify the presence of technological transformations at the regional level and to classify regions according to their dominant technological transformation profile. It is in fact rationale to expect that the presence of specific sectors together with a high degree of exploitation of specific 4.0 technologies signal the presence of a certain technological transformation. In particular, it is reasonable that the Servitisation transformation primarily takes place in regions with a greater specialisation and adoption intensity in technology and carrier service sectors, which are at the core of this type of transformation. Similarly, Industry 4.0 transformation primarily takes place in regions with a greater specialisation and adoption intensity in technology and carrier manufacturing sectors, which are at the core of this type of transformation. However, there might be regions lacking such specialisations and high degree of adoption in core transforming sectors. Regions primarily specialised in induced service and/or manufacturing sectors, even if with a high adoption intensity, are likely to be exposed to less pervasive transformation processes, whose intensity weakens the lower the adoption intensity is.

The indicators developed to identify the different typologies of *transforming regions* in the adoption domain are detailed in Sections 4 and 5..

The exact methods applied to identify the different typologies of *transforming regions* in the adoption domain are detailed in Section 7.

3 Measuring the 4.0 technological transformation in the research and technology invention domain

3.1 The identification of 4.0 inventions

In order to measure the capability of regions to produce new ideas and inventions in the 4.0 technological fields, we stand in the general tradition of relying upon patent data analysis, i.e. the analysis of the technological content of patents. The 4.0 technological revolution is, in fact, driven by inventions in new fields and most of these inventions are patented, supporting the choice of using patent data as the primary source of information for studying the emerging technological trends.

The application of patent data analysis in the context of the 4.0 technological transformation, however, is confronted with a major bottleneck, which is the definition of the **exact technological fields pertaining to this new technological revolution**. The rapidly changing technological landscape has hindered so far any attempt to set and to identify specific technological boundaries and to achieve a codified and shared definition of 4.0 technologies.

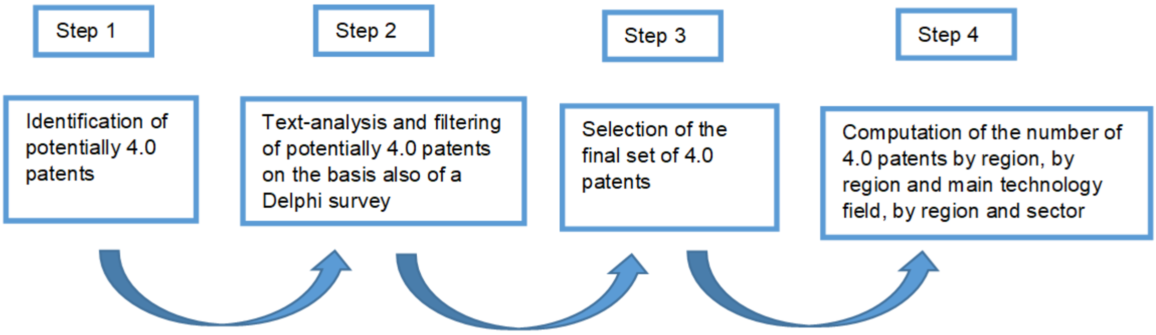
A specific methodology has therefore to be applied in order to identify the 4.0 technologies. A landmark study by the European Patent Office (EPO, 2017) represents an important progress in this respect and proposes a novel methodology for the identification of 4.0 technological fields.

The methodology developed by EPO consists of three main steps.

1. Patent examiners at EPO, which are in charge of assessing patent applications and thus have significant knowledge and expertise in the related technological fields, developed a cartography of 16 technological fields that can be defined as 4.0. They aggregated them according to three main, not mutually exclusive, dimensions: two of technological nature (core technologies and enabling technologies) and one describing the application field (application domain), (see Table A.3.1 for examples).
2. Patent examiners matched each of the 16 technological fields (Table A.3.1) to specific ranges of technology codes in the Cooperative Patent Classification (CPC) scheme (i.e. 320 CPC ranges). Next, they extracted all patents corresponding to those CPC ranges and performed full-text search queries, based on keywords and text-mining techniques. Finally, they identified the final list of patents that could be safely classified as pertaining to 4.0 technologies by filtering them by using keywords (hereafter, 4.0 patents).
3. Patent examiners finally re-assigned each identified 4.0 patent to one or multiple technologies of Table A.3.1, based on their respective CPC codes.

In this project, we follow EPO (2017)'s approach with the introduction of a few adaptations. Figure A.3.1 describes the logical chain driving the methodology to identify 4.0 patents in NUTS 2 and NUTS 3 areas belonging to ESPON countries.

Figure A.3.1. Step-by-step methodology for the identification of the generation of 4.0 technologies in ESPON regions



In this project, we followed the EPO's step-by step methodology, innovating in some steps. A first novelty we introduced in the EPO's methodology concerns **the textual analysis of patent documents** (step 2 above). Differently from the EPO (2017)'s study, the text analysis is going to be performed on the title, abstract, claims and descrption of patents (and not on the full text). More importantly, the filtering and final identification of 4.0 patents is based on **selected keywords, whose identification is the outcome of a Delphi study involving about 20 experts, including university professors, engineers and technology transfer officers**, asked to propose, validate and rate the importance of a group of keywords, as detailed below.

Table A.3.1 Overview of the main 4.0 technological fields

Main technologies	**Example**
Core technologies	
Basic hardware technologies	Sensors, advanced memories, processors, adaptive displays
Basic software technologies	Intelligent cloud storage and computing structures, adaptive databases, mobile operating systems, virtualisation
Basic connectivity systems	Network protocols for massively connected devices, adaptive wireless data systems
Enabling technologies	
Enabling the interpretation of information	Diagnostic systems for massive data
Enabling the display and input of information	User interfaces, virtual reality, information display in eyewear
Enabling the realisation of physical or simulated 3D systems of information	Additive manufacturing, 3D printers and scanners for parts manufacture, automated 3D design and simulation
Enabling the machine understanding	Artificial intelligence, machine learning, neural networks
Enabling the determination of the position of objects	Enhanced GPS, device to device relative and absolute positioning
Enabling intelligent power handling and supply	Situation-aware charging systems, shared power transmission objectives
Enabling the security of data or physical objects	Adaptive security systems, intelligent safety systems

Application domain including transport, energy and manufacturing	
Applications pertaining to the individual	Personal health monitoring devices, smart wearables, entertainment devices
Applications for the home environment	Smart homes, alarm systems, intelligent lighting and heating, consumer robotics
Applications for moving vehicles	Autonomous driving, vehicle fleet navigation devices
Applications for business enterprises	Intelligent retail and healthcare systems, autonomous office systems, smart offices, agriculture
Applications for industrial manufacture	Smart factories, intelligent robotics, energy saving
Applications for infrastructure	Intelligent energy distribution networks, intelligent transport networks, intelligent lighting and heating systems

Source: adaptation on EPO (2017)

In particular, we proceeded as follows:

1. raw patent data has been obtained from the OECD-REGPAT database for all ESPON countries covered by this database (about 1.4 million patents). Tte OECD-REGPAT database lists patents according to their technological content and the geographical localization (at the NUTS3 level) of their inventors from 1977 to 2015. More recent data, although interesting, are not fully reliable as patent data, unfortunately, suffers from problems of so-called right–truncation. Specifically, the number of patents reported in the OECD-REGPAT database in the most recent years (e.g. from 2016) is lower than in the previous ones, due to delays in the examination of applications and in their publication, raising warnings in their use.
2. We identified in the CPC scheme all possible CPC codes corresponding to the 16 technological fields identified by EPO (2017). There are 11139 such codes out of the 259840 present in the CPC scheme;
3. out of all the patents in the OECD_REGAPAT database, only those classified into the technological fields identified by EPO (2017) as potentially pertaining to 4.0 technologies have been retained (212.034 patents);
4. a textual analysis on the legal documents accompanying each of these patents was implemented in order to select those that can be safely identified as truly belonging to 4.0 technological fields[1] according to specific technological keywords.

The textual analysis, the most original part of our approach, required to collect and to the examine the patent document texts (i.e. abstract, title, description, claims). The latter were retrieved from the proprietary database ORBIT, available at Politecnico di Milano premises. The selection of the keywords to run the text analysis is clearly a crucial element of our approach since an inappropriate set of keywords could distort the result of the text analysis, leaving parts of the 4.0 phenomenon aside or inflating others.

The second novelty with respect to EPO methodology concerns the pool of experts consulted to obtain the list of keywords. In order to guarantee the monitoring of the most

[1] Despite numerous contacts and trials, EPO did not disclose the list of keyword used in their text analysis. This will probably lead to a different size and composition, though comparable, of the final sample of patents classified as pertaining to 4.0 technologies.

recent scientific and technological developments, **the experts interviewed were primarily scientists and not patent examiners as in the EPO study**. As a first step, we identified a *meta-expert* to name other experts as to guarantee a balanced choice of experts across the 16 4.0 technological fields identified by EPO. By applying a roaster-recall procedure, a final panel of 20 experts (primarily working in Italian universities and specialised in 4.0 technologies, as well as Technology Transfer Office representatives) was pooled and involved in the two-stage DELPHI study aimed to identify the final set of keywords. **This latter represents the third novelty of the methodology applied to identify the list of keywords**. In order to enhance the scientific quality of the selection process and to get a rigorous and complete representation of the 4.0 technologies in terms of technological keywords, **a two-stage Delphi study[2] was developed in order to obtain and validate the set of keywords to be applied**. The first stage included the implementation and administration of an online questionnaire in which the experts listed, for each of the 16 4.0 technological fields, the most relevant technologies and keywords to describe them. The second stage included the implementation and administration of an online questionnaire in which the experts rated the selected keywords on a Likert scale ranging from 0 to 5.[3]

The final outcome of the DELPHI study was a list of 434 technological keywords, each of them rated from 1 to 5, covering of all the 16 4.0 technological fields identified in EPO (2017). **Nearly half of these keywords (i.e. 196 keywords) were rated between 4 and 5, on average, and were then applied, after a careful expansion process, in the text analysis and matched with one or more patents**. This means that the text analysis was able to identify 4.0 patents belonging to all the 16 4.0 technological fields and that no significant bias is present in the analysis. Some examples of the the keywords' selection and expansion processare reported below in Box A1.

As a result, **out of the 212.034 potentially 4.0 patents identified in the first step on the basis of their CPC codes, 21.092 turned out to be real 4.0 inventions**; interestingly enough, the spatial, temporal and technological trends of the obtained database are consistent with the ones presented in EPO (2017).

Finally, by summing the number of patents in 4.0 technologies by region[4], and by region and by each of three main technological aggregates (i.e. core technologies, enabling technologies and

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[2] Generally speaking, the goal of the Delphi method is that of obtaining the most reliable consensus in groups of experts about a specific topic. This approach consists of an anonymous and independent consultation of experienced experts in the field of interest so that the opinion expressed by the participants are not influenced by external factors. Usually, the panel of experts is consulted more than once, in a series of sequential interactions.

[3] Both the first and the second stage were performed by means of web questionnaires and are reported in the in the Annex to the Inception Report.

[4] The attribution of patents to regions follows standard practice in the literature, consistent with EUROSTAT and OECD approaches. Specifically, the geo-referencing of patents is based on the address of inventors (i.e. the persons responsible of the invention) and not on that of the patent applicants (i.e. the holders of the intellectual property right). In most cases, in fact, patents are assigned to multiple inventors, whose addresses may correspond to different regions. In such cases, fractional counts by the region of

application domains and their combinations), it is possible to map the creation of distinct groups of 4.0 technologies at NUTS 2 regional level for all ESPON countries.

Box A.3.1. Examples of the technological keywords' selection and expansion process.

1. A keyword with a high score is not included in the final list because it represents a broad concept.
Original keyword: wireless; score 4
The concept is very important when it comes to connectivity and this is the reason for its high score (4/5). Nevertheless, this expression is not suitable for the text analysis, since it is too much general and could involve inventions that are not necessarily 4.0 in terms of technological content.

2. A keyword with a low score (<4) is included in the final list because it is relevant.
Original keyword: predictive maintenance; score 3
The keyword received a score of 3 in the second interaction but, given its relevance, it has been included in the final list anyway.

3. Expansion of a keyword: synonyms
Original keyword: autonomous car; derivative keywords: self-driving car; autonomous vehicle; self-driving vehicle

4. Expansion of a keyword: wording
Original keyword: 3-d printing; derivative keywords: 3 d print*; 3d print*; 3-d print*; three d print*; three dimensional print*; three-d print*
In this case, the same concept has to be linked to different new keywords in order to take into account all the wording possibilities. Sometimes we truncate the keywords so that we capture plurals and related keywords (e.g. print*, printing, printer).

3.2 Spatial trends in the research and technology invention domain

The analysis developed in Section 3.1 of the main report was expanded at the NUTS 3 level. In particular, we computed the 4.0 patent intensity (yearly number of patents per 1,000 inhabitants in a period of time) in European NUTS 3 regions in the periods 2000-2009 and 2010-2015 respectively.[5] A **clear trend of spatial concentration emerges**, with core areas in core countries and major cities in each country displaying the highest 4.0 patent intensity. The east-west and north-south divides are further confirmed also at the NUTS 3 level (Map A.3.1). By moving from the NUTS 2 level to the NUTS 3 level, interesting cases can be highlighted. For example in French NUTS 2 regions that did not show a high 4.0 patent intensity there are NUTS 3 regions of excellence exist (e.g. Lyon within Rhône-Alps). The second period (2010-2015), instead, shows **interesting dynamics in Eastern countries, through an increase of 4.0 patent intensity** (especially in Poland) in major urban centres and regions close to the western borders. At the same time, **a tendency of concentration emerges in urban areas of countries commonly considered as technologically advanced** (Map A.3.2).

Additionally, the analysis was expanded by focusing on the transport and energy technological fields. In this cases, the analysis has been carried out at the NUTS 2 rather than at the NUTS 3

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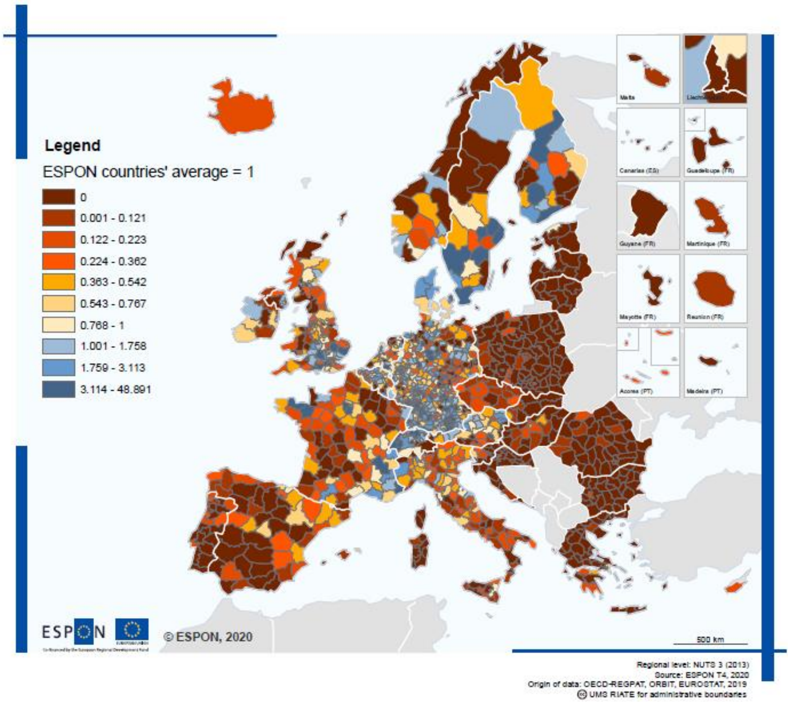
residence of the inventor(s) are computed, e.g. for a patent listing inventors from two different regions, each region will obtain a count of 0.5, to avoid double-counting of inventions.

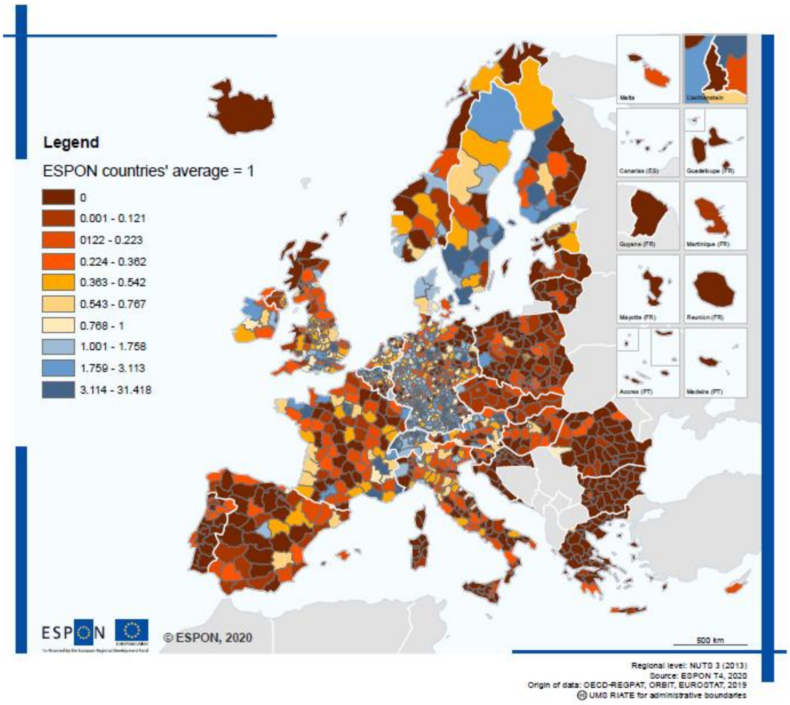
[5] The data are normalised with respect to the European average. Values greater than 1 are above the European average, and data below or equal to 1 are below the European average. Categories in Map 3.1 have been identified by decile; the same categories have been next applied to Map 3.2, in order to improve comparability and to simplify interpretation.

level as the largest majority of NUTS 3 regions would present nil patent activity in a single technological field.

Map A.3.1. 4.0 inventions, 2000-2009

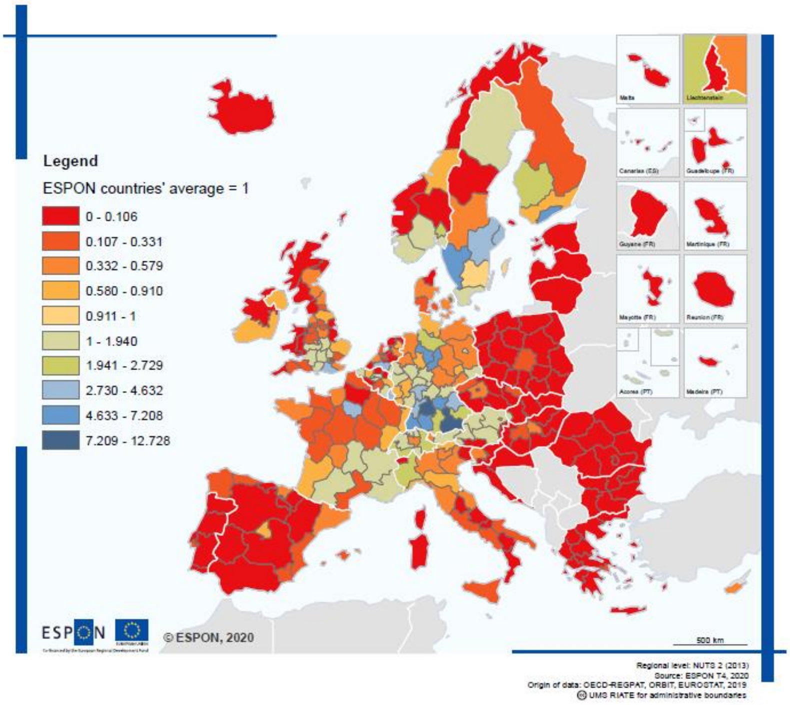


Map A.3.2. 4.0 inventions, 2010-2015

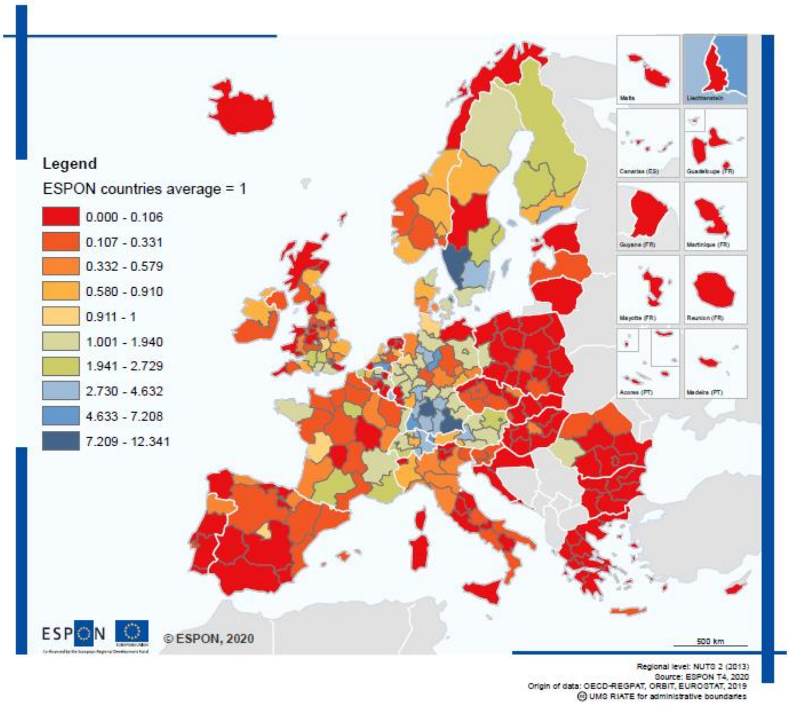


For the transport sector, we considered those patents dealing with technologies such as enhanced GPS, device to device relative and absolute positioning, autonomous driving, vehicle fleet navigation devices (see Table A.3.1). Maps A.3.4 and A.3.5 show the 4.0 patent intensity (yearly number of patents per 1,000 inhabitants in a period of time) in European NUTS 2 regions in the periods 2000-2009 and 2010-2015 respectively. For the energy sector, we considered those patents dealing with technologies such as situation-aware charging systems, shared power transmission, intelligent energy distribution networks, intelligent lighting and heating systems (see Table A.3.1.). Maps A.3.6 and A.3.7 show the 4.0 patent intensity (yearly number of patents per 1,000 inhabitants in a period of time) in European NUTS 2 regions in the periods 2000-2009 and 2010-2015 respectively.

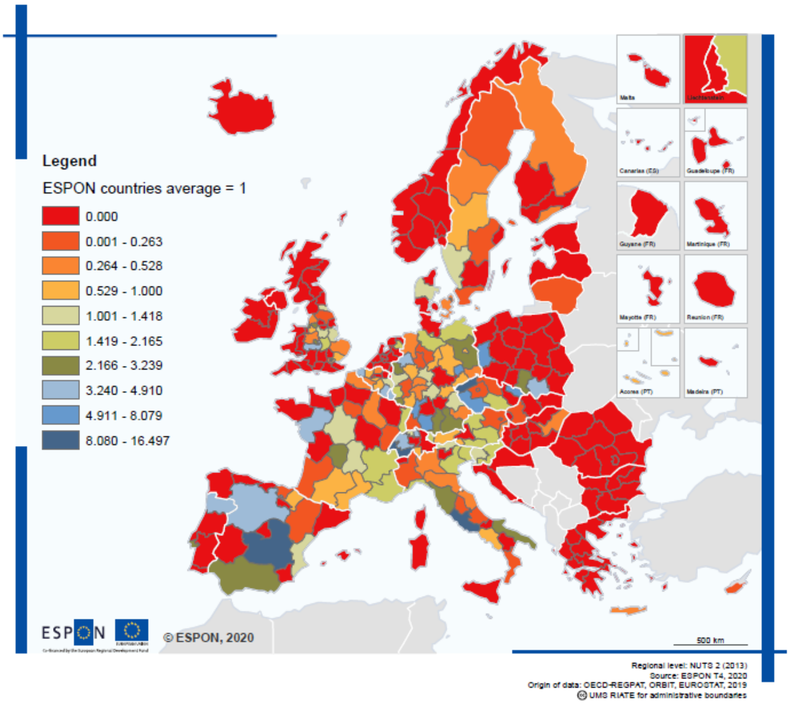
Map A.3.3. 4.0 inventions in smart transport technologies, 2000-2009



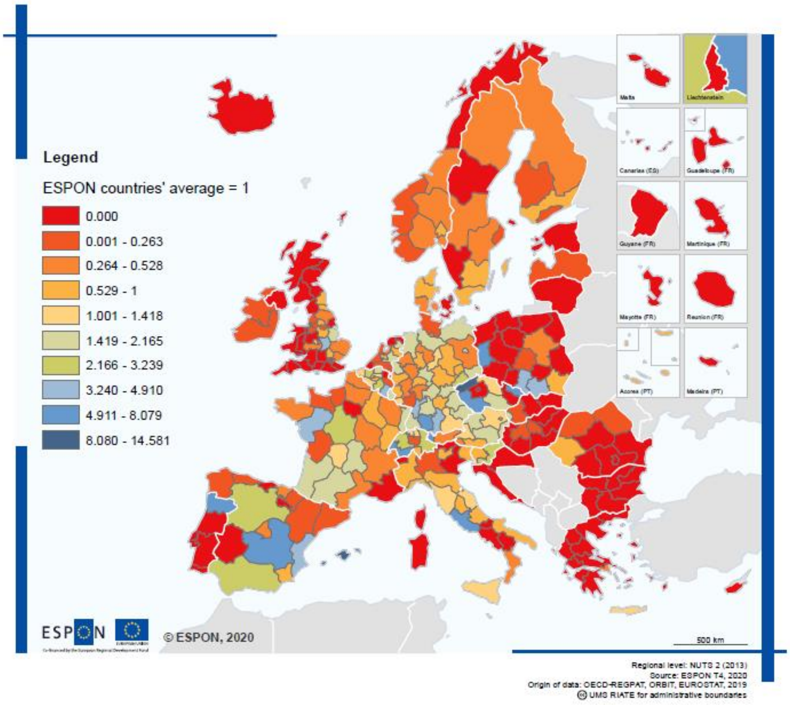
Map A.3.4. 4.0 inventions in smart transport technologies, 2010-2015



Map A.3.5. 4.0 inventions in smart energy technologies, 2000-2009



Map A.3.6. 4.0 inventions in smart energy technologies, 2010-2015



3.3 The identification of new islands of innovation

The capacity to reap new emerging technological opportunities, also in applicative recombinatorial 4.0 inventions, is not universal across space. An important advantage in this respect is represented by the local availability of technological competences in the technologies driving the previous technological revolution (i.e. 3.0 technologies). In other words, the technological cumulativeness between 3.0 and 4.0 technologies can explain whether and, thus *where*, 4.0 technology creation opportunities are present. But, more interestingly, the degree of technological cumulativeness can explain whether previous 3.0 technological knowledge is necessary to enter the 4.0 technology creation market or, rather, 4.0 technological opportunities can emerge also in areas where 3.0 technologies were weak if not absent.

In order to address this conjecture, a two steps methodology has been put in place. In the first step, regions have been classified in terms of their patent specialisation and their patent intensity in the creation of 4.0 technologies in the period 2010-2015, obtaining:

- **4.0 leader regions**, with a patent intensity in 4.0 technologies greater than the European median intensity and with a share of 4.0 technologies in their patent portfolio greater that the European one (i.e. regions specialised in 4.0 technologies);
- **4.0 niche regions**, with a patent intensity in 4.0 technologies lower than the European median intensity but a share of 4.0 technologies in their patent portfolio greater than the European one (i.e. regions specialised in 4.0 technologies);
- **4.0 producing regions**, with a 4.0 patent intensity greater than the European median intensity but without specialisation in 4.0 technologies and, finally
- **no 4.0 regions**, in which 4.0 patent intensity and the share of 4.0 technologies in their patent portfolio are below the European values.

The same classification has been applied to 3.0 technologies[6] in the previous period 2000-2009 (Figure A.3.2), obtaining:

- **3.0 leader regions**, with a patent intensity in 3.0 technologies greater than the European median intensity and with a share of 3.0 technologies in their patent portfolio greater that the European one (i.e. regions specialised in 3.0 technologies);
- **3.0 niche regions**, with a patent intensity in 3.0 technologies lower than the European median intensity but a share of 3.0 technologies in their patent portfolio greater than the European one (i.e. regions specialised in 3.0 technologies);
- **3.0 producing regions**, with a 3.0 patent intensity greater than the European median intensity but without specialisation in 3.0 technologies and, finally
- **no 3.0 regions**, in which 3.0 patent intensity and the share of 4.0 technologies in their patent portfolio are below the European values.

Next, the two classifications have been compared as to obtain the **taxonomy of 4.0 inventing regions** described in Section 3.1 of the main report:

- **low tech regions**, i.e. no 4.0 regions that in the previous period were no 3.0 regions;
- **technology falling behind regions**, i.e. no 4.0 regions that in the previous period were 3.0 producing or 3.0 niche or 3.0 leader regions;
- **new islands of innovation,** i.e. 4.0 producing, niche or leader regions that in the previous period were no 3.0 regions or 3.0 producing regions;
- **technology leader regions**, i.e. 4.0 leader or niche regions that in the previous period were 3.0 leader or niche regions.

Figure A.3.2. Classification of 4.0 and 3.0 technological regions

Figure A.3.2 (a) 4.0 technological regions 2010-2015

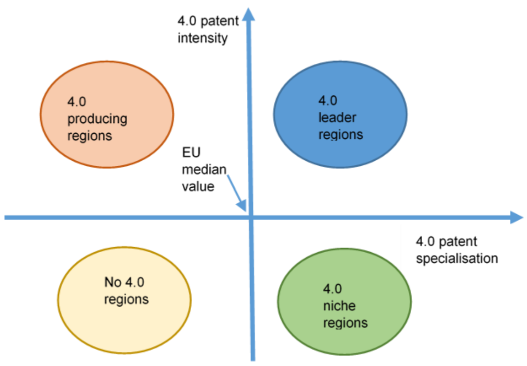
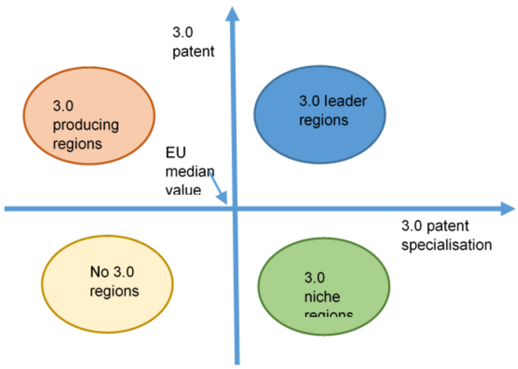


Figure A.3.2 (b) 3.0 technological regions 2000-2009



[6] 3.0 technologies are defined as high-tech technologies according to EUROSTAT definition (https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:High-tech, last visited 06/05/2019) and include Computer and automated business equipment.

4 Regional specialisation in ‘technology’, ‘carrier’ and ‘induced’ sectors

4.1 The definition of ‘technology’, ‘carrier’ and ‘induced’ sectors

As noted in Section 2 of the main report, ‘technology’ and ‘carrier’ sectors are those with a high digitalisation level, while ‘induced’ sectors are those with a low degree of digitalisation.

The OECD has provided a classification of sectors according to their digital intensity level based on ISIC Rev. 4 classification (OECD, 2018). **Accordingly, ‘technology’ and ‘carrier’ sectors are those with high or medium high digital intensity, whereas induced are those with low or medium low digital intensity**, as summarised in Table 4.1 below.

The subsequent distinction between ‘technology’ and ‘carrier’ sector is instead based on the degree of 4.0 patent intensity, the fomer with a high, the latter with a low degree of patenting activity.

For this purpose, then, 4.0 patents have been re-classified according to the IPC classification (International Patent Classification) as there is no direct concordance between the CPC classification and the NACE one.[7] Next, by applying the Schmoch[8] concordance between IPC and NACE Rev.2.2 codes, each 4.0 patent was assigned to a NACE Rev. 2.2 sector and we computed the number of 4.0 patents by each NACE Rev. 2.2 sector. The NACE Rev. 2.2 classification has a rather direct matching with ISIC Rev.4, enabling thus a direct mapping into the OECD sectoral classification by digital intensity.

Two manufacturing sectors accounts for nearly 75% of 4.0 patents in our sample, namely *Manufacture of computer, electronic and optical products* (61.15%) and *Manufacture of machinery and equipment* (13.58%). Accordingly, they are classified as ‘technology’ sectors. The remaing manufacturing sectors account for negligible fractions of 4.0 patents and are classified as ‘carrier’ sectors. There is only one service sectors with high digital intensity and registering same 4.0 patents; it is the Information and Communication sector (slightly above 3% of 4.0 patent), which accordingly is classified as the only ‘technology’ sectors within services. All the remaining service sectors with high digital intensity are classified as ‘carrier’ sectors.

[7] NACE - Statistical Classification of Economic Activities in the European Community.
[8] https://circabc.europa.eu/sd/a/d1475596-1568-408a-9191-426629047e31/2014-10-16-Final%20IPC_NACE2_2014.pdf, last visited on 21/02/2019.

Table A.4.1. Classification of sectors according to their digital intensity

'Technology' and 'carrier' sectors	**'Induced' sectors**
INDUSTRY Manufacture of wood and paper products, and printing, furniture (16-17-18-31) **Manufacture of computer, electronic and optical products (C26)** Manufacture of electrical equipment (C27) **Manufacture of machinery and equipment (C28)** Manufacture of transport equipment (C29-30) Other manufacturing, repairs of computer (C32-33)	INDUSTRY Manufacture of food, beverages, tobacco products (C10-11-12) Manufacture of textiles, wearing apparel, leather (C13-14-15) *Manufacture of coke and refined petroleum products (C19)* *Manufacture of chemical and chemical products (C20)* *Manufacture of pharmaceutical products (C21)* *Manufacture of rubber and plastics products, and other non-metallic mineral products (C22-23)* Manufacture of fabricated basic metal and fabricated metal products (C24-25) Agriculture, Forestry and Fishing (A) Mining and Quarrying (B) Electricity, gas, steam and air conditioning (D) Water Supply; Sewerage, Waste Management and Remediation Activities (E) Construction (F)
SERVICES Wholesale and retail trade, repair (G) **Information and Communication (J)** Professional, Scientific and Technical Activities (M) Administrative and Support Service Activities (N) Public Administration and Defence; Compulsory Social Security (O) Arts, entertainment and recreation (R) Other Service Activities (S)	SERVICES Transportation and Storage (H) Accommodation and Food Service Activities (I) Real Estate Activities (L) Education (P) Human Health and Social Work Activities; residential care and social work activities (Q)

Notes.
1) Sectors are defined as 'technology' or 'carrier' if in at least one of two periods examined by OECD (i.e. 2001-2003 or 2013-2015) they are classified as of high or medium-high digital intensity.
2) In bold, 'technology' sectors, i.e. high patent intensity in 4.0 technologies in our database.
3) Public services have been excluded from the following analysis because data on SBS are not available.
4) In italics, sectors with high patent intensity but at the margins of the 4.0 transformation because based on continuous rather than discontinuous production processes.
5) Nace Rev. 2.2 2-digit code in parentheses.

4.2 The measurement of regional specialisation in 'technology', 'carrier' and 'induced' sectors

Regional specialisation in 'technology', 'carrier' and 'induced' sectors have been measured on the basis of Location Quotient (LQ) indicators (a standard practice in the scientific literature) by using employment data in the three different groups of sectors, for both manufacturing sectors and services. Data on regional sectoral employment at the NACE 2-digit level has been obtained from SBS (Structural Business Statistics) available from EUROSTAT in the period

2008-2016.[9] **Employment in the 'technology' (respectively, 'carrier' and 'induced') sector (further divided into manufacturing and services) has been obtained by summing up employment in each of NACE 2-digit level sector defined as 'technology' sector** (see Table 4.1 above). LQs have been computed by applying the following formula

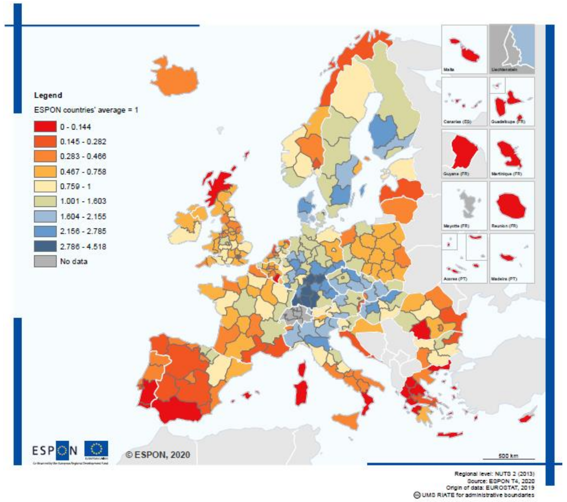
$LQ_{r,s} = [(Emp_{r,s} / Emp_{r})] / [(Emp_{EU,s} / Emp_{EU})]$

where Emp stands for the number of employees, r the region, s the sector (i.e. 'technology', 'carrier' or 'induced', respectively). When LQ is greater than 1, the region is specialised in a specific sector (i.e. its share of employment in the sector is greater than the respective share in the EU). When LQ is lower or equal than 1, the region is not specialised in a specific sector (i.e. its share of employment in the sector is lower than the respective share in the EU). It is worth remarking that regions can present multiple sectoral specialisations, i.e. they can be specialised in all sectors, in only one, or in none of them.

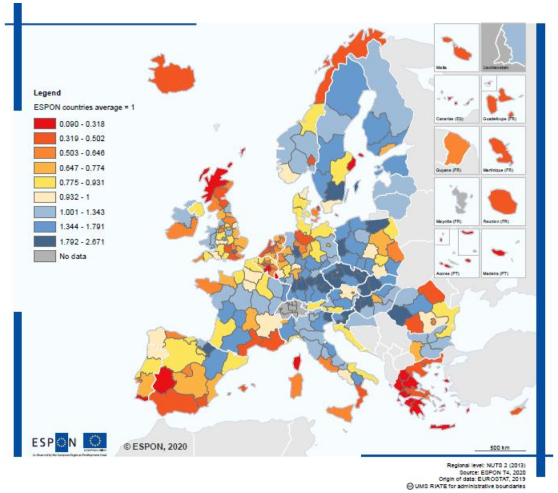
Maps A.4.1 to A.4.6 display the regional sectoral specialisation in 'technology', 'carrier' and 'induced' sectors, both for manufacturing and services.

[9] The combination of a rather fine sectoral and regional breakdowns makes SBS presenting substantial data gaps. The availability of time series data in the period 2008-2016 enabled to mitigate this problem at the expenses, however, of observing temporal trends. The financial sector and the public sector ares not included in SBS. SBS is not conducted in Switzerland nor in Liechtstein; data for these two countries are therefore missing.

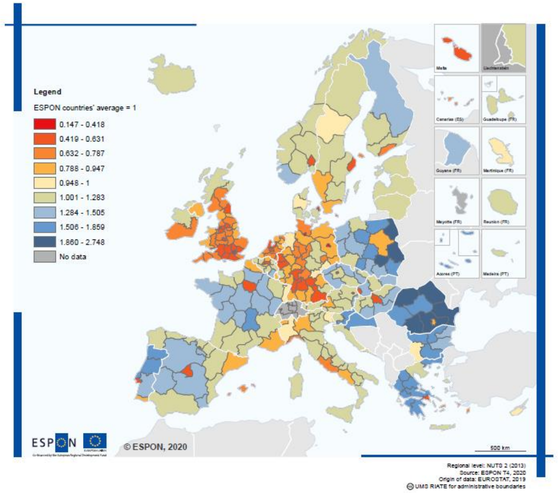
Map A:4.1. Regional specialisation in 'technology' manufacturing sectors, 2008-2016



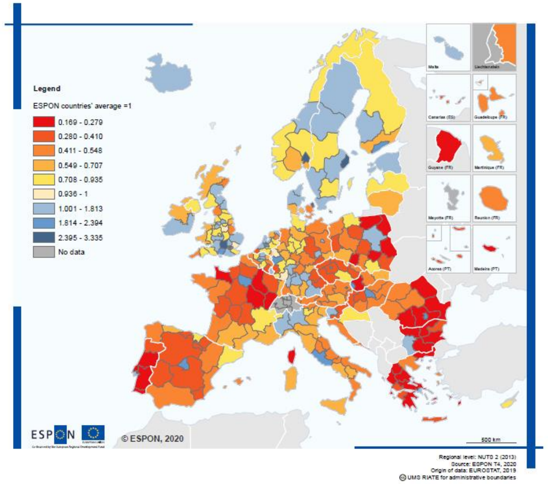
Map A.4.2. Regional specialisation in 'carrier' manufacturing sectors, 2008-2016



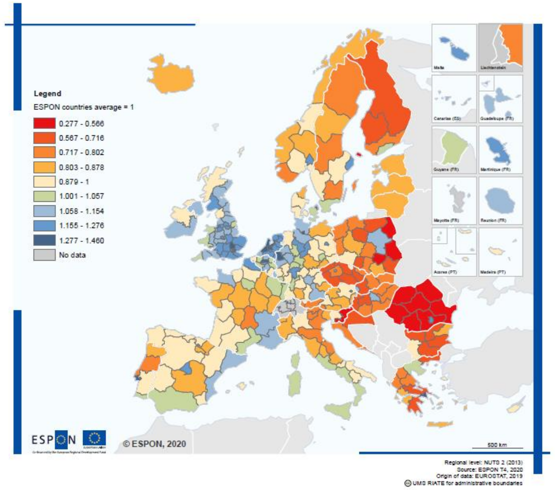
Map A.4.3. Regional specialisation in 'induced' manufacturing sectors, 2008-2016



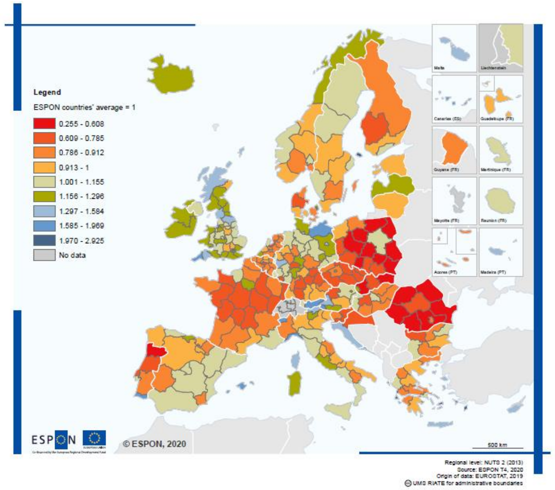
Map A.4.4. Regional specialisation in 'technology' services, 2008-2016



Map A.4.5. Regional specialisation in 'carrier' services, 2008-2016



Map A.4.6. Regional specialisation in 'induced' services, 2008-2016



5 Regional adoption of 4.0 technologies

5.1 4.0 adoption in manufacturing sectors

5.1.1 Robot adoption

Data on robot adoption have been obtained from the International Federation of Robotics (IFR) which classifies robot sales by groups of sectors and country of the purchasing firm. Data are available for most of ESPON countries at the NUTS0 level (with the exclusion of Liechtstein, Luxembourg and Cyprus) starting from 2004. For previous years, the sectoral breakdown is unavailable for most of the countries. **The yearly robot stock has been computed by applying the perpetual inventory method with a 12% depreciation rate as recommended by IFR**, as follows:

$$Robot_{r,t} = (1 - d)Robot_{r,t-1} + Robot_{r,2004}$$

Specifically, $Robot_{r,t}$, the capital stock of region r at time t, is obtained as the sum of the robots purchased in the in the previous periods with a constant (across regions and over time) 12% depreciation rate (d). The robot stock value for the initial year was that of 2004.

National data have been apportioned at the regional (NUTS 2) and sectoral (i.e. ‘technology’, ‘carrier’ and ‘induced’ sectors) level by applying the simple average of a set of three weights accounting for the following aspects:

- the **relevance of the sectors in the region with respect to the country**; the use of this weight is common in the scientific literature and follows the assumption that robot regional sectoral adoption depends on regional sectoral specialisation, i.e. regions that are more specialised in specific sectors contribute more to national robot adoption in the same sectors.
- The **level of broadband penetration in the region with respect to the country**; the use of this weight follows the assumption that robot adoption is more likely in more digitalised regions, i.e. in regions more prone to adopt new technologies.
- The **relevance of manual occupations in the region with respect to the country**; the use of this weight follows the assumption that robot adoption is meant especially to replace manual routine occupations, i.e. regions with a larger proportion of such occupations are more likely to adopt new robots.

This approach improves upon existing methods applied in the literature, in which regional apportionment is based on the sectoral dimension only (Acemoglu and Restrepo, 2018). By using only a sectoral weight, in fact, robot adoption turns to be affected simply by the regional sectoral mix. The inclusion of two additional elements, instead, enables to take into consideration the fact that regions with the same sectoral mix can show different adoption rates depending on the jobs (i.e. occupations) involved in the adoption process and the general level of technological readiness of the region (i.e. digitalisation).

In particular, the three weights have been computed by applying the following formulas:

- $w_1 = (Emp_{r,s} / Emp_{n,s})$
  where *Emp* stands for the number of employees, *r* the region, *n* the country, *s* the sector (i.e. manufacturing sectors, 'technology' manufacturing sectors, 'carrier' manufacturing sectors or 'induced' manufacturing sectors, respectively). Source: EUROSTAT (SBS)
- $w_2 = (Pop_{r,bb} / Pop_{n,bb})$
  where $Pop_{r,bb}$ stands for the number of inhabitants in region r having access to broadband and $Pop_{n,bb}$ stands for the number of inhabitant in country n having access to broadband. EUROSTAT makes available only the share of persons with broadband access. In order to compute w_2, the number of inhabitants in the region (respectively, the country) with broadband access was obtained by multiplying the shares provided by EUROSTAT times the regional (respectively, national) population. Source: EUROSTAT (Digital society).
- $w_r = (Emp_{r,o} / Emp_{n,s})$
  where $Emp_{r,o}$ stands for the number of employees in region r in maual occupations (ISCO group 8 - Plant and machine operators, and assemblers) and $Emp_{n,o}$ stands for the number of employees in country n in manual occupations (ISCO code 8). Source: EUROSTAT (Labour Force Survey, LFS).

In order to account for size effects, the regional sectoral robot stock was divided by the number of employees, obtaining the regional sectoral robot density. Maps 3.4 to 3.6 in the main report show the regional sectoral robot density with respect to the European average.

This indicators has been obtained by applying the following formula

$$LQ_{r,s} = [(Robot_{r,s} / Emp_r)] / [(Robot_{EU,s} / Emp_{EU})]$$

where Robot stands for the robot stock, Emp stands for the number of manufacturing employees, r the region, s the sector (i.e. 'technology' manufacturing sectors, 'carrier' manufacturing sectors or 'induced' manufacturing sectors, respectively).

As noted in the main report, values above 1 indicates that a region has a robot adoption rate greater than the European value.

For countries and regions not covered by or with missing in SBS (e.g. Switerland), it was possible to compute the regional adoption rate only for the manufacturing sector as a whole, without further sectoral disaggregation. Because of data gaps in SBS at the regional/sectoral level, data on regional sectoral robot adoption have been averaged over the period 2008-2016 (see footnote 9).

5.1.2 Text-mining of online content of company websites

Analysing content available through the web has recently become a popular new way to get more insights into trends and areas where the traditional statistical approaches fail to provide timely information. Today, most of the companies across European countries and regions maintain a website, leave a 'digital footprint', communicate about their activities and inform their customers about their products and services through online content, hence analysing these texts is a promising way to get a better understanding about ongoing digitalisation processes.

Information extracted from business websites can help better understand technological transformation and generate timely and relevant information about the diffusion and uptake of digital and other novel technologies. The reason for their relevance is intuitive: websites are an important marketing medium for businesses. Many businesses that adopt digital technologies to differentiate themselves from competitors will desire to announce this as a signal of their innovative capabilities and quality or efficiency advantages, and to attract talent with relevant skills. According to Eurostat data[10] 77% of enterprises own a website in the EU28 and 80% in the EU15, which means that this method can cover the majority of the company population. We can assume that firms without a website are less innovative and are less likely to step on the path of digital transformation.

Website data was accessed using the web scraping programme of SpazioDati[11] and we applied text mining methodologies in order to identify mentions to the technologies of interest. For this specific project, we have built upon the database of webscraped business URLs developed in the framework of the 'Study on the potential of servitisation'[12] that we further extended to cover a larger population of European firms. Our sample of webscraped company websites includes data for the following EU countries:

Table A:5.1. Company coverage for the web-scraping and text-mining analysis

	Number of companies analysed	Number of enterprises (all companies) in the Structural Business Statistics in manufacturing (C code) in 2015	Share of manufacturing companies in the country, covered by the final sample
Netherlands	11940	63337	18%
Bulgaria	3526	30879	11%
Czech Republic	17350	169247	10%
Denmark	5060	14963	34%
France	24611	216103	11%
Germany	44600	205028	21%
Italy	52567	396422	13%
Latvia	1702	10635	16%
Poland	26237	187242	14%
Spain	20920	161315	13%
Austria	10453	25323	41%
Hungary	9333	49310	19%

[10] Enterprises with a website as a percentage of enterprises.
[11] https://spaziodati.eu
[12] https://publications.europa.eu/en/publication-detail/-/publication/3db1a660-8648-11e8-ac6a-01aa75ed71a1/language-en/format-PDF/source-80915778

The indicator constructed is the share of firms using digital technologies (captured as firms referencing technology production or adoption on their websites), that was computed for 12 EU countries at the NUTS2/NUTS1 level (Table A.5.1 above). The sample includes both large firms and SMEs. Although in the cases of some countries, the sample could have included more sectors, there has been too much noise related to service sectors, hence we decided to restrict the analysis to the manufacturing industries. The industry classification that we took into account includes the Manufacturing sector (code C of NACE Rev. 2.2 classification). When interpreting the results it has to be kept in mind that EU countries have different culture to discuss or talk about their products and services on their websites. There is also a bias in terms of large international companies that operate in several locations but their main website and main digital activity might be linked only to the headquarters.

We prepared the semantic engine, designed and tuned the algorithm: **the semantic engine and the language model has been adapted based on pre-developed keywords**. Tuning the algorithm for each pair language/archetype was necessary because there is a risk for certain concepts/keywords to be much more significant for a given language (hence having a greater weight) with respect to another language. We identified mentions of keywords related to technological transformation for the project and expanding that initial list to also include semantically close words (synonyms). We have relied on the list of advanced technologies as identified under the European Commission DG GROW project called 'Advanced Technologies for Industry'[13]. The technologies along with their definitions are presented below with examples of the keywords used in the analysis. The selection of the technologies examined is consistent with those analysed in Section 3.

Based on our calculations as a result of the text-mining of company websites, we present below the share of firms in our sample that claim using or developing certain digital technologies as defined above. In many of the cases the results show that a relatively high share of firms use social media to reach out to customers and a considerably share offers online payment options. IoT, automatisation technologies, use of big data for monitoring and connected solutions are also applied, however, we see less use cases of artificial intelligence or blockchain adoption as expected.

There is a difference in the share of firms referencing the use of digital technologies on their websites among more developed and less developed countries and also among the capital regions and periphery, nevertheless we do not observe large gaps.

We also bring 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.

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[13] https://ec.europa.eu/growth/industry/policy/advanced-technologies/support-tools_en, last visited 16/06/2020.

Netherlands

In the Netherlands, around 46% of firms with a website referenced at least one type of digital technologies. The use cases reviewed include more traditional digitally drive services such as e-commerce but also feature the uptake of Internet of Things, blockchain and artificial intelligence.

The Dutch firm called Rutronik24[14] in North Brabant launched an **eCommerce** platform that allows customers to access the Online Catalog, the Procurement section and Product Change Notifications (PCNs) with a single login. The Online Catalogue provides an overview of all products supplied by Rutronik along with detailed data sheets, while smart search functions aid selection. The mass quotation link allows customers to conveniently use their bill of materials for purchasing. The Procurement function provides customers with an at-a-glance overview of their current and previous orders, offers, item lists, safety reserves, contracts, consignment stocks and traceability.

Dental Correct in Amsterdam is a specialist in the field of invisible braces and focuses primarily on adults. Dental Correct is always researching new technologies. One of their latest technological developments is **cryptocurrencies**, a form of electronic money. The Bitcoin is becoming increasingly known within the Netherlands and Belgium and there is a lot of speculation as to whether Bitcoin or other crypto currencies can have a future in the payment system. The firm decided to accept crypto currency as a payment method. The crypto currency that can be used to pay for Dental Correct includes Bitcoin, Litecoin and Ethereum.

The BMA Ergonomics in Overrijssel develops office furniture such as tables and chairs and uses the **Internet of Things and digital applications**. Their product called Axia Smart Active is accompanied by the Axia Smart Active App, which lets users know when it is time to move. On the App one can set their own seating profile and receive personal feedback on sitting position and duration. In addition, users also receive practical tips and advice for a more active work style.

Denmark

In Denmark, around 44% of firms with a website referenced at least one type of digital technologies. The use cases reviewed include mostly the development of products and services enhanced by big data, 3D printing, robotics and virtual reality. The development of digital applications and digitally driven services are also common.

The **Danish Mobile Industrial Robots** (MiR) is a leading manufacturer of collaborative mobile robots dedicated to developing user-friendly, flexible and secure robots to help companies improve their efficiency. The autonomous and collaborative mobile robots from MiR are used to boost productivity and add value across industries every day.

[14] www.rutronik24.com

Holger Hansen Shoes has been supplying orthopedic footwear for about 130 years and is today one of the country's oldest hand shoe companies. The company is headquartered in Brøndby and located in nine locations in the Danish Zealand. The activities are based on craft traditions but are continuously refined by new technology, new materials and new production methods. The firm is applying 3D scanners to make a scan of the customers' soles, feet and lower legs. This results in a very accurate model to work with when producing inlays and hand-sewn shoes that fit exactly.

Vestas is a Danish supplier of energy solutions. It designs, manufactures and provides services for wind turbines with +113 GW in 81 countries. The company offers a service called TurbineWatch, which means a 24-hour monitoring of the wind turbines installed. There is an ongoing contact with the mill and in the event of an alarm or mill stop, the customer is automatically notified by email or SMS. VestasOnline Enterprise gives a direct contact with the mills and provides both live data and historical results via the Internet.

France

In France, around 43% of firms with a website referenced at least one type of digital technologies.

Asteelflash is specialised in Electronic Manufacturing Services and Supply-Chain Management solutions. It offers Printed-Circuit Boards Assembly (PCBA), Box-Build Assembly, Full Product Assembly as well as Conformal Coating and Surface Treatment, Testing and Fulfillment. Artificial intelligence and machine learning have been integrated into the company's processes that foster opportunities for improvement in time and cost for manufacturing. They apply their own AI system for the supply chain, combining machine learning and big data for smart devices.

Daher is a French aircraft manufacturer and an industry and service equipment supplier. The firm is using immersive virtual prototyping solution, with the help of which engineers can immerse themselves inside the factory to set-up and fine-tune their aircraft final assembly lines.

Farinia Group is a manufacturing firm dedicated to material transformation, equipment, know-how and technical expertise and serving several industries such as fashion and textiles, automotive or medical devices. Farinia Group employs more than 1200 people in 11 plants in France with forge, casting, machining and additive manufacturing. The company developed wearable technologies that can be quickly and easily integrated into the Internet of Things. Spartacus3D, the Farinia subsidiary is specialised in additive manufacturing, aims to help fashion and luxury companies take advantage of this powerful technology to produce bespoke pieces with endless design variations.

Germany

In Germany 43% of firms with websites referenced the use of at least one of the digital technologies in the focus of this study. Use cases include for instance manufacturing firms that offer maintenance services enhanced by big data, real time data and machine learning algorithms.

ECH Elektrochemie Halle GmbH is a developing and producing company. They develop and produce standard analyzers as well as tailor-made metrology for analytical problem. In addition to standard products, they also produce individual solutions in the field of analytics. They also offer services in terms of: creation of customer-specific control and regulation systems in combination with sensor technology, development and production of analytical modules for third-party devices, and manufacture and sale of measuring instruments for laboratory, process and mobile on-site analysis. Market launch of an autonomous and online based hydrogen sulfide (H2S) Analyzer for the implementation of IIoT - digitalization of the sewer system.

Mediseal is a German company producing blister machines and sachet, stickpack and cartoning machines package solids such as tablets, capsules, dragees, ampoules, vials, syringes or liquid products. Mediseal develops dosing and packaging solution for pharmaceutical and cosmetic industry application. The firms is using real time data to supervise the status of a system. Preventive maintenance has been replaced by using data mining, modeling, statistics, machine learning.

Italy

In Italy, 30% of firms in our sample referenced the use of digital technologies on their websites.

ACUSTICA TRENTINA SRL is located in ARCO, TRENTO, Italy and is part of the Medical Equipment & Supplies Manufacturing Industry. The products offered by the firm allow transmitting phone calls, stereo music, audio video and audiobooks directly to the hearing aids, using them as wireless earphones. Thanks to the connection with the app, users can adjust the volume, change the programme and check the battery level with a simple click.

Unox was incorporated in 1990 and breaks into the market of professional ovens with a product designed to bake frozen bread and frozen croissants without proofing. When connected to the UNOX online Cloud, your MIND.Maps™ PLUS combi oven sends data to activate the DDC.Ai service. The artificial intelligence identifies and suggests new recipes and personalised hints accommodating to your needs.

Spain

In Spain, 29% of firms in our sample referenced the use of digital technologies on their websites.

Micro Epsilon provides very high-level systems and units for industrial coating technology applications in the automotive industry. They improve both the efficiency and quality of the coating process itself and the surface inspection of objects. One of their products, the Micro-Epsilon laser sensor offers measurement accuracy and provides reliable results during industrial operation. The laser scanners support dynamic measurement tasks in robotic applications.

Poland

In Poland, 19% of firms in our sample referenced the use of digital technologies on their websites.

The Polish firm called **S24A** is specialised in the design and supply of low voltage systems and industrial solutions. The broadly understood concept of low-voltage systems includes for instance audio-video systems, extensive conference support systems, video systems - displaying images using multimedia projectors, industrial monitors, large-format screens. One of their products is the Olympus brand from the Pro Line series which provides autonomous sound recording systems and support for transcribing audio files into text form. The company offers services in the field of total predictive maintenance, industrial automation, programming and analytical approach to technological and production problems making use of big data.

Hungary

In Hungary, 21% of firms in our sample referenced the use of digital technologies on their websites.

The **MÁTRA Industrial Manufacturing KFT** is a Hungarian distributor of products and services for industrial maintenance, repair and refurbishment, including bearings, mechanical transmission systems, pneumatics, hydraulics, tools and health and safety equipment. The company offers 3D printing services.

Table A.5.2. Definition of the technologies included in the web-scraping and text-mining analysis

Technologies	Definition	Example of keywords
Robotics	Robotics is technology that encompasses the design, building, implementation, and operation of robots. Robotics is often organised into three categories: 1) Application specific. This includes robotics designed to conduct a specific task or series of tasks for commercial purposes. These robots may be stationary or mobile but are limited in function as defined by the intended application.	Robotics, robot, robotic process automation, autonomous mobile robot, automate, automation, drone
The Internet of Things (IoT)	The Internet of Things (IoT) refers to the network of smart, interconnected devices and services that are capable of sensing or even listening to requests. IoT is an aggregation of endpoints that are uniquely identifiable and that communicate bi-directionally over a network using some form of automated connectivity. Objects become interconnected, make themselves recognizable, and acquire intelligence in the sense that they can communicate information about themselves and access information that has been provided by another source.	internet of things, IoT, process automation, asset tracking and management, optimising processes, integrate web applications, connect to cloud, autonomous vehicle, continuous exchange of data, network of connected devices
Artificial Intelligence	Artificial Intelligence is a heterogenous field/area in terms of its technology base. While some aspects like sensors, chips, robots as well as certain applications like autonomous driving, logistics or medical instruments refer to hardware components, a relevant part of AI is rooted in algorithms and software.	artificial intelligence, AI, machine learning, machine intelligence, deep learning, cognitive computing, natural language processing, ML-driven solution, AI-driven solution, Natural language understanding (NLU), Natural language interpretation (NLI), chatbot, AI bot, autopilot, human-machine interaction, image recognition, computer vision, semantic analysis, data visualisation
Big Data	Big Data is a term describing the continuous increase in data, and the technologies needed to collect, store, manage, and analyse it. It is a complex and multidimensional phenomenon, impacting people, processes and technology. From a technology point of view, Big Data encompasses hardware and software that integrate, organize, manage, analyze, and present data	big data, big data analytics, data gathering, data processing system, real time information, predictive analytics, high volume data, high velocity data, high variety data, real time data, data-driven, predict trends, machine learning, data mining, data warehousing
Augmented/Virtual Reality	Augmented reality devices look to overlay digital information or objects with a person's current view of reality. As such, the user is able to see his/her surroundings while also seeing the AR content - Virtual reality devices place end users into a completely new reality, obscuring the view of their existing reality.	augmented reality, virtual reality, AR content, VR content, fully-immersive reality, digital information on real-world elements, VR head-mounted display, VR headset, computer-generated imagery, computer-generated sounds , immersive

		experience, Augmented Reality Platform, advanced computer visualization, stereoscopic camera, virtual reality gaming, Mixed Reality, VR UI/UX design, AR UI/UX design, virtualisation
Blockchain	Blockchain is a digital, distributed ledger of transactions or records, in which the ledger stores the information or data and exists across multiple participants in a peer-to-peer network.	Blockchain, ethereum, Bitcoin, cryptocurrency, crypto
3D printing	Advanced manufacturing technology encompass the use of innovative technology to improve products or processes that drive innovation.	3D scanning, 3D printing, 3D tools, 3D calibration
Cloud technologies	Public cloud services are available on public networks and open to a largely unrestricted universe of potential users. Public clouds are designed for a market, not a single enterprise. Public cloud has all or most of the following characteristics.	cloud service, cloud platform, cloud technology
Connectivity	Connectivity refers to all those technologies and services that allow end-users to connect to a communication network. It encompasses an increasing volume of data, wireless and wired protocols and standards, and combinations within a single use case or location.	Fixed Voice and Mobile Voice , Fixed Data connectivity, Low Power Wide Area Network (LPWAN), Bluetooth, zigbee, connected devices, machine to machine, machine connectivity, intelligent machine, connected solution, telematic solution, remote controll services, remote management

5.2 4.0 adoption in services

Data on the share of firms with online sales have been obtained from EUROSTAT and are available for most of ESPON countries at the NUTS0 level with a sufficient sectoral breakdown only for private services (excluding the financial sector) starting from 2009.

EUROSTAT makes available only the share of firms selling online, not the actual number of firm. In order to compute the number of firms with online sales at the national level to be approportionated at the regional level, data on sectoral local units have been used. Source: EUROSTAT (SBS).

National data have been apportioned at the regional (NUTS2) and sectoral (i.e. ‘technology’, ‘carrier’ and ‘induced’ services) level by applying the simple average of two weights accounting for the following aspects:

- **the relevance of the sectors in the region with respect to the country**; the use of this weight follows the assumption that regional sectoral online sales depend on regional sectoral specialisation, i.e. regions that are more specialised in specific sectors contribute more to national sales online in the same sectors and have, thus, a greater share of firms selling on line.
- **The level of internet access in the region with respect to the country**; the use of this weight follows the assumption that robot adoption is more likely in regions with a more digitalised population, i.e. in regions more prone to adopt new technologies.

In particular, the two weights have been computed by applying the following formulas:

- $w_1 = (Emp_{r,s} / Emp_{n,s})$
  where *Emp* stands for the number of employees, *r* the region, *n* the country, *s* the sector (i.e. private services, ‘technology’ services, ‘carrier’ services or ‘induced’ services, respectively). Source: EUROSTAT (SBS)
- $w_2 = (Pop_{r,int} / Pop_{n,int})$
  where $Pop_{r,int}$ stands for the number of inhabitants in region *r* having access to internet and $Pop_{n,int}$ stands for the number of inhabitant in country *n* having access to internet. EUROSTAT makes available only the share of persons with internet access. In order to compute w_2, the number of inhabitants in the region (respectively, the country) with internet access was obtained by multiplying the shares provided by EUROSTAT times the regional (respectively, national) population. Source: EUROSTAT (Digital society).

By this apportionment methodology, it was possible to compute **the number of firms with online sales at the regional level**. The regional/sectoral share of firms selling online was obtained by dividing, for each group of sectors, the number of firms with online sales at the regional level by the number of local units obtained from SBS.

Maps 3.8 to 3.10 in the main report show the regional share of firms with online sales with respect to the European average. Map 3.11 shows the same indicator for the case of the **transport and storage services**.

This indicator has been obtained by dividing the regional share of firms with online sales by the same average share across European countries, as follows:

$LQ_{r,s} = \textit{Share of firms with online sales}_{r,s} / \textit{Share of firms with online sales}_{EU,s}$

where *r* stands for the region and *s* the sector (i.e. 'technology' services, 'carrier' services or 'induced' services, respectively).

As noted in the main report, values above 1 indicates that a region has a greater share of firms selling online with respect to the European average value.

For countries and regions not covered by or with missing in SBS (e.g. Switerland), it was possible to compute the regional adoption rate only for services as a whole, without further sectoral disaggregation. Because of data gaps in SBS at the regional/sectoral level, data on regional sectoral online sales have been averaged over the period 2009-2016 (see footnote 9).[15]

5.3 4.0 adoption in the society

Data on the share of population using e-banking services, e-government services and purchases of travel and holiday accommodation online has been sourced from EUROSTAT in the period 2008-2016.

LQ indicators have been computed by applying the following formula

$LQ_{r,j} = [(Pop_{r,j} / Pop_{r})] / [(Pop_{EU,j} / Pop_{EU})]$

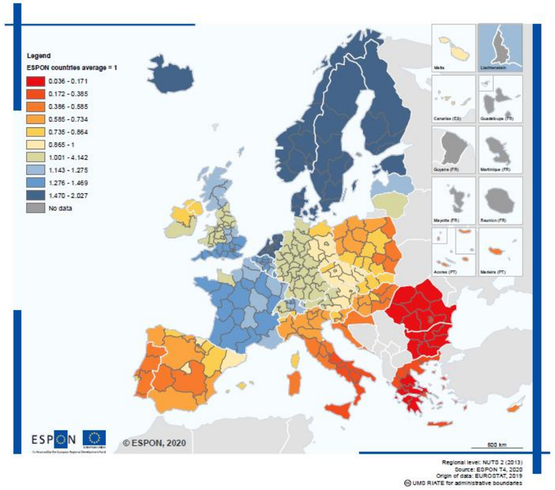
where *Pop* stands for the number of inhabitants, *r* the region, *j* the speficic indicator considered (i.e. use of e-banking services, use of e-government services or online purchase of holidays).

When LQ is greater than 1, the share of regional population making use of a specific digital service is greater than the same share in the EU. The opposite applies when LQ is lower or equal than 1. Maps A.5.1 to A.5.3 display these indicators.

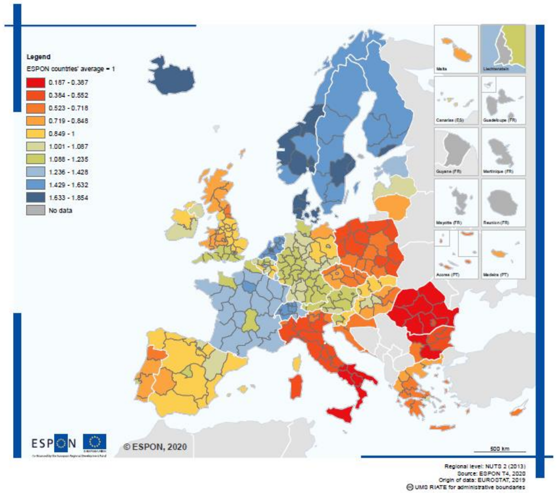
These indicators have been used in order to describe the regional types of technological trasnformations and to estimate the regional risk of job automation (see Section 6).

[15] The availability of time series data in the period 2007-2016 enabled to mitigate the existence of substantial data gaps at the expenses, however, of observing temporal trends. The public sector is not included in SBS.

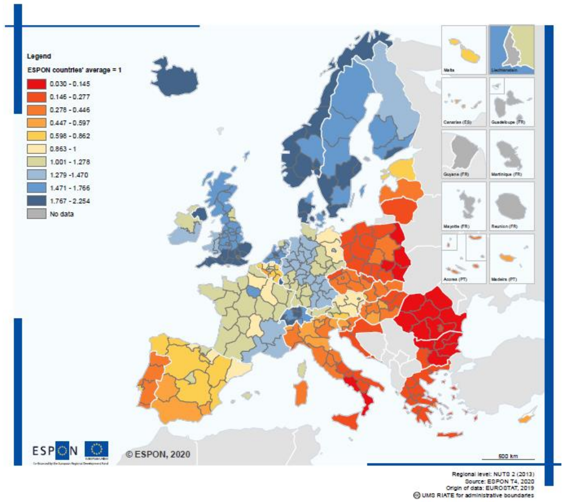
Map A.5.1. Share of population using e-banking services, 2008-2016



Map A.5.2. Share of population using e-government services, 2008-2016



Map A.5.3. Share of population purchasing holidays online, 2008-2016



6 The exposure of the regional labour market to the 4.0 technological transformation

In order to measure the exposure of regional labour market to 4.0 technological trasnformation, we stand in a robust tradition of studies in labor economics analysing the potential impact of the adoption of new technologies on employment (i.e. substitution of labour with machines).

The premise of this line of research rests on the idea that, generally, the probability of automation can be interpreted as a measure of **potential adoption of the new technologies in the economy and society**. What differs in the technologies characterizing the 4.0 technological transformation with respect to previous ones is that the risk of labour substitution affects routine and non-routine tasks, in both manual and cognitive occupations (Frey and Osborne, 2017). The greater the share of automatable tasks in a job is, the greater is the risk of automation and the exposure of regional labour markets to the diffusion of 4.0 technologies (Acemoglu and Autor, 2011; Autor and Dorn, 2013; Goos et al., 2014; Arntz et al., 2016; Nedelkoska and Quintini, 2018).

A landmark study in this line of research is the one developed by Frey and Osborne (2017), which estimated the probability of automation for each of the 732 occupations of the US Standard Occupational Classification (SOC) (at the 5-digit level) as dependent on the task content associated to each occupation, derived from the O*NET database[16]. Occupations with a probability of automation equal or greater than 70% were classified as at high risk of automation.

In this project, we follow this general approach and extend at the territorial level the methodologies applied in the scientific literature (Frey and Osborne, 2017) and by international institutions (Arntz et al., 2016; Nedelkoska and Quintini, 2018; OECD, 2018) in order to identify tasks and occupations that are more likely to be automatable.

Specifically, we follow Nedelkoska and Quintini (2018) and OECD (2018), which propose an extension of the methodology developed by Frey and Osborne (2017) for the US to OECD countries. This methodology consists in the following steps:

1. application of the study by Frey and Osborne (2017) to OECD-PIIAC[17] data. PIIAC offers individual-level data on job tasks. The use of individual-level data with respect to occupation-level data (as in Frey and Osborne, 2017) enables to take into account the differences in the task content of individuals within occupations (i.e. two individuals with the same occupation may show different probability of automation because of a different organization of tasks). In particular, the study by Frey and Osborne (2017) was replicated on Canada which presents a substantially larger sample than any other country in PIIAC;

[16] The Occupational Information Network (O*NET) https://www.onetonline.org/, last visited on 22/02/2019.

[17] The Programme for the International Assessment of Adult Competencies (PIAAC) is responsible for the Survey of Adult Skills, aimed at measuring adults' proficiency in key information-processing skills (see http://www.oecd.org/skills/piaac/, last visited 7/3/2019).

2. computation of the estimation of individual probability of automation for all the other individuals, in all the other countries covered by OECD-PIIAC. This probability was computed as out-of-sample prediction based on the estimations obtained for Canada;
3. classification of individuals with a probability of automation greater than 70% as at high risk;
4. computation of the average individual probability of automation in the OECD, by country, by sector and by occupation;
5. computation of the share of jobs at high risk of automation in the OECD, by country, sector and occupation;
6. computation of the share of jobs at high risk of automation by using, for each region, data on regional employment by occupation and the probabilities of automation obtained from Nedelkoska and Quintini (2018).

In this project, we follow this approach with the introduction of important variations:

1. we do not obtain the risk of automation through an out-of-the-sample prediction from the Canadian data because of lack of Canadian individual data. We rather obtained the risk of automation by applying the Canadian impact of each task on the risk of automation:
2. we calculate the risk of automation directly at the regional level while they apply the national risk of automation for each region belonging to the same nation.

Data have been collected by exploiting several sources:

1. raw data from OECD-PIIAC database have been obtained for the ESPON countries participating in PIIAC from the OECD website;
2. for some countries (Austria, Estonia, Germany, Italy and Finland), however, occupational, sectoral and regional breakdown was not available. For each case, we adopted ad hoc solutions:
    a) for Austria, data was obtained from Statistics Austria[18] with occupational and sectoral breakdown. Due to privacy requirements, Austrian authorities do not provide any regional breakdown of the dataset;
    b) for Germany, data was obtained from GESIS[19] with occupational, sectoral and regional breakdown (NUTS 1 level);
    c) for Italy, data was obtained from INAPP with occupational, sectoral and regional breakdown (NUTS 1 level);[20]
    d) for Finland, data was obtained from the Finnish Social Science Data Archive[21], with occupational, sectoral and regional breakdown (NUTS 2 level);
    e) for Estonia, data was obtained from the the Estonian Ministry of Education at the national level with occupational and sectoral breakdown;
3. regional employment data by occupation (ISCO) and NACE Rev. 2.2 have been obtained from EUROSTAT (2011 Census) and supplemented with additional extraction of data from the LFS when Census data were unavailable (i.e. in the case of Belgium and The Netherlands);

The computation of the regional average risk of automation and the regional share of jobs at high risk, we followed a step-by-step methodology, illustrated in Figure 6.1, namely:

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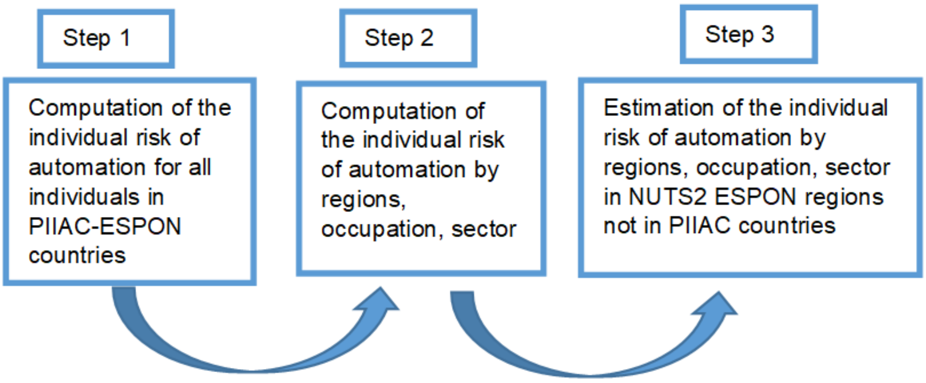
[18] http://www.statistik.at/web_en/statistics/index.html, last visited 21/02/2019.
[19] https://www.gesis.org/en/piaac/piaac-home/, last visited 21/02/2019.
[20] https://inapp.org/it/dati/piaac, last visited 21/02/2019.
[21] https://www.fsd.uta.fi/en/, last visited 21/02/2019.

Figure A.6.1. Step-by-step methodology for the measurement of individual risk of job automation in ESPON regions



1. **for ESPON countries where PIIAC exists**, the individual probability of automation was directly estimated, based on the estimations obtained for Canada by Nedelkoska and Quintini (2018)[22];
2. next, the weighted average probability of automation by NUTS-2 region, by region and occupation (ISCO 1-digit), by region and sector (NACE Rev.2.2. 1-digit) was computed as well as the share of jobs at high risk of automation by region, by region and occupation and by region and sector[23]
3. **for ESPON countries not participating to PIIAC,** estimation of average probability of automation by NUTS2 region and the regional share of jobs at high risk of automation have been obtained as out-of-the-sample estimates obtained from an econometric regression analysis on PIIAC NUTS-2 regions in ESPON. This methodology allows to highlight the statistically significant relationship between the risk of automation and both the degree of penetration of ICTs and the local behaviour in using such technologies for the countries that have PIIAC data. This methodology enables to identify the importance (i.e the weight) of each variable to the risk of automation. These weights will be multiplied times their variables for the non PIIAC countries, obtaining their risk of automation at NUTS-2 level. The specific variables used in this regression analysis have been sourced from EUROSTAT and include:

   - the regional share of population having access to broadband connection,
   - the regional share of population using e-banking services,
   - the regional share of population purchasing holidays online,
   - the regional share of population registering online purchases in the last 3 months,
   - the regional share of people using internet daily.

Maps A.6.1 and A.6.2 show the regional average risk of job automation and the regional share of jobs at high risk of job automation.

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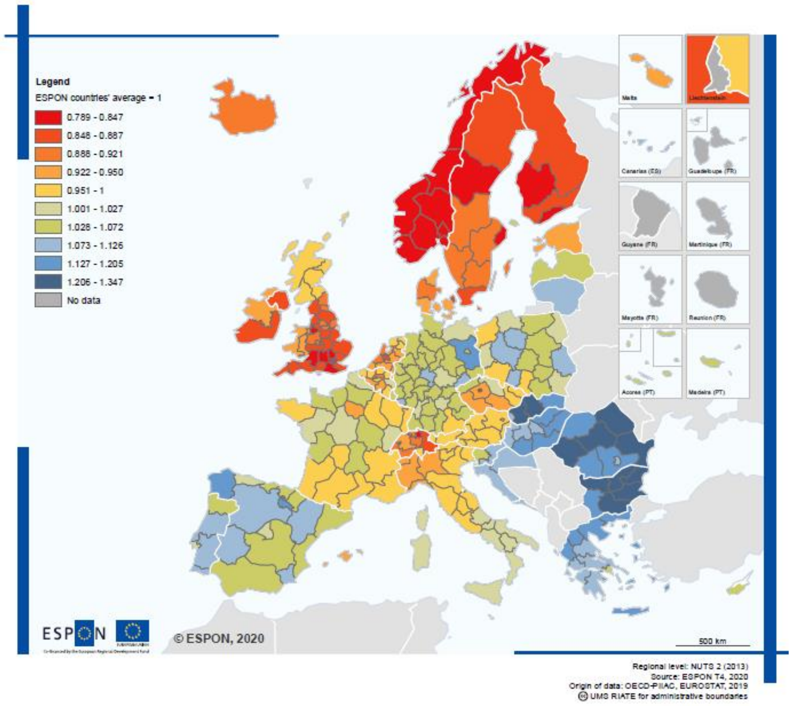
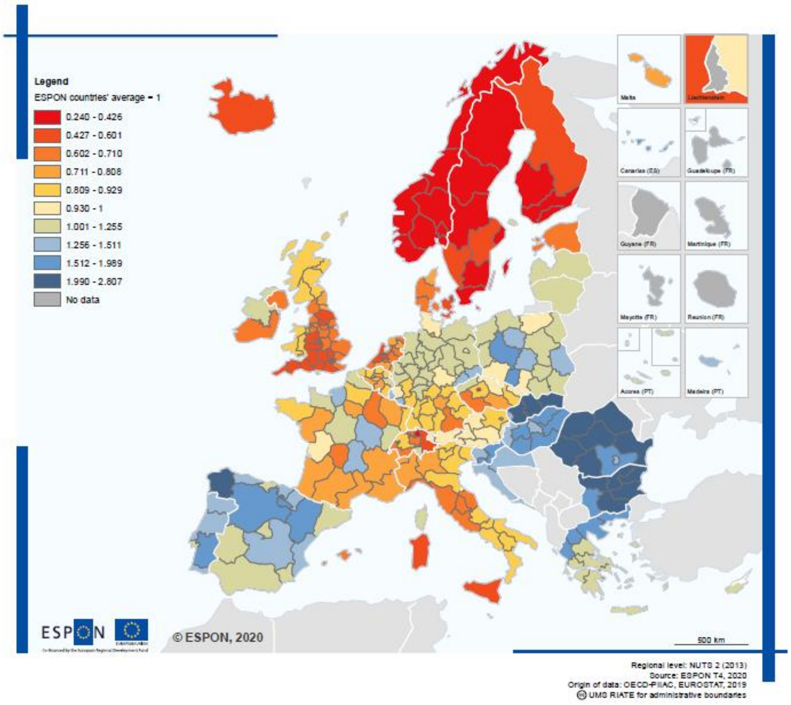
[22] The countries participating in the ESPON 2020 Cooperation Programme and PIIAC are as follows: Austria, Belgium, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Norway, Poland, Slovak Republic, Spain, Sweden, United Kingdom.

[23] PIIAC is not stratified by occupation nor by sector. To mitigate the risk due to absence of strata in the sample for these two dimensions of analysis, we prefer to compute weighted averages where weights are the regional share of each ISCO 1-digit occupation or NACE 1-digit sector.

Map A.6.1. Average risk of job automation, 2011



Map A.6.2. Share of jobs at high risk of automation, 2011



7 Types of technological transformations

In order to identify the prevailing technological transformation occurring in each region of the ESPON space,, a k-means cluster analysis has been performed on six regional sectoral specialisation variables (i.e. specialisation in ‘technology’ manufacturing sectors, specialisation in ‘carrier’ manufacturing sectors, specialisation in ‘induced’ manufacturing sectors, specialisation in ‘technology’ services, specialisation in ‘carrier’ services, specialisation in ‘induced’ services).

We considered various statistical criteria with which to identify the appropriate number of clusters to be retained, such as the relationship between within-cluster and between-cluster variance, but also the number of regions per se. The balance between the information advantages provided by expanding the number of clusters and the interpretability of the results in terms of types of technological transformations supported the extraction of five clusters; each cluster included a reasonable portion of observations, so that they could be plausibly interpreted as typologies of technological transformation. They statistically and significantly differed in themain variables used for the clustering exercise, as the results of the ANOVA tests presented below show. Indeed, the magnitude of the F values performed on each dimension is an indication of how well the respective dimension discriminated between clusters. These five clusters were overall highly stable. Repeating the extraction with different similarity measures and specifying different k random initial group centers yielded highly consistent results. Only a minor portion of regions, in fact, were assigned to a different group.

Performing an ANOVA exercise on a series of variables describing the regional degree of 4.0 technologies adoption, regional structural characteristics and enabling condintion for adoption provided interesting additional information that made it possible to emphasize the differences among clusters in terms of key distinctive territorial preconditions for technololgical transformation. Table A.7.1 synthesizes the results of the ANOVA exercise and presents the mean values of the variables across the five clusters and on average across the ESPON regions. The ANOVA tests are always significant at statistically conventional levels, with only two exceptions (marked with an asterics in the table).

The description of the variables and their sources is in Table A.7.2

Table A.7.1. Types of technological transformations: mean values by cluster and ESPON regions average

	Type of technological trasnformation					
	Servitisation	**Industry 4.0**	**Digitalisation of traditional services**	**Robotisation of traditional manufacturing**	**Niches of robotisation**	**Average**
Variable used in the cluster exercise: *Sectoral specialisation*						
Specialisation in ‘technology’ manufacturing sectors	0.55	2.47	0.52	1.07	0.32	0.91
Specialisation in ‘carrier’ manufacturing sectors	0.6	1.62	0.69	1.36	0.65	0.96
Specialisation in ‘induced’ manufacturing sectors	0.57	1.01	0.92	1.26	1.73	1.06
Specialisation in ‘technology’ service sectors	1.95	0.66	0.68	0.57	0.29	0.79
Specialisation in ‘carrier’ service sectors	1.2	0.86	1.05	0.82	0.73	0.95
Specialisation in ‘induced’ service sectors	1.15	0.84	1.21	0.86	0.75	1.01
Variables used to describe the different types of technological transformation *Robot adoption*						
Robot adoption (number of robots per employee in manufacturing) w.r.t. the European average	1.3	1.93	1.07	1.11	0.41	1.16
Robot adoption in ‘technology’ manufacturing sectors w.r.t. the European average	1.36	2.36	0.95	1.26	0.16	1.19
Robot adoption in ‘carrier’ manufacturing sectors w.r.t. the European average	1.35	2.02	0.96	1.04	0.36	1.11

Robot adoption in 'induced' manufacturing sectors w.r.t. the European average	1.32	1.83	1.16	1.13	0.46	1.19
Online sales adoption						
Digitalisation intensity (share of firms selling online, at least 1% of turnover) in service sectors w.r.t. the European average	1.49	1.44	1.57	1.29	0.94	1.4
Digitalisation intensity in 'technology' service sectors w.r.t. the European average	1.18	1.62	1.42	1.37	1.13	1.37
Digitalisation intensity in 'carrier' service sectors w.r.t. the European average	1.48	1.52	1.51	1.27	0.83	1.37
Digitalisation intensity in 'induced' service sectors w.r.t. the European average	1.45	1.19	1.44	1.13	0.9	1.27
Education						
Education (share of 25-64 age population with tertiary education attainment)	39.02	23.13	28.34	24.96	21.37	27.55
Human resources in S&T (share of active population with tertiary education (ISCED) and/or employed in science and technology)	52.19	38.14	39.86	37.96	29.28	39.73
Education (share of active population with tertiary education (ISCED))	39.92	23.12	29.38	26.58	23.69	28.72
Human resources in S&T (share of active population employed in science and technology)	38.51	31.18	28.26	28.65	19.67	29.24
Human resources in S&T (share of active population with tertiary education (ISCED) and employed in science and technology)	26.24	16.16	17.72	17.27	14.02	18.2
Human resources in S&T (share of scientists and engineers on active population)	8.81	5.2	5.79	5.21	4.24	5.83

Technological intensity						
Patent intensity (number of patents per 1,000 inhabitants)	0.133	0.178	0.064	0.083	0.019	0.089
4.0 patent intensity (number of 4.0 patents per 1,000 inhabitants)	0.032	0.021	0.01	0.011	0.003	0.014
Trademark intensity (number of trademarks per 1,000 inhabitants)	0.348	0.156	0.111	0.091	0.054	0.141
Entrepreneurship						
Entrepreneurship (share of new firms on existing firms)	2.95	2.53	2.7	2.36	2.53	2.61
Entrepreneurship (share of new firms on existing firms in emerging sectors)	2.84	2.29	2.54	2.06	2.38	2.41
Entrepreneurship (share of new firms on existing firms in traded sectors)	2.72	2.2	2.36	2.08	2.32	2.31
Entrepreneurship (share of firms with average annual growth rate >= 20% over a three year period)	1.87	1.2	1.5	0.99	1.34	1.37
Entrepreneurship (share of firms with average annual growth rate >= 20% over a three year period - emerging sectors)	2.15	1.73	1.7	1.35	1.61	1.67
Entrepreneurship (share of firms with average annual growth rate >= 20% over a three year period - traded sectors)	2.07	1.55	1.65	1.26	1.71	1.61
Amount of loans received per 1,000 inhabitants	70.873	110.684	78.85	174.9	77.28	103.86
Number of loans recipients per 1,000 inhabitants	0.12	0.15	0.25	0.35	0.21	0.23
Entrepreneurship (REDI)						
Entrepreneurship: capacity to recognise new business opportunities	0.35	0.33	0.3	0.31	0.22	0.31
Entrepreneurship: ability to start a new business	0.46	0.41	0.45	0.43	0.45	0.44
Entrepreneurship: risk acceptance	0.6	0.56	0.58	0.55	0.48	0.56

Entrepreneurship: embeddedness in entrepreneurial networks	0.33	0.33	0.31	0.38	0.36	0.34
Entrepreneurship: status and carrier opportunities for entrepreneurs*	0.63	0.63	0.65	0.64	0.66	0.64
Entrepreneurship: opportunity driven start-up	0.76	0.74	0.76	0.72	0.68	0.74
Entrepreneurship: technological skills	0.36	0.35	0.36	0.29	0.23	0.33
Entrepreneurship: educational attainment of entrepreneurs	0.5	0.45	0.45	0.4	0.43	0.44
Entrepreneurship: degree of competition and capacity to cope with it	0.48	0.44	0.5	0.46	0.48	0.48
Entrepreneurship: capacity to develop new products	0.43	0.41	0.41	0.48	0.49	0.44
Entrepreneurship: capacity to develop new processes	0.29	0.24	0.29	0.31	0.34	0.29
Entrepreneurship: high-growing firms in the region*	0.16	0.15	0.13	0.15	0.14	0.14
Entrepreneurship: regional export and connectivity potential	0.57	0.56	0.49	0.58	0.56	0.54
Entrepreneurship: capacity to raise financing	1308	1599	1119	1335	1048	1261
Attitude of a region's population towards entrepreneurship	48.68	45.42	49.9	44.45	29.18	46.68
Ability of a region's population to start new business with high-growth potentials	60.85	47.11	51.93	40.25	26.55	46.81
Aspiration of a region's to develop quality and strategic entrepreneurial activities	59.13	50.73	47.44	48.16	36.24	48.49
Regional entrepreneurship development index	59.21	47.46	49.76	44.29	30.65	47.33
Population digitalisation intensity						
Access to internet (share of population)	88.23	84.58	83.24	79.95	67.18	81.49
Access to broadband (share of	86.01	81.77	80.99	76.59	64.95	78.89

population)						
No use of internet (share of population)	8.54	12.08	13.84	16.35	29.42	15.22
Daily use of internet (share of population)	77.49	69.9	70.67	64.61	48.94	67.55
Weekly use of internet (share of population)	85.28	79.21	70.08	74.94	60.3	76.81
Use of social networks on the web (share of population)	57.74	47.56	52.22	46.16	40.57	49.53
Use of e-banking services (share of population)	57.73	49.23	50.5	46.96	22.65	47.27
Online purchase in the last month (share of population)	54.33	47.31	49.13	37.78	21.02	43.59
Online purchase in the last 12 months (share of population)	64.19	58.48	57.98	49.32	29.19	53.5
Online purchase more than 12 months ago (share of population)	5.84	7	5.14	7.39	6.4	6.2
Online purchase: travel and holiday accommodation (share of population)	38.78	29.05	32.65	23.69	10.57	28.28
Regional structural characteristics						
Personal wealth (GDP per capita)	46258	29889	28064	23921	13730	28301
Urbanisation (share of population living in metropolitan areas)	83.77	44.55	45.54	37.17	25.17	46.59
Urbanisation (borrow size)	4498	1243	1579	788	534	1647
Economic tissue (share of employment in the private sector; construction excluded)	57.81	60.6	52.88	56.07	48.92	54.97
Specialisation in the non-private sector (Location quotient on total employment)	0.97	0.9	1.1	1.01	1.19	1.04
Employment in the manufacturing sector (share of total employment)	10.36	26.3	12.99	21.76	17.03	17.03
Employment in the private service sector (share of total employment)	47.45	34.3	40.01	34.32	31.9	37.99

Average risk of automation	44.57	48.22	46.06	48.5	52.85	47.54
High risk of automation (% of jobs)	12.95	16.61	14.65	18.01	25.03	16.69

Note: ANOVA always significant at conventional statistical levels with the exception of the variables flagged with *

Table A:7.2. Variables definition and measurement

	Measurement	Years	Source
Variable used in the cluster exercise: *Sectoral specialisation*			
Specialisation in 'technology' manufacturing sectors	LQ on employment in 'technology' manufacturing sectors*	Average 2008-2016	EUROSTAT
Specialisation in 'carrier' manufacturing sectors	LQ on employment in 'carrier' manufacturing sectors*	Average 2008-2016	EUROSTAT
Specialisation in 'induced' manufacturing sectors	LQ on employment in 'induced' manufacturing sectors*	Average 2008-2016	EUROSTAT
Specialisation in 'technology' services	LQ on employment in 'technology' services *	Average 2008-2016	EUROSTAT
Specialisation in 'carrier' services	LQ on employment in 'carrier' services*	Average 2008-2016	EUROSTAT
Specialisation in 'induced' services	LQ on employment in 'induced' services *	Average 2008-2016	EUROSTAT
Variable used to describe the different types of technological transformation *Robot adoption*			
Robot adoption (number of robots per employee in manufacturing) w.r.t. the European average	Number of robots per employee in manufacturing w.r.t. the European average	Average 2008-2016	IFR, EUROSTAT
Robot adoption in 'technology' manufacturing sectors w.r.t. the European average	Number of robots per employee in 'technology' manufacturing sectors w.r.t. the European average	Average 2008-2016	IFR, EUROSTAT
Robot adoption in 'carrier' manufacturing sectors w.r.t. the European average	Number of robots per employee in 'carrier' manufacturing sectors w.r.t. the European average	Average 2008-2016	IFR, EUROSTAT
Robot adoption in 'induced' manufacturing sectors w.r.t. the European average	Number of robots per employee in 'induced' manufacturing sectors w.r.t. the European average	Average 2008-2016	IFR, EUROSTAT
Online sales adoption			
Digitalisation intensity in service sectors w.r.t. the European average	Share of firms selling online, at least 1% of turnover	Average 2009-2016	EUROSTAT

Digitalisation intensity in ‘technology’ services w.r.t. the European average	Share of firms selling online, at least 1% of turnover	Average 2009-2016	EUROSTAT
Digitalisation intensity in ‘carrier’ services w.r.t. the European average	Share of firms selling online, at least 1% of turnover	Average 2009-2016	EUROSTAT
Digitalisation intensity in ‘induced’ services w.r.t. the European average	Share of firms selling online, at least 1% of turnover	Average 2009-2016	EUROSTAT
Education			
Education	Share of 25-64 age population with tertiary education attainment	Average 2013-2016	EUROSTAT
Human resources in S&T	Share of active population with tertiary education (ISCED) and/or employed in science and technology	Average 2013-2016	EUROSTAT
Education	Share of active population with tertiary education (ISCED)	Average 2013-2016	EUROSTAT
Human resources in S&T	Share of active population employed in science and technology	Average 2013-2016	EUROSTAT
Human resources in S&T	Share of active population with tertiary education (ISCED) and employed in science and technology	Average 2013-2016	EUROSTAT
Human resources in S&T	Share of scientists and engineers on active population	Average 2013-2016	EUROSTAT
Technological intensity			
Patent intensity	Number of patents per 1,000 inhabitants	Average 2010-2015	OECD-REGPAT, EUROSTAT
4.0 patent intensity	Number of 4.0 patents per 1,000 inhabitants	Average 2010-2015	OECD-REGPAT, ORBIT EUROSTAT
Trademark intensity	Number of trademarks per 1,000 inhabitants	Average 2010-2016	EUROSTAT
Entrepreneurship			
Entrepreneurship	Share of new firms on existing firms	Average 2013-2016	TECHNOPOLIS on ORBIS and EUROSTAT
Entrepreneurship	Share of new firms on existing firms in emerging sectors	Average 2013-2016	TECHNOPOLIS on ORBIS and EUROSTAT
Entrepreneurship	Share of new firms on existing firms in traded sectors	Average 2013-2016	TECHNOPOLIS on ORBIS and EUROSTAT
Entrepreneurship	Share of firms with average annual growth rate >= 20% over a three year period	Average 2013-2016	TECHNOPOLIS on ORBIS and EUROSTAT

Entrepreneurship	Share of firms with average annual growth rate >= 20% over a three year period - emerging sectors	Average 2013-2016	TECHNOPOLIS on ORBIS and EUROSTAT
Entrepreneurship	Share of firms with average annual growth rate >= 20% over a three year period - traded sectors	Average 2013-2016	TECHNOPOLIS on ORBIS and EUROSTAT
Amount of loans received per 1,000 inhabitants	Euro per 1,000 inhabitants	2016	TECHNOPOLIS on COSME and EUROSTAT
Number of loan recipients per 1,000 inhabitants	Count of loan recipients per 1,000	2016	TECHNOPOLIS on COSME and EUROSTAT
Entrepreneurship (REDI)			
Entrepreneurship: capacity to recognise new business opportunities	Composite indicator***	2011	REDI
Entrepreneurship: ability to start a new business	Composite indicator***	2011	REDI
Entrepreneurship: risk acceptance	Composite indicator***	2011	REDI
Entrepreneurship: embeddedness in entrepreneurial networks	Composite indicator***	2011	REDI
Entrepreneurship: status and carrier opportunities for entrepreneurs*	Composite indicator***	2011	REDI
Entrepreneurship: opportunity driven start-up	Composite indicator***	2011	REDI
Entrepreneurship: technological skills	Composite indicator***	2011	REDI
Entrepreneurship: educational attainment of entrepreneurs	Composite indicator***	2011	REDI
Entrepreneurship: degree of competition and capacity to cope with it	Composite indicator***	2011	REDI
Entrepreneurship: capacity to develop new products	Composite indicator***	2011	REDI
Entrepreneurship: capacity to develop new processes	Composite indicator***	2011	REDI
Entrepreneurship: high-growing firms in the region*	Composite indicator***	2011	REDI
Entrepreneurship: regional export and connectivity potential	Composite indicator***	2011	REDI
Entrepreneurship: capacity to raise financing	Composite indicator***	2011	REDI
Attitude of a region's population towards entrepreneurship	Composite indicator***	2011	REDI
Ability of a region's population to start new business with high-growth potentials	Composite indicator***	2011	REDI
Aspiration of a region's to develop quality and strategic entrepreneurial activities	Composite indicator***	2011	REDI
Regional entrepreneurship development index	Composite indicator***	2011	REDI

Population digitalisation intensity			
Access to internet	Share of population	Average 2013-2016	EUROSTAT
Access to broadband	Share of population	Average 2013-2016	EUROSTAT
No use of internet	Share of population	Average 2013-2016	EUROSTAT
Daily use of internet	Share of population	Average 2013-2016	EUROSTAT
Weekly use of internet	Share of population	Average 2013-2016	EUROSTAT
Use of social networks on the web	Share of population	Average 2013-2016	EUROSTAT
Use of e-banking services	Share of population	Average 2013-2016	EUROSTAT
Online purchase in the last month	Share of population	Average 2013-2016	EUROSTAT
Online purchase in the last 12 months	Share of population	Average 2013-2016	EUROSTAT
Online purchase more than 12 months ago	Share of population	Average 2013-2016	EUROSTAT
Online purchase: travel and holiday accommodation	Share of population	Average 2013-2016	EUROSTAT
Regional structural characteristics			
Personal wealth	GDP per capita	Average 2013-2016	EUROSTAT
Urbanisation	Share of population living in metropolitan areas	Average 2013-2015	EUROSTAT
Economic tissue	Share of employment in the private sector; construction excluded	Average 2013-2016	EUROSTAT
Specialisation in the non-private sector	Location quotient on total employment**	Average 2013-2016	EUROSTAT
Employment in the manufacturing sector	Share of total employment	Average 2013-2016	EUROSTAT
Employment in the private service sector	Share of total employment	Average	EUROSTAT

		2013-2016	
Average risk of automation	See Section 6	2011	See Section 6
High risk of automation	See Section 6	2011	See Section 6

*Note: * for the definition of ‘technology’, ‘carrier’ and ‘induced’ sectors, see Table A.4.1. **For the measurement of LQ, please see Section 4.2. *** see the report website: https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/regional_entrepreneurship_development_index.pdf, last visited 2020/02/14*

8 The economic impact of technological transformation at the regional level

In order to assess the impact of 4.0 technologies adoption on regional economies, we adopted an econometric approach.

As mentioned in the main report, the measurement of the economic impact is a rather complex task, since it depends on several intertwined dimensions:

- the type of sectors involved (and therefore on the type of transformation),
- the type of technology adopted,
- the capacity of the regions to exploit the technology,
- and the period of time.

Last but not least, the impact can be on different aspects of the economy, namely GDP or productivity growth. The following analyses take all these elements explicitly into account. The analysis is carried out for two different periods of time, the crisis period (2007-2012) and the recovery one (2013-2017).

As an illustrative example, the impact on GDP (respectively productivity) growth has been measured by estimating the following equation, through (spatial) econometric tools:

$$\Delta GDP\_pc_{r,t} = F(X_{r,t}) + \varepsilon_{r,t} \qquad \text{eq. 2}$$

Where ΔGDP_pc_r is the regional GDP per capita growth rate made dependent of a series of regional level determinants X_r and a random error term ε_r, and *t* the period considered, 2007-2012 and 2013-2017.

According to the existing literature in the field (Capello and Lenzi, 2019), the regional level determinants, X_r, includes variables accounting for the following aspects: the initial level of GDP per capita; the population growth rate; the share of employment in service and in manufacturing; the regional population educational attainment level; the regional innovativeness level; the FDI penetration rate; the quality of government; the regional settlement structure; **and new to the literature the regional adoption of 4.0 technologies and the regional creation of 4.0 technologies**.

The econometric analysis was performed in the frame of a random effects panel setting consisting on two periods. Random effects rather than fixed effects were adopted because of the presence of time-invariant explanatory variables (i.e. the different types of technological transformations). The first period accounts for the years of the crisis with the dependent variable measured in the period 2007-2012 and explanatory variables are measured at the beginning of the period (i.e. 2007, or the least recent year when this was not feasible). The second period accounts for the years of the recovery with the dependent variable measured in the period 2013-2017 and explanatory variables are measured at the beginning of the period (i.e. 2013).

Importantly, differentiated spatial impacts of the adoption of different 4.0 technologies and of the creation of different typologies of 4.0 technologies have be obtained by computing the marginal effects over time and across the different types of regions, characterised by different prevailing technological transformations.

For what concerns the selection of the most appropriate econometric model, the literature suggests two main approaches to select the most adequate model in consideration of the possible spatial interdependencies across regional units (Elhorst, 2010). The first is generally described as the specific-to-general (bottom-up) approach, which starts from a-spatial specification and using a Lagrange multiplier tests whether a spatial error specification or a spatial lag specification is more appropriate for the specific analysis. The second is described as the general-to-specific (top-down) approach, which is based on a general-to-simple model selection rule and a Spatial Durbin Model (SDM) to identify which specification is the most appropriate (Elhorst, 2010). The debate on the best approach is still ongoing. There are strong proponents of the top-down approach (e.g., LeSage and Pace 2009, 2014) and evidence showing that, overall, the bottom up approach is better (Florax et al., 2003), while some scholars suggest using a mixed approach (Elhorst, 2010).

In the present context, we follow the general-to-simple model selection rule and the test procedure proposed by Elhorst (2010) to decide whether and which spatial model is the best in the present empirical context. We start by estimating a SDM using a row-standardized spatial weight matrix whose elements, the w_{ij} spatial weights, represent the row-standardised inverse distance between the centroids of the i and j regions. In all model specifications, the significance of the spatially lagged dependent variable (tested in the SDM specification) is rejected, as is the joint significance of the spatially lagged independent variables. In this case, Elhorst's (2010) method suggests that the disturbances should be tested for spatial dependence. In all model specifications, tests do not allow rejecting the null hypothesis of absence of spatial dependence in the disturbances, supporting the use of Generalised Least Squares (GLS) random effects estimates. The estimates reported below, then, are based on robust GLS.

Table A.8.1 reports the description, measurement and sources of the variables used in the regressions. Table A.8.2 reports the main results of GDP per capita growth estimations and Table A.8.3 the computation of marginal effects by type of the prevailing technological transformation and period (Maps 4.1-4.5; Figures 4.1-4.2 and A.8.1-A.8.4). Table A.8.4 reports the main results on productivity growth estimations and Table A.8.5 the computation of marginal effects by type of the prevailing technological transformation and period (Maps 4.6-4.7; Figures 4.3-4.4 and A.8.6-A.8.8). Table A.8.6 reports the main results on producitivty growth estimations and Table A.8.7 the computation of marginal effects by typology of 4.0 inventing regions and period (Figure 4.5).

Table A:8.1. Variables description

	Measurement	Years	Source
Dependent variables			
GDP percapita growth rate (GDP per inhabitant)	Average annual compound growth rate	2007-2012; 2013-2017	EUROSTAT
Labour productivity (GDP on total employment)	Average annual compound growth rate	2007-2012; 2013-2017	EUROSTAT
Explanatory variables			
GDP per capitaper capita	GDP per inhabitant	2007; 2013	EUROSTAT
Labour productivity (GDP on total employment)	GDP per employee	2007; 2013	EUROSTAT
Population growth rate	Annual average population growth rate	2007-2009; 2010-2012	EUROSTAT
Employment in the manufacturing sector	Share of total employment	2007; 2013	EUROSTAT
Employment in the private service sector	Share of total employment	2007; 2013	EUROSTAT
Urbanisation	Share of population living in metropolitan areas	2007; 2013	EUROSTAT
FDI penetration rate	Amount of FDIs per 1,000 inhabitants	Two values: 2003-2005 and 2005-2007	FDI-Regio, Bocconi-ISLA
Quality of government	European Quality of Government Index	2010; 2013	Charron et al. (2014)
Education	Share of 25-64 age population with tertiary education	2007; 2013	EUROSTAT
Patent intensity	Number of patents per 1,000 inhabitants	Average 2004-2007 and 2007-2011	OECD-REGPAT, EUROSTAT
4.0 patent intensity	Number of 4.0 patents per 1,000 inhabitants	Average 2000-2009 and 2010-2015	OECD-REGPAT, ORBIT EUROSTAT
4.0 recombination patent intensity	Number of 4.0 recombination patents per 1,000 inhabitants	Average 2000-2009 and 2010-2015	OECD-REGPAT, ORBIT EUROSTAT
4.0 application recombination patent intensity	Number of 4.0 application recombination patents per 1,000 inhabitants	Average 2000-2009 and 2010-2015	OECD-REGPAT, ORBIT EUROSTAT
3.0 patent intensity	Number of 3.0 patents per 1,000 inhabitants	Average 2000-2009 and 2010-2015	OECD-REGPAT, EUROSTAT; see Section 3
Trademark intensity	Number of trademarks per 1,000 inhabitants	Average 2008-2010 and 2010-2012	EUROSTAT
Specialisation in 'technology' manufacturing sectors	LQ on employment in 'technology' manufacturing sectors*	Average 2008-2010 and 2011-2013	EUROSTAT
Specialisation in 'induced' manufacturing sectors	LQ on employment in 'induced' manufacturing sectors*	Average 2008-2010 and 2011-2013	EUROSTAT
Specialisation in 'induced' service sectors	LQ on employment in 'induced' service sectors*	Average 2008-2010 and 2011-2013	EUROSTAT

Robot adoption in 'technology' manufacturing sectors	Number of robots per employee in 'technology' manufacturing sectors	Average 2008-2010 and 2011-2013	IFR, EUROSTAT
Robot adoption in 'induced' manufacturing sectors	Number of robots per employee in 'induced' manufacturing sectors	Average 2008-2010 and 2011-2013	IFR, EUROSTAT
Online sales in 'induced' services	Share of firms selling online, at least 1% of turnover	Average 2009-2011 and 2011-2013	EUROSTAT

Note: * for the definition of 'technology', 'carrier' and 'induced' manufacturing sectors and services, see Table A.4.1. **For the measurement of LQ, please see Section 4.2.

Table A.8.2. Impact of 4.0 technologies adoption on GDP per capita growth, 2007-2012 and 2013-2017 periods

Dependent variable: Annual average GDP per capita growth rate				
GDP per capita (log)	-0.0196***	-0.0198***	-0.0213***	-0.0165***
	(0.003)	(0.003)	(0.004)	(0.003)
Population growth rate	-0.0391***	-0.0279**	-0.0269**	-0.0406***
	(0.013)	(0.012)	(0.013)	(0.015)
Urbanisation	0.0069**	0.0094***	0.0074**	0.0070**
	(0.003)	(0.003)	(0.003)	(0.003)
Dummy variable for the period 2013-2017	-0.0092	0.0102	0.0165**	0.0108
	(0.018)	(0.008)	(0.008)	(0.007)
Urbanisation*period 2013-20017	-0.0051	-0.0100**	-0.0099**	-0.0109**
	(0.005)	(0.005)	(0.005)	(0.005)
Employment in service	-0.0274***	-0.0213***	-0.0236***	-0.0198***
	(0.005)	(0.004)	(0.005)	(0.004)
Employment in service *period 2013-20017	0.0826***	0.0439*	0.0255	0.0439**
	(0.031)	(0.024)	(0.024)	(0.022)
Employment in manufacturing	0.0487***	0.0389**	0.0340**	0.0303**
	(0.015)	(0.017)	(0.015)	(0.014)
FDI	-0.0000	0.0000	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)	(0.000)
Quality of government	0.0076***	0.0065***	0.0069***	0.0065***
	(0.001)	(0.001)	(0.001)	(0.001)
Education	0.0002*	0.0002*	0.0002***	0.0001
	(0.000)	(0.000)	(0.000)	(0.000)
Trademark intensity	0.0336***	0.0324***	0.0323***	0.0350***
	(0.007)	(0.006)	(0.007)	(0.007)
Industry 4.0	-0.0091**	-0.0082**	-0.0066*	-0.0022
	(0.005)	(0.004)	(0.004)	(0.004)
Digitalisation of traditional services	-0.0107***	-0.0044*	-0.0037	-0.0034
	(0.004)	(0.003)	(0.003)	(0.003)
Robotisation of traditional manufacturing	-0.0111**	-0.0074**	-0.0050	-0.0036
	(0.004)	(0.003)	(0.003)	(0.003)
Niches of robotisation	-0.0203***	-0.0082**	-0.0035	-0.0072**
	(0.005)	(0.003)	(0.004)	(0.004)
Industry 4.0*period 2013-2017	0.0110			
	(0.009)			
Digitalisation of traditional services*period 2013-2017	0.0127*			
	(0.007)			
Robotisation of traditional manufacturing*period 2013-2017	0.0128			
	(0.009)			
Niches of robotisation*period 2013-2017	0.0267***			
	(0.010)			
Specialisation in 'technology' manufacturing sectors		-0.0015		
		(0.002)		
Specialisation in 'induced' manufacturing sectors			-0.0055	
			(0.004)	
Specialisation in 'induced' services				-0.0182***
				(0.005)
Robot adoption in 'technology' manufacturing sectors		-0.2889		
		(0.395)		
Robot adoption in 'induced' manufacturing sectors			1.5482*	
			(0.931)	
Online sales adoption in 'induced' services				-0.0004**
				(0.000)

Specialization in 'technology' manufacturing sectors * Robot adoption in 'technology' manufacturing sectors		1.2984^{***}		
		(0.420)		
Specialisation in 'induced' manufacturing sectors * Robot adoption in 'induced' manufacturing sectors			2.0238^{*}	
			(1.215)	
Specialisation in 'induced' services * Online sales in 'induced' services				0.0005^{**}
				(0.000)
EU15 countries	-0.0115^{***}	-0.0137^{***}	-0.0159^{***}	-0.0141^{***}
	(0.004)	(0.003)	(0.004)	(0.004)
Constant	-0.0917	-0.1690^{***}	-0.1788^{***}	-0.1260^{***}
	(0.173)	(0.030)	(0.033)	(0.034)
Wald test – spatial lag of the dependent variable (p-value), SDM	0.334	0.20	0.298	0.179
Wald test (joint) – spatial lag of the independent variables (p-value), SDM	0.072	0.141	0.250	0.112
Wald test – spatial error (p-value), SEM	0.955	0.718	0.860	0.887
R2	0.63	0.62	0.62	0.62

Note: N = 522. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Spatially lagged independent variables included though not displayed in Model 1. Servitisation is the reference case.

Table A:8.3. Marginal effects of 4.0 technologies adoption on GDP per capita growth on average and by type of technological transformation, 2007-2012 and 2013-2017 periods

	Robot adoption in 'technology' manufacturing sectors	**Robot adoption in 'induced' manufacturing sectors**	**Online sales adoption in 'induced' services**
2007-2012			
Average	0.9482	3.6258	0.0163
Servitisation	0.5033	2.6351	0.02512
Industry 4.0	2.8378	3.4975	0
Digitalisation of traditional services	0.4508	3.3228	0.02572
Robotisation of traditional manufacturing	1.1411	4.0282	0
Niches of robotisation	0	5.0632	0
2013-2017			
Average	0.9370	3.6906	0.0164
Servitisation	0.4465	2.6514	0.02504
Industry 4.0	2.9313	3.6006	0
Digitalisation of traditional services	0.4540	3.3975	0.02596
Robotisation of traditional manufacturing	1.0807	4.1042	0
Niches of robotisation	0	5.0877	0

Note: Marginal effects significant with $p<0.01$.

Figure A.8.1. GDP per capita growth rate by type of technological transformation: comparison between the 2007-2012 and 2013-2017 periods

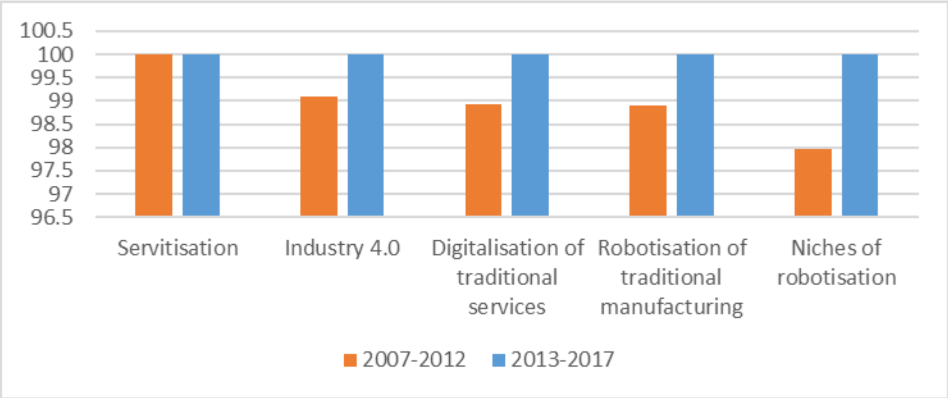


Figure A.8.2. Impact of robot adoption in 'technology' manufacturing sectors on GDP per capita growth by type of technological transformation: comparison between the 2007-2012 and 2013-2017 periods

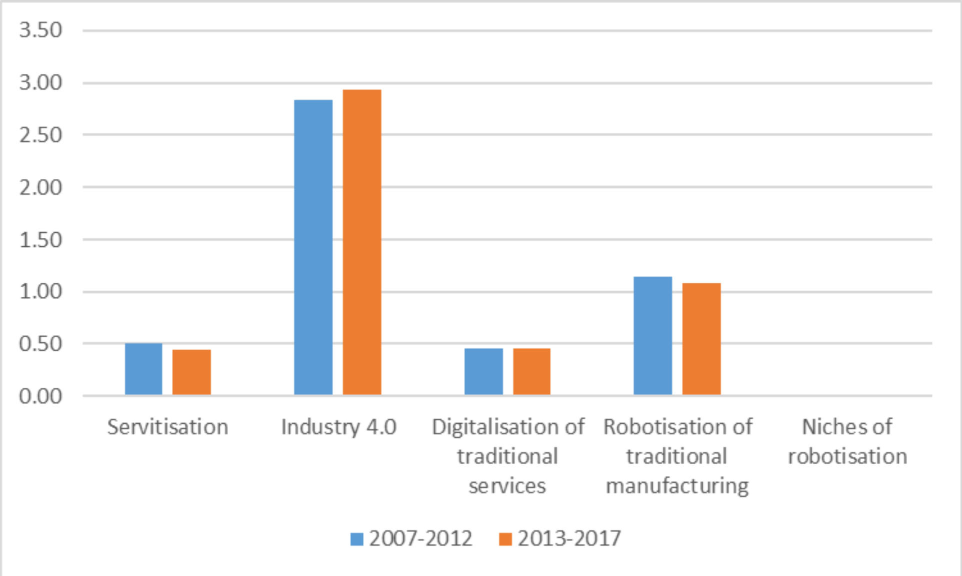


Figure A.8.3. Impact of robot adoption in 'induced' manufacturing sectors on GDP per capita growth by type of technological transformation: comparison between the 2007-2012 and 2013-2017 periods

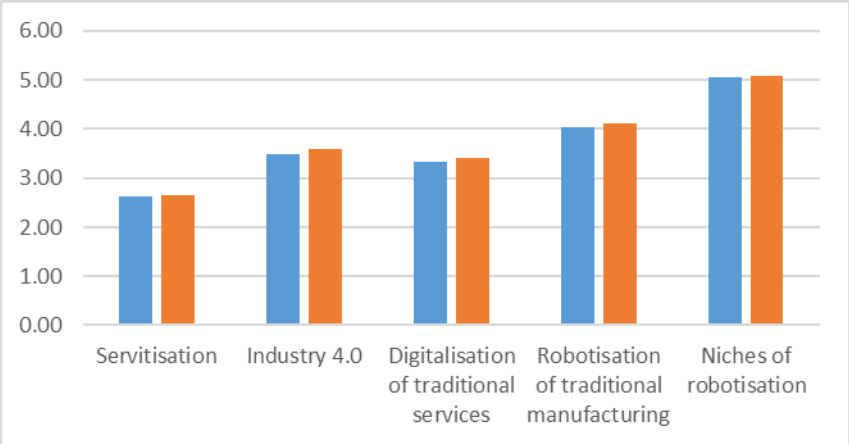


Figure A.8.4. Impact of online sales adoption in 'induced' services on GDP per capita growth by type of technological transformation: comparison between the 2007-2012 and 2013-2017 periods

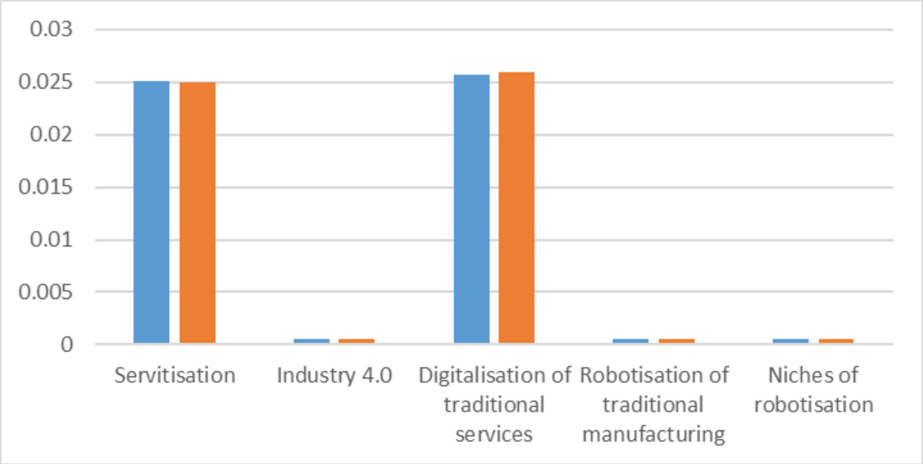


Figure A.8.5. Impact on GDP per capita by type of technological transformation and adoption intensity, 2013-2017

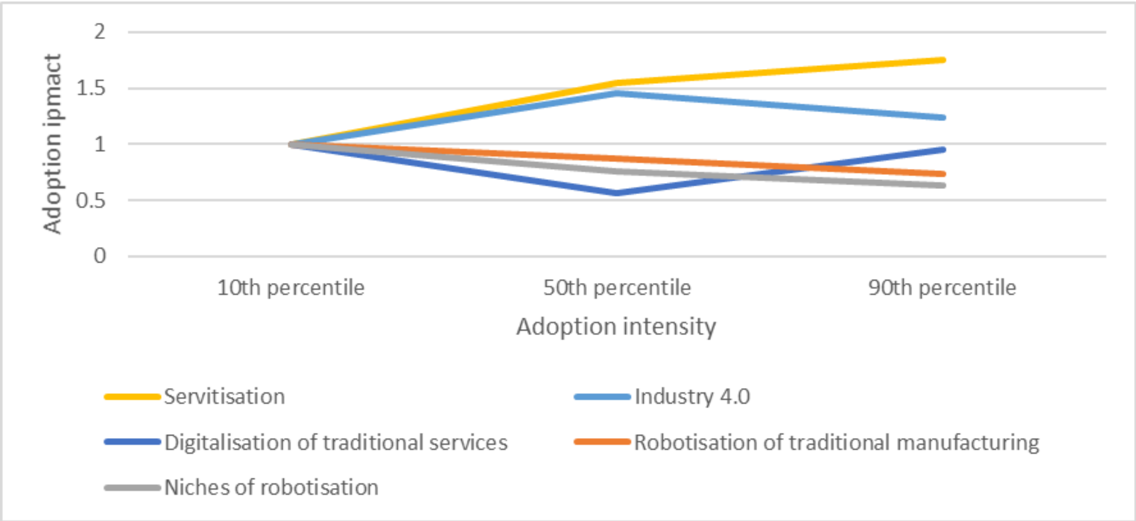


Table A:8.4. Impact of 4.0 technologies adoption on productivity growth, 2007-2012 and 2013-2017 periods

Dependent variable: Annual average productivity growth rate			
Labout productivity (log)	-0.0189***	-0.0199***	-0.0178***
	(0.003)	(0.003)	(0.003)
Urbanisation	0.0042**	0.0046***	0.0030*
	(0.002)	(0.002)	(0.002)
Employment in service	-0.0245***	-0.0182***	-0.0174**
	(0.005)	(0.005)	(0.007)
Employment in manufacturing	0.0420**	0.0322**	0.0301*
	(0.019)	(0.016)	(0.017)
FDI	-0.0000	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)
Quality of government	0.0025***	0.0035***	0.0035***
	(0.001)	(0.001)	(0.001)
Education	0.0003***	0.0004***	0.0003***
	(0.000)	(0.000)	(0.000)
Trademark intensity	0.0262***	0.0274***	0.0281***
	(0.008)	(0.009)	(0.008)
Industry 4.0	-0.0040	-0.0083**	-0.0035
	(0.004)	(0.004)	(0.004)
Digitalisation of traditional services	-0.0021	-0.0038	-0.0010
	(0.003)	(0.003)	(0.003)
Robotisation of traditional manufacturing	-0.0058*	-0.0084**	-0.0037
	(0.003)	(0.004)	(0.003)
Niches of robotisation	-0.0027	-0.0058	-0.0020
	(0.003)	(0.004)	(0.003)
Specialization in ‘technology’ manufacturing sectors’	-0.0049**		
	(0.002)		
Specialization in ‘induced’ manufacturing sectors’		0.0055	
		(0.004)	
Specialization in ‘induced’ services			-0.0139**
			(0.006)
Robot adoption in ‘technology’ manufacturing sectors	-0.4457		
	(0.377)		
Robot adoption in ‘induced’ manufacturing sectors		-0.3825	
		(0.899)	
Online sales adoption in ‘induced services			-0.0003*
			(0.000)
Specialization in ‘technology’ manufacturing sectors*robot adoption in ‘technology’manufacturing sectors	1.3020***		
	(0.399)		
Specialization in ‘induced manufacturing sectors*robot adoption in ‘induced’ manufacturing sectors		2.8557**	
		(1.240)	
Specialization in ‘induced’ services *online sales adoption in ‘induced’ services			0.0003**
			(0.000)
EU15 countries	-0.0030	-0.0028	-0.0011
	(0.003)	(0.003)	(0.003)
Dummy period = 2013-2017	0.0202***	0.0112**	0.0150***
	(0.005)	(0.005)	(0.004)
Constant	0.0220	0.0227	-0.3622
	(0.039)	(0.104)	(0.337)
Wald test – spatial lag of the dependent variable (p-value), SDM	0.194	0.215	0.110
Wald test (joint) – spatial lag of the	0.085	0.03	0.001

independent variables (p-value), SDM			
Wald test – spatial error (p-value), SEM	0.945	0.898	0.786
R2	0.41	0.40	0.40

Note: N = 522. Robust standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Spatially lagged independent variables included though not displayed in all models. Servitisation is the reference case.

Table A.8.5. Marginal effects of 4.0 technologies adoption on productivity growth on average and by types of technological transformation, 2007-2012 and 2013-2017 periods

	Robot adoption in 'technology' manufacturing sectors	**Robot adoption in 'induced' manufacturing sectors**	**Online sales adoption in 'induced' services**
2007-2012			
Average	0.795	2.549	0
Servitisation	0.349	1.328	0
Industry 4.0	2.690	2.513	0
Digitalisation of traditional services	0	2.273	0
Robotisation of traditional manufacturing	0.988	3.242	0
Niches of robotisation	0	4.664	0
2013-2017			
Average	0.784	2.641	0
Servitisation	0	1.351	0
Industry 4.0	2.784	2.655	0
Digitalisation of traditional services	0	2.376	0
Robotisation of traditional manufacturing	0.928	3.347	0
Niches of robotisation	0	4.698	0

Note: Marginal effects significant with p<0.01.

Figure A.8.6. Impact of robot adoption in 'technology' manufacturing sectors on productivity growth by type of technological transformation: comparison between the 2007-2012 and 2013-2017 periods

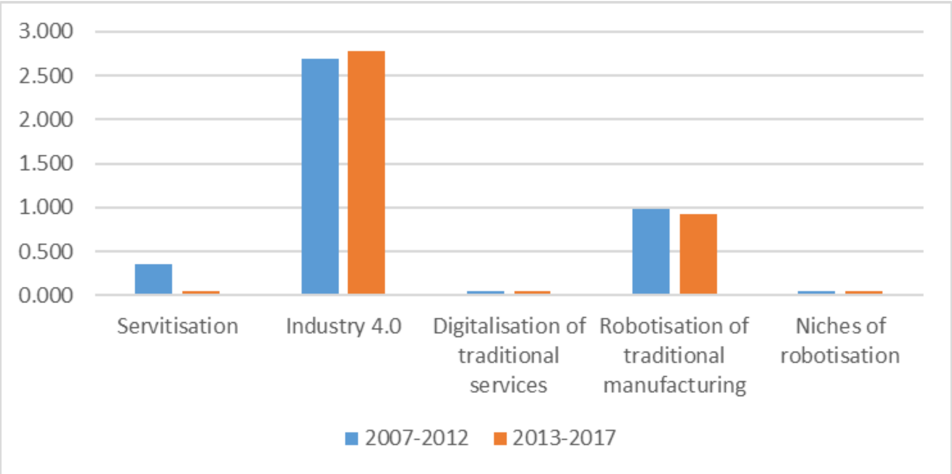


Figure A.8.7. Impact of robot adoption in 'induced' manufacturing sectors on productivity growth by type of technological transformation: comparison between the 2007-2012 and 2013-2017 periods

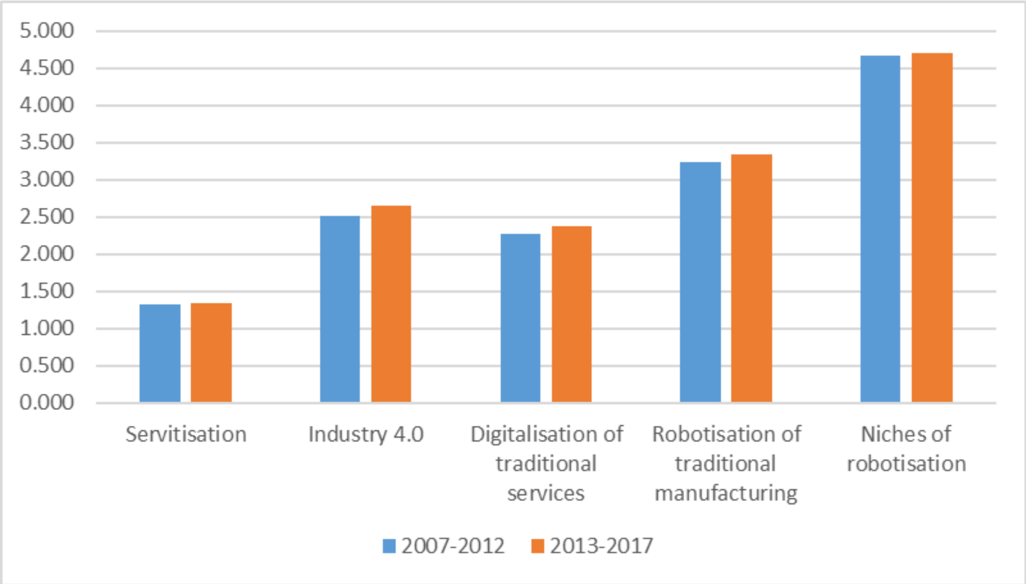


Figure A.8.8. Impact on productivity growth by type of technological transformation and adoption intensity, 2007-2012

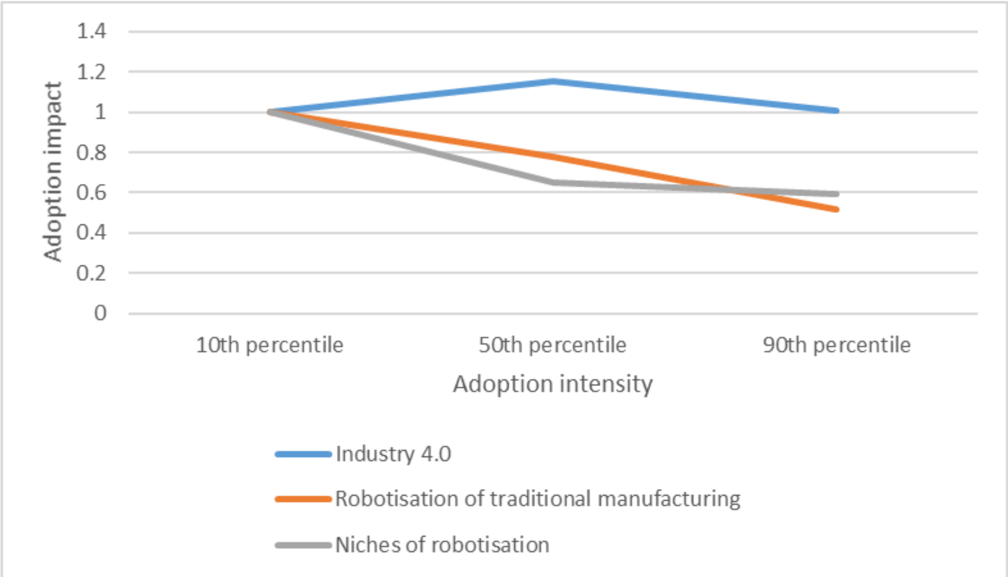


Table A.8.6. Impact of 4.0 technologies creation on productivity growth, 2007-2012 and 2013-2017 periods

Dependent variable: Annual average productivity growth rate			
Labout productivity (log)	-0.0177***	-0.0179***	-0.0178***
	(0.003)	(0.003)	(0.003)
Urbanisation	0.0043***	0.0042***	0.0041**
	(0.002)	(0.002)	(0.002)
Employment in service	-0.0264***	-0.0260***	-0.0259***
	(0.005)	(0.005)	(0.005)
Employment in manufacturing	0.0162	0.0154	0.0147
	(0.010)	(0.010)	(0.010)
FDI	-0.0000	-0.0000	-0.0000
	(0.000)	(0.000)	(0.000)
Quality of government	0.0023***	0.0021**	0.0021**
	(0.001)	(0.001)	(0.001)
Education	0.0003***	0.0003***	0.0003***
	(0.000)	(0.000)	(0.000)
Trademark intensity	0.0212***	0.0226***	0.0222***
	(0.007)	(0.007)	(0.006)
Technology falling behind regions	0.0027	-0.0006	-0.0006
	(0.003)	(0.002)	(0.002)
Technology leader regions	0.0035*	0.0029	0.0029
	(0.002)	(0.002)	(0.003)
New islands of innovation regions	0.0033	0.0031	0.0029
	(0.002)	(0.002)	(0.002)
3.0 patent intensity		0.0139	-0.0136
		(0.077)	(0.067)
4.0 patent intensity	0.6734	-0.0845	-0.0656
	(0.653)	(0.105)	(0.120)
4.0 patent intensity*Technology falling behind regions	-2.2556		
	(1.570)		
4.0 patent intensity 4.0*Technology leader regions	-0.6102		
	(0.650)		
4.0 patent intensity 4.0*New islands of innovation regions	-0.4463		
	(0.727)		
3.0 patent intensity*4.0 patent intensity		-0.1129	0.2259
		(1.041)	(1.309)
3.0 patent intensity* Period 2013-2017		0.0897	0.1099
		(0.106)	(0.098)
4.0 recombination patent intensity* Period 2013-2017		0.3154**	
		(0.136)	
4.0 applicative recombination patens* Period 2013-2017			0.4177***
			(0.157)
3.0 patent intensity * 4.0 recombination patent intensity * Period 2013-2017		-3.3080*	
		(1.756)	
3.0 patent intensity * 4.0 applicative recombination patent intensity * Period 2013-2017			-5.4194*
			(2.817)
EU15 countries	-0.0024	-0.0028	-0.0029
	(0.003)	(0.003)	(0.003)
Dummy period = 2013-2017	0.0056***	0.0036**	0.0034*
	(0.002)	(0.002)	(0.002)
Constant	-0.0226***	-0.0156**	-0.0152**
	(0.006)	(0.006)	(0.006)
Wald test – spatial lag of the dependent variable (p-value), SDM	0.294	0.297	0.295
Wald test (joint) – spatial lag of the independent	0.354	0.326	0.304

variables (p-value), SDM			
Wald test – spatial error (p-value), SEM	0.753	0.811	0.800
R2	0.38	0.37	0.37

Note: N = 524. Robust standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Low tech regions are the reference case.

Table A:8.7. Marginal effects of 4.0 technologies creation on productivity growth on average and by type of 4.0 inventing region, 2007-2017

	4.0 patents	**4.0 recombination patents**	**4.0 applicative recombination patents**
Average	0	0	0
Low tech	0	0.226	0.345
Technology falling behind	0	0.216	0.330
New islands of innovation	0	0.222	0.338
Technology leader	0.0632	0	0

Note: Marginal effects significant with p<0.10.

9 The social impact of technological transformations on regional labour markets

In order to assess the impact of 4.0 technologies adoption on regional societies, and specifically on regional labour markets, we adopted an econometric approach.

As discussed in the main report, the measurement of the social impact is a rather complex task, since it depends on several intertwined dimensions:

- the type of sectors involved (and therefore on the type of transformation),
- the type of technology adopted,
- the categories of jobs considered (high- vs low-skill jobs),
- and the period of time.

The following analyses take all these elements explicitly into account. The analysis is carried out for two different periods of time, the crisis period (2007-2012) and the recovery one (2013-2017).

As an illustrative example, the impact on employment level (respectively share of high-skill or shre of low-skill jobs) has been measured by estimating the following equation, through (spatial) econometric tools:

$$EMPL_{r,t} = F(X_{r,t}) + \varepsilon_{r,t} \qquad \text{eq. 2}$$

Where $EMPL_r$ is the regional employment level made dependent of a series of regional level determinants X_r and a random error term ε_r, and *t* the period considered, 2007-2012 and 2013-2017.

According to the existing literature in the field, the regional level determinants, X_r, includes variables accounting for the following aspects: the initial level of population; the share of employment in service and in manufacturing; the regional population educational attainment level; the regional innovativeness level; the FDI penetration rate; the quality of government; the regional settlement structure; **and new to the literature the regional adoption of 4.0 technologies and share of jobs at high risk of automation**. The econometric analysis follows the same approach and steps described in Section 8; all details are reported there.

Table A.9.1 reports the description, measurement and sources of the variables used in the regressions. Table A.9.2 reports the main results of employment level estimations and Table A.9.3 the computation of marginal effects by type of technological transformation and period (Map 5.1; Figures A.9.1-A.9.2). Table A.9.4 reports the main results on high-skill employment share estimations and Table A.9.5 the computation of marginal effects by type of technological transformation and period (Maps 5.2-5.3; Figures A.9.3-A.9.4). Table A.9.6 reports the main results on low-skill employment share estimations and Table A.9.7 the computation of marginal effects by type of technological transformation and period (Maps 5.4-5.6; Figures A.9.5-A.9.7). Finally, Maps A.9.1 and A.9.2 present the regional creation and displacement of high-skill and low-skill jobs, respectively, and are summarised in Map 5.7 in the main report.

Table A:9.1. Variables description

	Measurement	Years	Source
Dependent variables			
Employment level	Log of thousands of persons	2012; 2018	EUROSTAT
Share of employment in low-skill jobs	Share of employees in ISCO 8 and 9 occupations	2012; 2018	EUROSTAT
Share of employment in high-skill jobs	Share of employees in ISCO 1 and 2 occupations	2012; 2018	EUROSTAT
Explanatory variables			
Population	Log of thousands inhabitants	2007; 2013	EUROSTAT
Employment level	Log of thousands of persons	2007; 2013	EUROSTAT
Employment in the manufacturing sector	Share of total employment	2007; 2013	EUROSTAT
Employment in the private service sector	Share of total employment	2007; 2013	EUROSTAT
Urbanisation	Share of population living in metropolitan areas	2007; 2013	EUROSTAT
FDI penetration rate	Amount of FDIs per 1,000 inhabitants	Two values: 2003-2005 and 2005-2007	FDI-Regio, Bocconi-ISLA
Quality of government	European Quality of Government Index	2010; 2013	Charron et al. (2014)
Education	Share of 25-64 age population with tertiary education	2007; 2013	EUROSTAT
Patent intensity	Number of patents per 1,000 inhabitants	Average 2004-2007 and 2007-2011	OECD-REGPAT, EUROSTAT
Trademark intensity	Number of trademarks per 1,000 inhabitants	Average 2008-2010 and 2010-2012	EUROSTAT
Specialisation in ‘technology’ manufacturing sectors	LQ on employment in ‘technology’ manufacturing sectors*	Average 2008-2010 and 2011-2013	EUROSTAT
Specialisation in ‘induced’ manufacturing sectors	LQ on employment in ‘induced’ manufacturing sectors*	Average 2008-2010 and 2011-2013	EUROSTAT
Specialisation in ‘induced’ services	LQ on employment in ‘induced’ services *	Average 2008-2010 and 2011-2013	EUROSTAT
Robot adoption in ‘technology’ manufacturing sectors	Number of robots per employee in ‘technology’ manufacturing sectors	Average 2008-2010 and 2011-2013	IFR, EUROSTAT
Robot adoption in ‘induced’ manufacturing sectors	Number of robots per employee in ‘induced’ manufacturing sectors	Average 2008-2010 and 2011-2013	IFR, EUROSTAT
Online sales in ‘induced’ services	Share of firms selling online, at least 1% of turnover	Average 2009-2011 and 2011-2013	EUROSTAT
High risk of automation	Share of jobs at high risk of automation***	2011	OECD-PIIAC; EUROSTAT

Note: * for the definition of ‘technology’, ‘carrier’ and ‘induced’ sectors, see Table A.4.1. **For the measurement of LQ, please see Section 4.2. See Section 6.

Table A:9.2. Impact of 4.0 technologies adoption on employment level, 2007-2012 and 2013-2018 periods

Dependent variable: employment level			
Population (log)	0.9855***	0.9866***	0.9925***
	(0.009)	(0.010)	(0.009)
Employment in service	0.0462	0.0557	0.0340
	(0.040)	(0.037)	(0.037)
Employment in manufacturing	-0.0121	0.0084	0.0996
	(0.124)	(0.129)	(0.131)
Urbanisation	0.0189	0.0339*	0.0355*
	(0.017)	(0.020)	(0.020)
FDI	0.0000	0.0000	-0.0000
	(0.000)	(0.000)	(0.000)
Quality of government	0.0448***	0.0461***	0.0467***
	(0.010)	(0.010)	(0.011)
Education	0.0016	0.0011	0.0019*
	(0.001)	(0.001)	(0.001)
Patent intensity	189.5818***	266.8877***	261.0941***
	(44.588)	(49.728)	(47.342)
Industry 4.0	-0.0509*	-0.0159	0.0172
	(0.031)	(0.027)	(0.028)
Digitalisation of traditional services	-0.0504***	-0.0537***	-0.0425**
	(0.018)	(0.020)	(0.019)
Robotisation of traditional manufacturing	-0.0487**	-0.0335	-0.0023
	(0.023)	(0.027)	(0.027)
Niches of robotisation	-0.0462*	-0.0498*	0.0008
	(0.026)	(0.030)	(0.028)
Sectoral specialisation	0.0134	0.0414	0.0602**
	(0.012)	(0.032)	(0.029)
Sectoral specialization*Period 2013-2018	0.0059	-0.0381***	0.0379***
	(0.004)	(0.013)	(0.014)
High risk of automation	-0.8450***	-1.1416***	-1.1713***
	(0.204)	(0.260)	(0.351)
4.0 technologies adoption	-9.3742***	-34.4343**	-0.0022
	(3.595)	(15.995)	(0.001)
High risk of automation*Robot adoption in 'technology' manufacturing sectors	26.5259		
	(18.673)		
High risk of automation*Robot adoption in 'induced' manufacturing sectors		198.5374**	
		(99.268)	
High risk of automation*Online sales adoption in 'induced' services			0.0128
			(0.008)
High risk of automation*Period 2013-2018	0.3666***	0.4608***	0.2945***
	(0.055)	(0.073)	(0.105)
Robot adoption in 'technology' manufacturing sectors *Period 2013-2018	5.3059***		
	(1.963)		
Robot adoption in 'induced' manufacturing sectors *Period 2013-2018		8.3712	
		(7.919)	
Online sales adoption in 'induced' services *Period 2013-2018			-0.0003
			(0.001)
High risk of automation*Robot adoption in 'technology' manufacturing sectors *Period 2013-2018	-14.6716		
	(9.450)		
High risk of automation*Robot adoption in 'induced' manufacturing sectors *Period 2013-2018		-44.6663	
		(42.562)	
High risk of automation*Online sales adoption in 'induced' services *Period 2013-2018			0.0009
			(0.004)
Constant	-6.3251***	-6.3820***	-4.3359**
	(1.388)	(1.631)	(2.166)

Period 2013-2018	-0.0116 (0.033)	-0.0178 (0.042)	-0.0445 (0.047)
Wald test – spatial lag of the dependent variable (p-value), SDM	0.165	0.343	0.205
Wald test (joint) – spatial lag of the independent variables (p-value), SDM	0.056	0.004	0.006
Wald test – spatial error (p-value), SEM	0.846	0.542	0.840
R2	0.99	0.99	0.99

Note: N = 524. Robust standard errors in parentheses. * p < 0.10, ** p < 0.05, *** p < 0.01. Country and Eurozone dummy variable included though not displayed. Spatially-lagged independent variables included though not displayed. Servitisation is the reference case.

Table A.9.3. Marginal effects of 4.0 technologies adoption on employment level on average and by type of technological transformation, 2007-2012 and 2013-2018 periods

	Robot adoption in 'technology' manufacturing sectors	**Robot adoption in 'induced' manufacturing sectors**	**Online sales adoption in 'induced' services**
2007-2012			
Average	-4.985	0	0
Servitisation	-6.042	0	0
Industry 4.0	-5.062	0	0
Digitalisation of traditional services	-5.601	0	0
Robotisation of traditional manufacturing	-4.532	0	0
Niches of robotisation	0	0	0
2013-2018			
Average	-2.084*	0	0
Servitisation	-2.538	0	0
Industry 4.0	-2.117	0	0
Digitalisation of traditional services	-2.349	0	0
Robotisation of traditional manufacturing	-1.889	0	0
Niches of robotisation	0	0	0

Note: Marginal effects significant with p<0.01. * Marginal effects significant with p<0.10.

Figure A.9.1. Impact of technology adoption on employment level by type of technology: comparison between the 2007-2012 and 2013-2018 periods

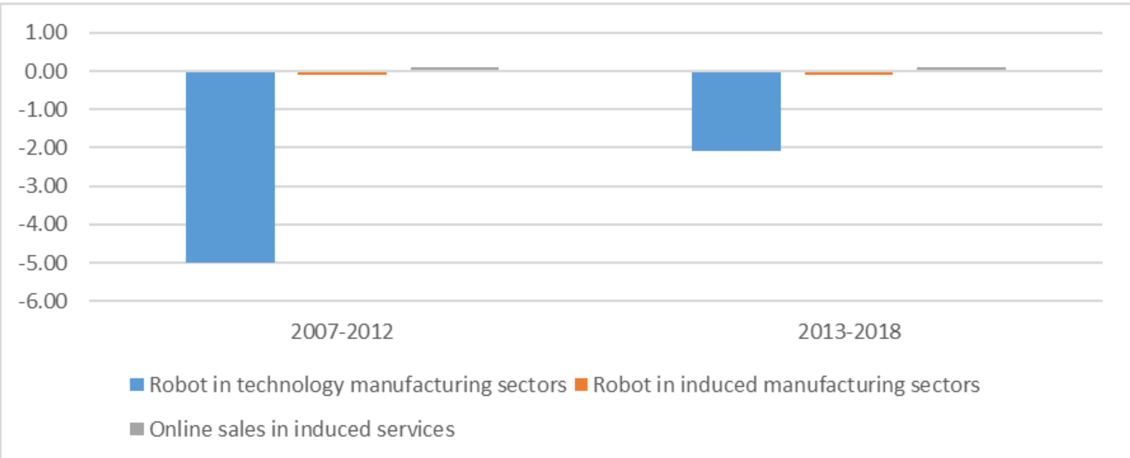


Figure A.9.2. Impact of robot adoption in 'technology' manufacturing sectors on employment level by type of technological transformation: comparison between the 2007-2012 and 2013-2018 periods

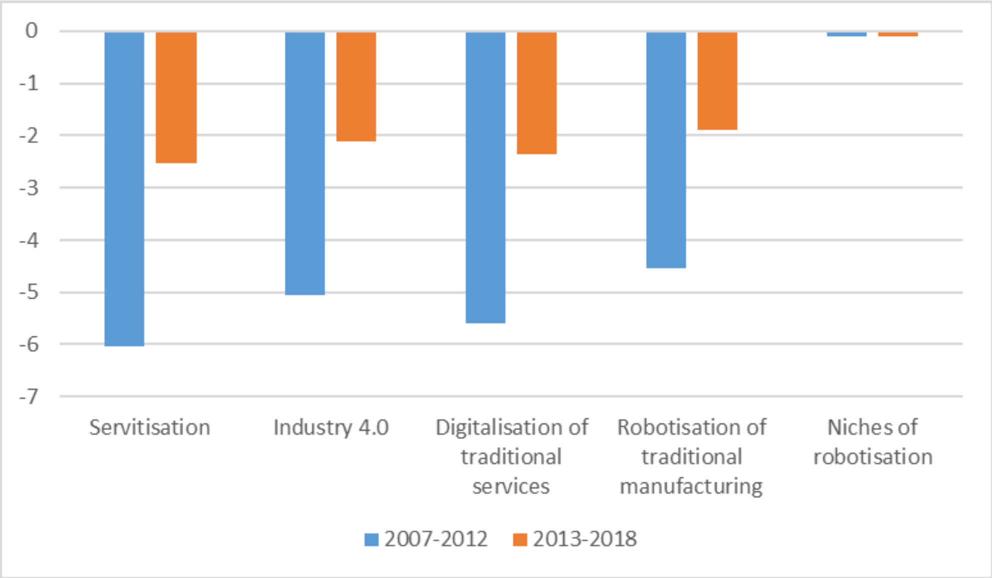


Table A.9.4. Impact of 4.0 technologies adoption on low-skill employment share, 2007-2012 and 2013-2018 periods

Dependent variable: share of low-skill employment			
Employment (log)	0.0120***	0.0130***	0.0123***
	(0.003)	(0.003)	(0.003)
Employment in manufacturing	0.2057***	0.2119***	0.1681***
	(0.046)	(0.047)	(0.047)
Employment in service	-0.0489***	-0.0508***	-0.0444***
	(0.010)	(0.011)	(0.011)
Urbanisation	0.0084	0.0096	0.0036
	(0.008)	(0.009)	(0.008)
FDI	-0.0000**	-0.0000**	-0.0000***
	(0.000)	(0.000)	(0.000)
Quality of government	0.0013	0.0021	-0.0003
	(0.003)	(0.003)	(0.003)
Education	0.0000	-0.0001	-0.0001
	(0.000)	(0.000)	(0.000)
Patent intensity	-116.5896***	-112.5882***	-116.1295***
	(21.926)	(19.754)	(18.227)
High risk of automation	0.0990**	0.1685***	0.1925**
	(0.049)	(0.058)	(0.088)
Industry 4.0	0.0249**	0.0295***	0.0275***
	(0.011)	(0.010)	(0.010)
Digitalisation of traditional services	0.0224***	0.0249***	0.0237***
	(0.006)	(0.006)	(0.006)
Robotisation of traditional manufacturing	0.0289***	0.0341***	0.0320***
	(0.008)	(0.009)	(0.008)
Niches of robotisation	0.0193	0.0225	0.0246*
	(0.012)	(0.014)	(0.013)
Specialization in 'technology' manufacturing sectors'	-0.0037		
	(0.005)		
Specialization in 'induced' manufacturing sectors'		-0.0136	
		(0.011)	
Specialization in 'induced' service sectors'			0.0098
			(0.010)
Specialization in 'technology' manufacturing sectors*Period 2013-2018'	0.0039**		
	(0.002)		
Specialization in 'induced' manufacturing sectors'*Period 2013-2018		0.0093**	
		(0.005)	
Specialization in 'induced' service sectors'*Period 2013-2018			-0.0148***
			(0.006)
Robot adoption in 'technology' manufacturing sectors	-0.3653		
	(1.594)		
Robot adoption in 'induced' manufacturing sectors		1.7585	
		(5.263)	
Online sales adoption in 'induced service sectors			0.0013**
			(0.001)
High risk of automation*Robot adoption in 'technology' manufacturing sectors	-1.2945		
	(10.709)		
High risk of automation*Robot adoption in 'induced' manufacturing sectors		-56.4160*	

		(33.028)	
High risk of automation*Online sales adoption in ‘induced’ service sectors			-0.0033
			(0.003)
High risk of automation*Period 2013-2018	0.0385	0.0169	-0.0945**
	(0.026)	(0.035)	(0.047)
Robot adoption in ‘technology’ manufacturing sectors *Period 2013-2018	0.5613		
	(1.008)		
Robot adoption in ‘induced’ manufacturing sectors *Period 2013-2018		3.2717	
		(3.115)	
Online sales adoption in ‘induced’ service sectors *Period 2013-2018			-0.0009**
			(0.000)
High risk of automation*Robot adoption in ‘technology’ manufacturing sectors *Period 2013-2018	-0.5976		
	(5.991)		
High risk of automation*Robot adoption in ‘induced’ manufacturing sectors *Period 2013-2018		-2.3609	
		(19.057)	
High risk of automation*Online sales adoption in ‘induced’ service sectors *Period 2013-2018			0.0037**
High risk of automation*Robot adoption in ‘technology’ manufacturing sectors *Period 2013-2018			(0.002)
EU15	0.0039	0.0105	-0.0079
	(0.009)	(0.008)	(0.009)
Period 2013-2018	-0.0295***	-0.0413***	0.0226*
	(0.006)	(0.015)	(0.013)
Constant	0.0863***	0.5784	-0.0070
	(0.029)	(0.365)	(0.040)
Wald test – spatial lag of the dependent variable (p-value), SDM	0.913	0.673	0.966
Wald test (joint) – spatial lag of the independent variables (p-value), SDM	0.243	0.092	0.304
Wald test – spatial error (p-value), SEM	0.150	0.308	0.592
R2	0.53	0.58	0.55

Note: N = 524. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Spatially-lagged independent variables included though not displayed in model 2.

Table A.9.5. Marginal effects of 4.0 technologies adoption on low-skill employment share on average and by type of technological transformation, 2007-2012 and 2013-2018 periods

	Robot adoption in 'technology' manufacturing sectors	Robot adoption in 'induced' manufacturing sectors	Online sales adoption in 'induced' services
2007-2012			
Average	0	-7.768	0.0774
Servitisation	0	-5.602	0.0902
Industry 4.0	0	-7.611	0.0783
Digitalisation of traditional services	0	-6.505	0.0849
Robotisation of traditional manufacturing	0	-8.696	0.0719
Niches of robotisation	0	-12.442	0.0497
2013-2018			
Average	0	-4.895	0.0475**
Servitisation	0	0	0.0462**
Industry 4.0	0	-4.732	0.0474**
Digitalisation of traditional services	0	-3.579**	0.0467**
Robotisation of traditional manufacturing	0	-5.862	0.0481**
Niches of robotisation	0	-9.764*	0.0504**

Note: Marginal effects significant with p<0.01. * Marginal effects significant with p<0.10. * Marginal effects significant with p<0.05.

Figure A.9.3. Impact of robot adoption in 'induced' manufacturing sectors on low-skill employment share by type of technological transformation: comparison between the 2007-2012 and 2013-2018 periods

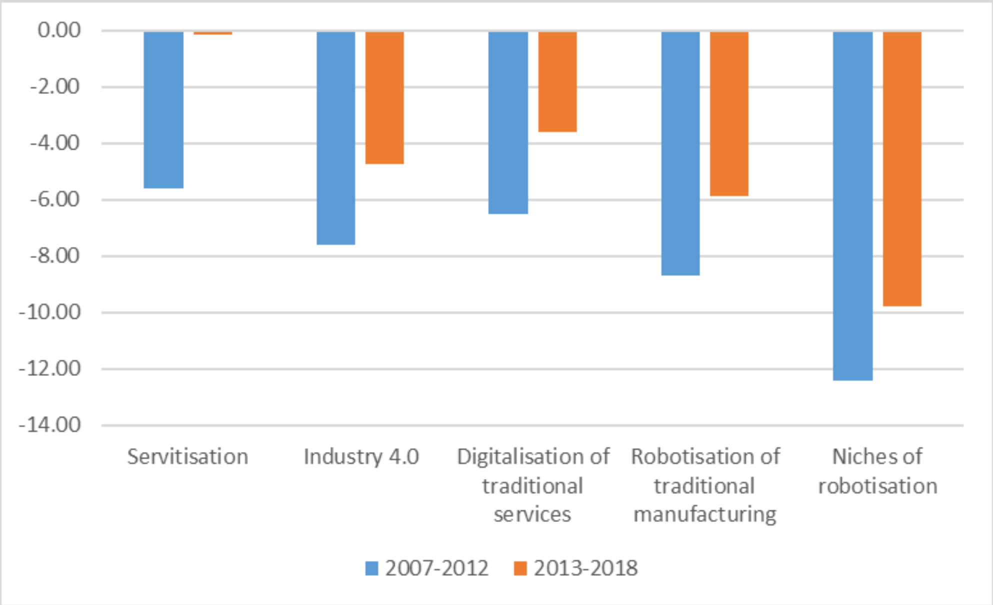


Figure A.9.4. Impact of online sales adoption in 'induced' services on low-skill employment share by type of technological transformation: comparison between the 2007-2012 and 2013-2018 periods

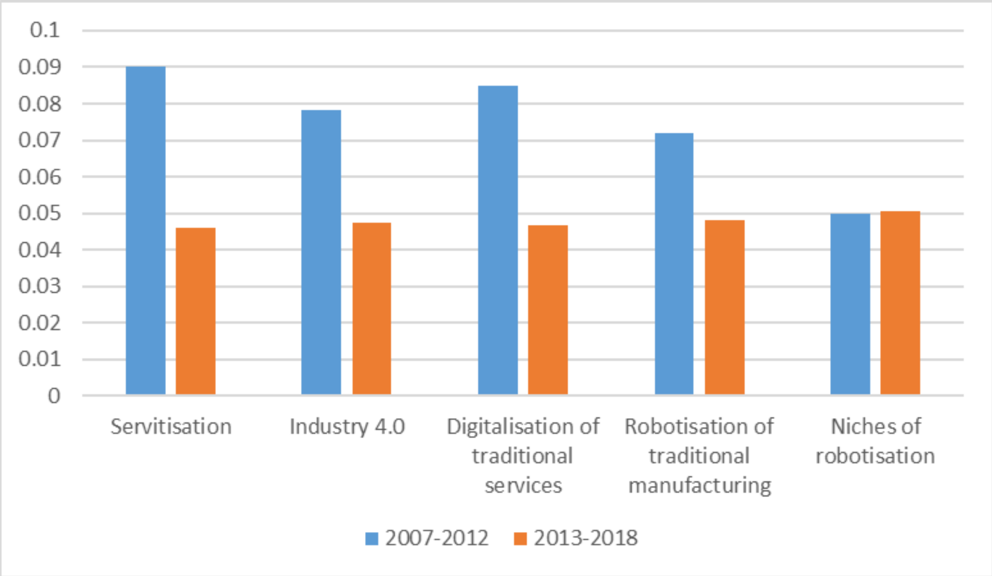


Table A.9.6. Impact of 4.0 technologies adoption on high-skill employment share, 2007-2012 and 2013-2018 periods

Dependent variable: share of high-skill employment			
Population (log)	0.0031	0.0045	0.0001
	(0.003)	(0.003)	(0.003)
Employment in service	-0.0938**	-0.0574	-0.1269***
	(0.042)	(0.039)	(0.041)
Employment in manufacturing	0.0359*	0.0110	0.0565***
	(0.019)	(0.018)	(0.020)
Urbanisation	-0.0181***	-0.0185***	-0.0219***
	(0.006)	(0.006)	(0.006)
FDI	0.0000***	0.0000*	0.0000***
	(0.000)	(0.000)	(0.000)
Quality of government	-0.0102***	-0.0110***	-0.0114***
	(0.003)	(0.003)	(0.003)
Education	0.0053***	0.0049***	0.0053***
	(0.000)	(0.000)	(0.000)
Patent intensity	48.1677***	55.1967***	35.3953***
	(17.569)	(17.047)	(13.703)
High risk of automation	-0.2315***	-0.2108***	-0.2177***
	(0.033)	(0.037)	(0.054)
Industry 4.0	-0.0384***	-0.0318***	-0.0485***
	(0.010)	(0.009)	(0.009)
Digitalisation of traditional services	-0.0201***	-0.0137**	-0.0201***
	(0.006)	(0.006)	(0.006)
Robotisation of traditional manufacturing	-0.0392***	-0.0228***	-0.0456***
	(0.008)	(0.008)	(0.008)
Niches of robotisation	-0.0386***	-0.0046	-0.0465***
	(0.009)	(0.010)	(0.009)
Specialization in ‘technology’ manufacturing sectors’	-0.0058		
	(0.005)		
Specialization in ‘induced’ manufacturing sectors’		-0.0470***	
		(0.009)	
Specialization in ‘induced’ service sectors’			-0.0225**
			(0.011)
Specialization in ‘technology’ manufacturing sectors*Period 2013-2018’	0.0007		
	(0.002)		
Specialization in ‘induced’ manufacturing sectors’*Period 2013-2018		-0.0104	
		(0.007)	
Specialization in ‘induced’ service sectors’*Period 2013-2018			-0.0184**
			(0.007)
Robot adoption in ‘technology’ manufacturing sectors	-1.6339		
	(1.067)		
Robot adoption in ‘induced’ manufacturing sectors		-15.0220***	
		(4.212)	
Online sales adoption in ‘induced service sectors			0.0001
			(0.000)
High risk of automation*Robot adoption in ‘technology’ manufacturing sectors	0.8800		
	(4.933)		
High risk of automation*Robot adoption in ‘induced’ manufacturing sectors		31.4010	

		(24.868)	
			-0.0004
			(0.002)
High risk of automation*Period 2013-2018	-0.0213	0.0162	0.1656***
	(0.027)	(0.032)	(0.046)
Robot adoption in 'technology' manufacturing sectors *Period 2013-2018	1.2898	8.3792*	0.0020***
	(1.104)	(4.719)	(0.000)
Robot adoption in 'induced' manufacturing sectors *Period 2013-2018			
Online sales adoption in 'induced' service sectors *Period 2013-2018			
High risk of automation*Robot adoption in 'technology' manufacturing sectors *Period 2013-2018	-4.1081	-62.9541**	-0.0071***
	(6.149)	(27.233)	(0.002)
High risk of automation*Robot adoption in 'induced' manufacturing sectors *Period 2013-2018			
High risk of automation*Online sales adoption in 'induced' service sectors *Period 2013-2018			
High risk of automation*Robot adoption in 'technology' manufacturing sectors *Period 2013-2018			
EU15	-0.0325***	-0.0292***	-0.0366***
	(0.007)	(0.007)	(0.008)
Period 2013-2018	-0.0088	0.0056	-0.0520***
	(0.007)	(0.009)	(0.014)
Constant	0.1901***	0.2144***	0.2708***
	(0.029)	(0.030)	(0.038)
Wald test – spatial lag of the dependent variable (p-value), SDM	0.163	0.492	0.127
Wald test (joint) – spatial lag of the independent variables (p-value), SDM	0.721	0.891	0.548
Wald test – spatial error (p-value), SEM	0.123	0.749	0.197
R2	0.84	0.86	0.85

Note: N = 522. Robust standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Servitisation is the reference case.

Table A.9.7. Marginal effects of 4.0 technologies adoption on high-skill employment share on average and by type of technological transformation, 2007-2012 and 2013-2018 periods

	Robot adoption in 'technology' manufacturing sectors	Robot adoption in 'induced' manufacturing sectors	Online sales adoption in 'induced' services
2007-2012			
Average	-1.485	-9.362	0
Servitisation	-1.519	-10.703	0
Industry 4.0	-1.488	-9.456	0
Digitalisation of traditional services	-1.506	-10.164	0
Robotisation of traditional manufacturing	-1.471	-8.782	0
Niches of robotisation	-1.412	-6.455	0
2013-2018			
Average	-0.889	-12.281	0.094
Servitisation	-0.765	-10.621	0.117
Industry 4.0	-0.880	-11.609	0.095
Digitalisation of traditional services	-0.815	-11.048	0.107
Robotisation of traditional manufacturing	-0.942	-12.142	0.084
Niches of robotisation	-1.157	-13.985	0.044

Note: Marginal effects significant with $p<0.01$.

Figure A.9.5. Impact of robot adoption in 'technology' manufacturing sectors on high-skill employment share by type of technological transformation: comparison between the 2007-2012 and 2013-2018 periods

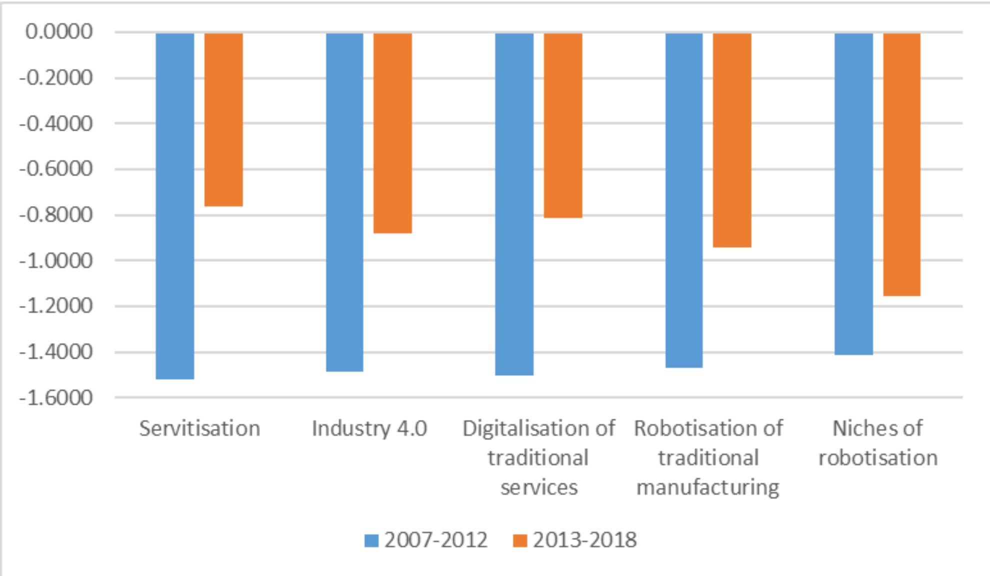


Figure A.9.6. Impact of robot adoption in 'induced' manufacturing sectors on high-skill employment share by type of technological transformation: comparison between the 2007-2012 and 2013-2018 periods

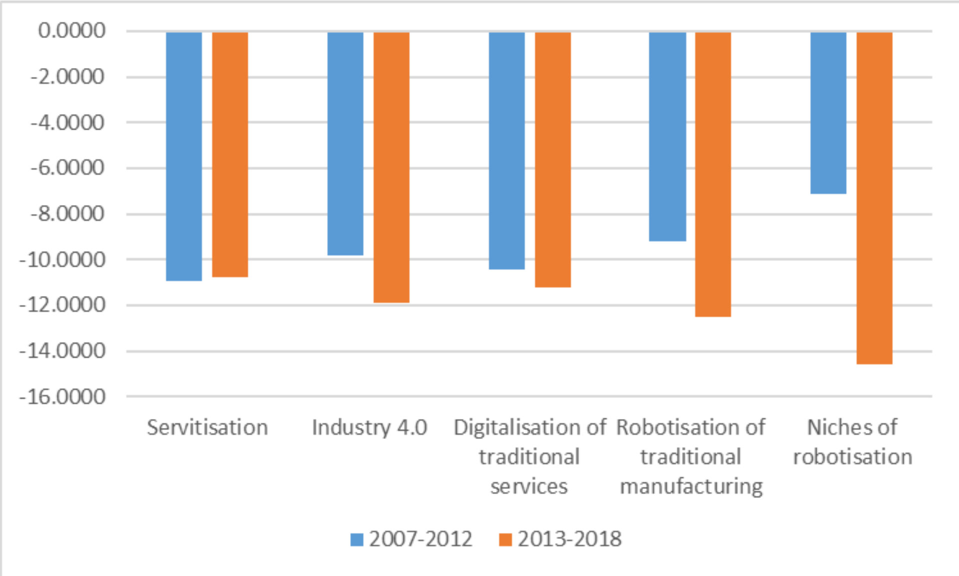
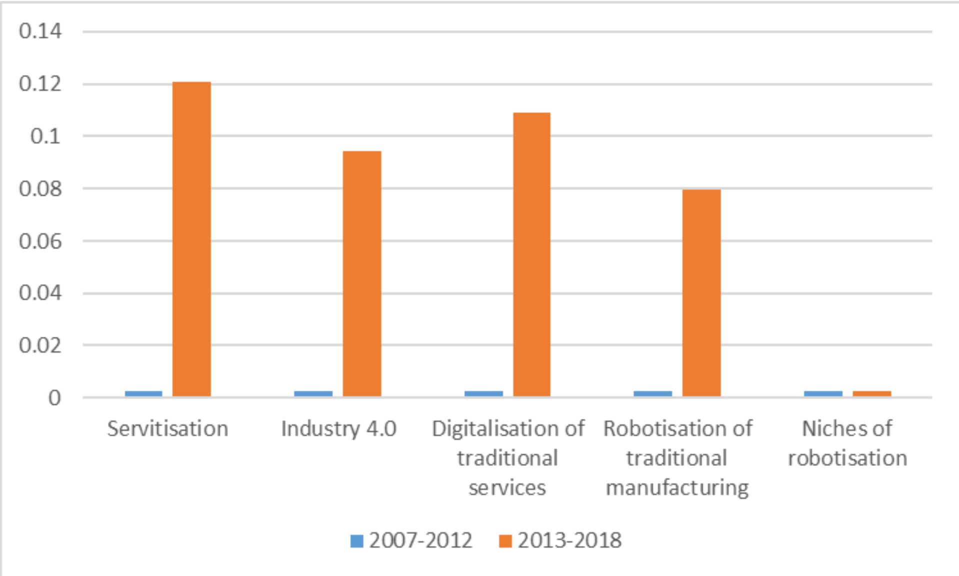


Figure A.9.7. Impact of online sales adoption in 'induced' services on high-skill employment share by type of technological transformation: comparison between the 2007-2012 and 2013-2018 periods



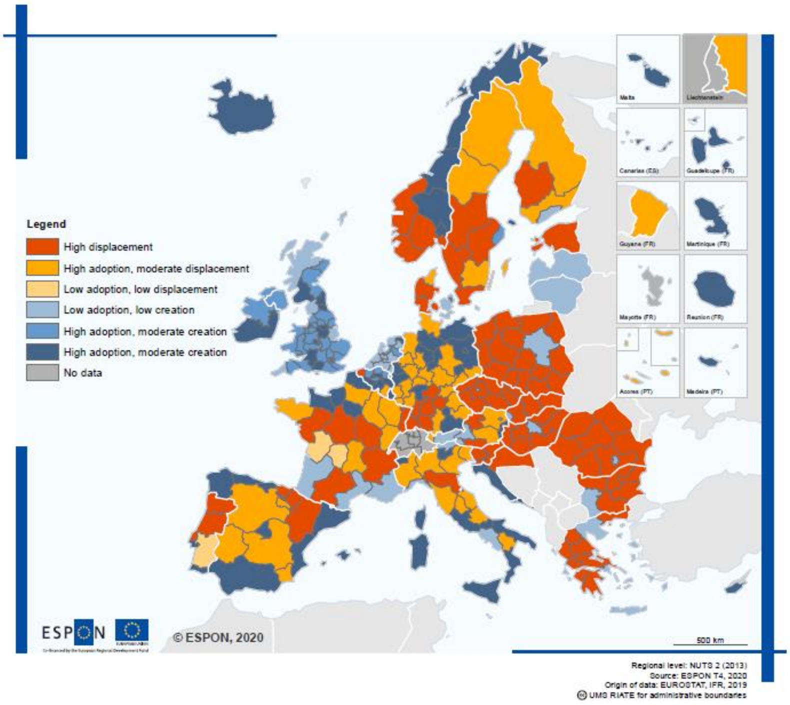
Within each type of technological transformation, **the impact of technology adoption on low-skill and high-skill employment is certainly not evenly distributed and can vary according to the intensity of technology adoption**. By looking at the degree of adoption and the adoption impact on employment at the same time within each type of technological transformation, regions can be defined as:

- **regions with no adoption and no labour market effects**, when regions have both an adoption and an impact below the average of their group. The regional economy and labour markets seem neutral with respect to the ongoing technological transformation;
- **regions with high adoption but limited labour market effects**, when regions have a lower than average impact and a higher than average adoption rate. The higher than average adoption rate does not generate comparable effects on regional labour markets. In the case of manufacturing-related technological transformations, displacement of jobs through robots takes place but moderately, suggesting the existence of sheltered labour markets and a limited displacement of jobs. In the case of service-related technological transformations, the creation of jobs through new digital activities takes place but moderately, suggesting the existence of weaknesses in the local entrepreneurial tissue to respond and to accommodate the job opportunities offered by the new technologies and a limited creation of new jobs;
- **regions with high labour market effects**, when regions have an impact higher than the group average, regardless their adoption rate, suggesting the existence of highly responsive local labour markets to technology adoption. In the case of manufacturing-related technological transformations, displacement of jobs through robots takes place at high rates. In the case of service-related technological transformations, the creation of jobs takes place at high rates.

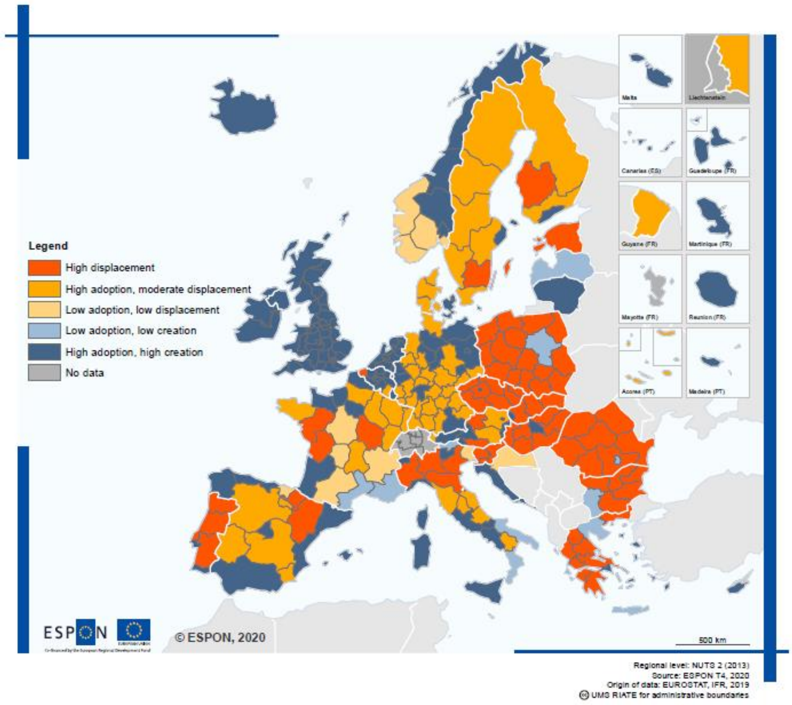
Applied to the case of low-skill employment, this classification shows interesting results. For what concerns manufacturing-related technological transformations, high displacement of low-skill jobs affects primarily Eastern countries, Portugal, Greece, and Northen Italy, with some sparce regions in Spain, France, Belgium, Sweden, Austria and Finland. Moderate displacement of low-skill jobs, instead, is taking place in Germany, Austria and Scandinavian countries. For what concerns service-related technological transformations, high creation of low-skill jobs is taking place primarily in UK, Ireland, the Netherlands, and most capital city regions (with some exceptions in Eastern countries) (Map A.9.1).

Applied to the case of high-skill employment, this classification highlights different situations depending on the type of technological transformation. For what concerns manufacturing-related transformations, high displacement of high-skill jobs primarily Eastern countries, and Greece, but also in Germany, France and Scandinavian countries, while it reduces in Italy and Portugal, France, Belgium, Sweden and Finland. Moderate displacement of high-skill jobs is taking place in several regions in Germany, Scandinavian countries, France, Spain and Italy. For what concerns service-related transformations, the number of regions showing limited impact is greater, suggesting, on average a greater increase of low-skill than of high-skill jobs (i.e. more gig than élite jobs). Moderate creation of high-skill jobs is taking place primarily in UK, Belgium, the Netherlands and the Stockolm region. High creation of high-skill jobs takes place primarily in Germany, Southern Italy, the Spanish costal regions and Belgium (Map A.9.2).

Map A.9.1. Regional creation and displacement of high-skill jobs, 2013-2018



Map A.9.2. Regional creation and displacement of low-skill jobs, 2013-2018



10 Policy recommendations based on case studies

10.1 Education and Training – Addressing the current gaps and ensuring sufficient supply of professionals and users with sufficient skills and competences in Industry 4.0

This is a common theme in all country/regional cases. There are three types of target groups: (1) Industry 4.0 professionals needed in developing new Industry 4.0 technologies, (2) industry sector professionals and managers, who need to understand how and which kinds of Industry 4.0 can help address their business needs and challenges or provide new growth opportunities, and (2) users who need to be able to make use of Industry 4.0 technologies.

As to the first target group, Industry 4.0 related topics attract students, which means that the supply will eventually be met in mid- to long-term. The challenge is to manage the interim period, when the demand for professionals willbe higher than the supply. Three types of initiatives are possible:

- Increase intake in HEI to ensure future supply of Industry 4.0 professionals. Design curricula in collaboration with companies.
- Attract professionals from other regions and countries.
- Launch training programmes for professionals with relevant background, but outdated skills and competences in new Industry 4.0 technologies (i.e. AI). These should be designed in close collaboration with the companies (or industry associations) or these could be tailored to company consortia. Also working with company specific practical Industry 4.0 challenges, opportunities or applications should be strongly featured in these trainings.

Furthermore, addressing the interim period, before supply of students/professionals meets the demand for professionals capable of developing Industry 4.0 technologies, is also important because it may hamper start-up creation in the region as ample supply of well-paid job opportunities can often discourage entrepreneurial aspirations.

The second target group may suffer from lack of attractiveness towards introducing Industry 4.0, especially in so called traditional industries (as evidence by some of the case studies). One of the underlying reasons is that both education and traditions in these sectors strongly emphasise sectoral professional skills and competences. Digitalisation and Industry 4.0 technologies are not integrated into products and are therefore only seen as supportive tools, not strategic core competences. Hence, there is a threefold challenge: first, existing sectoral professionals lack Industry 4.0 skills and competences, and second, students are not attracted to the sector, and third, educational curricula do not include sufficient emphasis on Industry 4.0 technologies.

Addressing these can include the following approaches:

- Launch sectoral foresight exercises targeted to sectoral professionals and company management. These will inevitably raise the awareness of the trends and possibilities offered by Industry 4.0 among this target group. Compared to awareness campaigns, these offer the possibility of longer-term interactive engagement, and compared to formal training courses, these can be less formal and much more closely related to practical and business relevant interactions. These need to be organised on a sectoral basis, preferably in collaboration with the relevant industry associations.

- Training programmes for sectoral professionals with lacking or outdated skills and competences in Industry 4.0 technologies. These should be designed in close collaboration with the companies (or industry associations) or these could be tailored to company consortia. Also working with company specific practical Industry 4.0 challenges, opportunities or applications should be strongly featured in these trainings.
- Educational curricula for sector professionals should be reviewed and revised to ensure that they provide new sectoral professionals with the necessary skills and competences in Industry 4.0 technologies. All sector professionals should have sufficient understanding of what benefits Industry 4.0 technologies can offer, and sufficient skills and competences to know what and how to apply in different circumstances. Selected sector professionals interested in Industry 4.0 technologies should have further skills and competences in developing and deploying Industry 4.0 applications and solutions into production and business processes. Educational curricula should be designed in collaboration between HEI and companies.
- Offer short-time or part-time employment opportunities in companies for students allowing them to work with Industry 4.0 applications and solutions, instead of offering them simple manual tasks (common use of students in traditional industries). This will allow them to experience the sector first-hand and see that there are Industry 4.0 related tasks and jobs. This may increase attractiveness of the sector among students.
- Student and graduate placement schemes may also be useful here, although to work, they need sufficient understanding from recipient companies and commitment to launch Industry 4.0 adoption projects. They should therefore be seen more as schemes targeted to companies rather than educational or training schemes, even if they also have this dimension.
- Showcase the most advanced companies and how they have become successful after adopting Industry 4.0 technologies. This is evident in measures such as the French Fab instrument that promotes a positive outlook on the industry to attract especially young professionals.

The last target group is often the largest and lack of competences in it may seriously delay or hamper progress in adopting Industry 4.0 technologies. Training needs depend largely on the degree of change necessary in working practices, existing ICT literacy levels among users, and how easy the adopted Industry 4.0 technologies are to use. As these are sector and at least partially also company and Industry 4.0 technology specific, so should the training be. Thus, training should be made available tailored for the specific needs of the sector, company or if possible, company consortia. One key feature of these trainings is to integrate more any generic Industry 4.0 training very closely to company specific every-day tasks. This ensures that the training provides all necessary skills and competences and therefore allows the adoption of Industry 4.0 technologies, while at the same time provides a reasonable overall understanding of Industry 4.0 technologies and their possibilities.

10.2 Enhancing the adoption of Industry 4.0 among companies - Addressing the current barriers and incentivising companies to adopt Industry 4.0 and develop Industry 4.0 technologies for local companies and for international markets

Adoption of Industry 4.0 can be driven either by needs or opportunities. Needs are often requirements posed by clients and markets. What this means in practice is that the company needs to adopt Industry 4.0 in order to survive in the markets and keep existing clients. Opportunities can be a driver only if companies' perception of Industry 4.0 is that it can offer significant enough new market and growth potential. However, opportunity can act as a driver only when these companies have an ambition to grow. Case studies clearly indicate that needs are the main driver in adopting Industry 4.0. However, there are also some signs indicating that opportunities can also drive the adoption of Industry 4.0.

Like adoption, development can also be driven either by needs or opportunities. Both can be strong drivers for developing Industry 4.0 products, applications and solutions. Needs refer here to the market demand, i.e. clients demand products and services which are based on or apply Industry 4.0. Opportunities refer to new market and business opportunities companies perceive are possible to capture by developing new Industry 4.0 products, applications and solutions. Measures to enhance the development can be direct and indirect.

There are both direct and indirect approaches that can be used to enhance adoption of Industry 4.0 among companies as well as the development of Industry 4.0 technologies. Direct measures are initiatives targeted at companies in the form of various incentives. Indirect measures are targeted to other companies, which pose requirements, pressure or encouragement to the companies in the actual target group.

Direct measures can consist of various well-known initiatives, such as

- Vouchers aimed at SMEs to engage external help in adopting and developing Industry 4.0 technologies. The key here is to ensure that the service providers that the company can use with the voucher are of high enough quality and their skills and competences match sufficiently with the needs of the local companies.
- Grants, loans and other financial instruments made available for companies for adopting and developing Industry 4.0 technologies.
- Collaborative R&D programmes as well as support for local companies and HEI to engage in international R&D programmes (i.e. EU). Such R&D programmes should be designed with the aim of introducing international know-how and practices that woud facilitate Industry 4.0 uptake and the development of new Industry 4.0 technologies.
- Information services related to global technology and market trends and predictions. These should be sectoral and include also interactive elements, where companies can make sense of relevant trends and predictions with respect to their businesses and their future.
- Business and innovation services made available to companies for adopting Industry 4.0 technologies. These can be either project based or diagnostic/mentoring/coaching types, but in all cases, of sufficiently high quality.
- Student and graduate placement schemes. These should be time limited and project based focusing on the adoption of specific Industry 4.0 technologies. Furthermore, the

existence of such chemes would also facilitate the emergence of new Industry 4.0 professionals who could fulfil demand for high-skill employees (a demand often featured in the case studies).

- Organise joint procurement of Industry 4.0 technologies, i.e. invite several companies with similar needs to identify and define Industry 4.0 technologies they are willing to adopt. Based on the joint definition organise a joint procurement process to select the solution provider or providers. If the required characteristics are not met by existing products, organise a procurement of innovation process. If a provider is selected, companies are required to make the purchase (pre-commitment). If no provider is able to meet with the set requirements, pre-commitment is released. This may also work without a binding pre-commitment, but in that case the procurement may not be as strong incentive for the Industry 4.0 technologies providers as a binding purchase pre-commitment would be.In cases where both demand and supply for Industry 4.0 tehnologies is present, but the interests or relevant parties don't seem to match sufficiently (i.e. Estonia), linking producers with adopters may not be an appropriate approach. Instead, it may be more effective to try to link adopters with companies not yet active in Industry 4.0, but who could be encouraged to develop new Industry 4.0 based businesses. These could be i.e. traditional software companies, equipment and device manufacturers, etc., possibly also active mainly in local markets. It may be easier to identify common interests among these than with companies already active with international clients.

The financial incentives work best in situations where companies are already faced with the need to adopt Industry 4.0 but lack the necessary financial resources to do so. If lack of financial resources is combined with lack of human resources (skills and competences), then the last two approaches become more relevant. In most cases, the combinations of financial and non-financial schemes are likely to produce best impact.

Indirect measures can be a more diversified selection of initiatives, which may also differ greatly depending on the context and pre-conditions in the region/country. For example, making use of international value-chains and client demands depends largely on access to and interest of large international corporations in the region. Similarly, enhancing adoption through links between producers with adopters is much easier in regions, which house both types of companies. For our purposes, we divide indirect measures into those that target the needs and opportunities linked to introducing Industry 4.0.

Indirect measures targeted to strengthening needs as the adoption driver may include:

- Encourage larger corporations active in international markets and located in the region to extend their Industry 4.0 technologies into their value-chains and local subcontractor networks. This can be done using financial support instruments, collaborative schemes, or i.e. by promising aid for local companies to support the adoption. This can also be integrated into active FDI cases. This may sometimes work better, if this can be integrated into a larger package of initiatives, which include education and training measures, possibly also measures related to framework conditions (incl. regulations). This approach may prove particularly effective in regions which house large multinational corporations in internationally highly competitive sectors which are advanced users of Industry 4.0 (i.e. automotive).

- Establish EU or national level regulations, which require companies to capture, maintain and analyse significantly larger amounts of data concerning their products and business operations. One example of this could be related to environmental impact and circular economy. If companies were required to be able to continuously monitor their environmental footprint and the extent in which their products are being circulated/re-used, they would have to establish systems not only to facilitate monitoring/data collection within the company, but also along the whole value chain, thus providing a requirement to all companies participating to it to adopt Industry 4.0, since without it they would not be able to comply with the requirements. However, even if this is likely to eventually come, it will probably take some time before it is realised at EU level. But there may be sectors to which some societal value (i.e. environmental impact) is so important that they may be encouraged to move faster into this direction, and if so, they may voluntarily adopt Industry 4.0 for such purposes.
- Offer e-government solutions which are easy to access and significantly decrease administrative burden for companies which have adopted Industry 4.0 technologies. Similarly, open access to public data through software interfaces, which make using them easier and less costly for companies that have adopted Industry 4.0 technologies.
- Other measures can also be launched, addressing specific framework or pre-conditions hampering the adoption of Industry 4.0 in the region, but what these could be depend highly on the specific characteristics of the region.

Indirect measures targeted to strengthening opportunities as the adoption driver may include:

- Cluster initiatives could be introduced with the aim of strengthening selected industries that are producing Industry 4.0 technologies. The added value of these compared to direct measures is that they can offer peer support, which may increase willingness to develop Industry 4.0 and encourage joint development between several companies. However, such initiatives can extend beyond working with clusters towards large companies that can produce spill-over effects in the form of increased Industry 4.0 technology production. For example, larger companies can be encouraged to organise (possibly with industry associations) hackathons and competitions to address business opportunities and challenges with Industry 4.0 tehnologies.
- Schemes aimed at networking and enhancing interaction between Industry 4.0 producers and potential adopters. This is easier in regions where both are present in sufficient numbers and their interest match enough. In regions where the gap between these two are greater, use of intermediary actors may help.
- Setting up virtual or physical centres to support Industry 4.0 adoption. These may focus only on supporting adoption but may also include development and even research of Industry 4.0. However, the focus should be more on supporting adoption and developing/experimenting with Industry 4.0, less if at all on academic research.
- Identifying and funding selectively specific advanced company applications and solutions showcasing potential and real benefits and business opportunities originating from Industry 4.0. This should be highly selective funding made available only to leading Industry 4.0 adopters in selected sectors, and in cases, which contain enough features to make them repeatable in other companies.

Measures may also be needed in improving other framework conditions, but these are often context dependent and vary across regions and sectors. One example raised in the cases was AI and how its adoption requires to review regulations and adopt new practices concerning responsibilities, safety, privacy, etc. in various application areas, including i.e. automotive (smart and autonomous vehicles). Similar concerns have been identified and analysed elsewhere i.e.

with respect to blockchain technologies (financial sector, fiscal systems, prevention of illegalities, etc.). These types of concerns and subsequently potential for policy measures can also be identified in other application areas such as smart cities and healthcare.

11 Review and analysis of existing strategies and policy measures to manage the current technological transformation

11.1 Main results

The review of the strategies and policy measures to manage the current technological transformation was conducted across the EU28 and EFTA countries. The review was conducted **at the national and regional levels** (NUTS 1 and NUTS 2). **In total, 61 strategies and/or policy measures were identified: 27 at the national level and 34 at the regional level**. While some countries (i.e. Belgium, France, Germany, Italy, Spain) demonstrate stronger policy interest at the regional level, **only a relatively small number of European regions overall have adopted policies specifically connected to 4.0 technologies**. The policies were analysed across 3 topics – sectors targeted by policies, support available, and expected impacts. The following presents the results for regional policies.

The analysis of the sectors reveals that **68% of the analysed policy measures are designed to support 4.0 technologies development across all sectors**. While such measures may include support directed to specific industries, overall they aim at introducing 4.0 technologies to the wider region.

As for specific sectors, **the information and communication sector was the most widely targeted, appearing in 15% of the regional policy measures**. **This was followed closely by: marine/naval; aeronautics; energy; and agriculture/food** – each of which were present in 12% of the regional policy measures. Unsurprisingly, the marine/naval was largely featured in the Spanish regions while agriculture/food was mostly present in regions in France and energy was most targeted by German regional policy measures.

Moving towards the support available through the analysed strategies and policy measures, three categories were used during the review: **funding, consulting and dissemination**. Funding support encompasses any funding being directed to beneficiaries. Consulting represents actions such as offering training courses for businesses, evaluating readiness to deploy 4.0 technologies, regional analysis/mapping related to 4.0 technologies. Finally, dissemination support includes such actions as development/deployment of platforms that provide information on economic actors working with 4.0 technologies and present upcoming opportunities about projects.

Of the three support categories, **funding actions were the most common**, employed in 62% of the regional policy measures while **dissemination support actions were part of 47%** of policy measures and **consulting support identified in 38% of the measures**. Various dissemination instruments about 4.0 technology opportunities are most frequent in Spanish and German regional policy measures, as well as Belgium, where dissemination forms a large part of the support activities. As for consulting, Spanish regions have paid the most attention to such instruments and they are featured in 60% of the regional policies.

For the last category, expected impacts are based on the available information and critical assessment by the researchers to determine what the strategies and policy measures were designed to achieve. These objectives/aims were categorised as:

- **Reduce disadvantage,** meaning that the measure is designed to reduce a regional disadvantage through the introduction of 4.0 technologies. These objectives/aims include, but are not limited to lowering unemployment, helping struggling sectors (21% of measures).
- **Maintain advantage**, representing the situation where the region aims at using 4.0 technologies to maintain the current situation, i.e. continue to maintain current levels of growth, reorganise well performing industries (26% of measures).
- **Increase advantage**, defining situations where the policy is designed primarily to, for example, further raise regional competitiveness, growth in competitiveness of industry (53% of measures).

These results present an interesting view on how 4.0 technological development is understood and treated at the policy level. Those policies that are aimed at increasing advantage can be broadly divided into either: **measures that target specific sectors that have a strong regional presence; or long-term strategies connected to innovation, R&D, smart specialisation**. Such strategies are most commonly found in Austria, Belgium and France. On the other hand, **the lowest share of policies was identified as aiming towards reducing regional disadvantage**. Such policies were most frequently found in the regions of, Greece, Italy and Spain. However, the relative lack of policies that are designed around utilising 4.0 technologies in low performing sectors does suggest that **the 4th industrial revolution is not yet understood as an effective way to solve underperformance of regions**. While the review and analysis of the strategies and policy measures is not sufficient to draw conclusive answers, it is perhaps telling that the largest share of regional policies revolve around the principle of "maintaining strength where there already is strength". This at least suggests that on the regional level, policy makers view 4.0 technologies as the next evolution of industry, but not necessarily as a tool that will spearhead the rise of regional competitiveness.

Box A11.1. Main outcome from the analysis of existing strategies and policy measures to manage the 4.0 technological transformation

- **Only relatively few European regions have adopted policies specifically connected to 4.0 technologies.**
- Most policy measures aim at introducing 4.0 technologies **to the wider region**.
- **The ICT sector was the most widely targeted**, followed closely by marine/naval, aeronautics, energy, and agriculture/food.
- **Supports are of different types**: funding actions (the most common), dissemination support actions and consulting support measures.
- **The 4.0 technological revolution is not yet understood as an effective way to solve underperformance of regions**. Only 21% of measures are developed with the aim to solve socio-economic disadvantage of regions.

11.2 List of policy documents analysed

3IF.be (2018) “Industrie 4.0 Training”, available at: https://www.3if.be/en/events-activities/168-2018-12-11-12-industrie-4-0-training-technopolis-mechelen-cursus-1-major-concepts-2-dagen, last accessed on 13/5/2019

3IF.be (2019) “3IF.eu services offering”, available at: https://www.3if.be/en/3if-be-services-offering, last accessed on 13/5/2019

Aarhuse University (2017) “R&D Programme Industry 4.0”, available at: *http://eng.au.dk/fileadmin/DJF/ENG/PDF-filer/smart_industry/industri_40-smart_industry-en.pdf*, last accessed on 13/5/2019

Abruzzo Sviluppo (2019) “Industria 4.0: iscrizioni aperte ai nuovi corsi ITS Sistema Meccanica”, available at: http://www.abruzzosviluppo.it/2019/07/09/industria-4-0-iscrizioni-aperte-ai-nuovi-corsi-its-sistema-meccanica/, last accessed on 13/8/2019

AIN (2018) “Diagnóstico De Industria 4.0 en Navarra”, available at: https://www.industrianavarra40.com/wp-content/uploads/2018/11/Diagn%C3%B3stico-regional-I4.0-Industrianavarra40.pdf, last accessed on 07/5/2019

Basque Industry 4.0 (2019) “4.0. Subsidies”, available at: https://basqueindustry.spri.eus/en/subsidies-4-0/, last accessed on 06/5/2019

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11.3 List of strategies and policy measures to manage the 4.0 technological transformation by country/region

Table A.11.1 List of strategies and policy measures to manage the 4.0 technological transformation by country/region

			Sectors targeted by policies																	Support Available			Objectives/aims		
Country	Region	Policy	All Sectors	Accommodation	Manufacturing	RDI	Agriculture / Food	Energy	Construction	Human health	Transport	Advanced manufacturing	Marine / Naval	ICT	Creative, arts and entertainment	Aeronautics	Manufacture of textiles	Virtual Engineering	Automotive	Funding	Consulting	Dissemination	Reduce Disadvantage	Maintain Advantage	Increase Advantage
AT	National	Industrie 4.0	■																	■	■	■		■	
AT	Tyrol	Snow Technology Centre Tyrol		■																■					■
AT	Styria	Die Industrie Plafform	■																		■	■			■
BE	Flanders	Visie 2050	■																	■	■	■			■
BE	Wallonia	Digital Strategy 2019-2024	■				■		■													■			■
HR	National	National Platform for Digitalisation of the Industry of the Republic of Croatia [24]	■																				■		
CY	National	The Cyprus New Industrial Strategy Policy 2019-2030	■																	■		■	■		

[24] Not published yet

Country	Region	Policy	Sectors targeted by policies																	Support Available			Objectives/aims		
			All Sectors	Accommodation	Manufacturing	RDI	Agriculture / Food	Energy	Construction	Human health	Transport	Advanced manufacturing	Marine / Naval	ICT	Creative, arts and entertainment	Aeronautics	Manufacture of textiles	Virtual Engineering	Automotive	Funding	Consulting	Dissemination	Reduce Disadvantage	Maintain Advantage	Increase Advantage
CZ	National	Industry 4.0	■																		■	■	■		
CZ	National	Digital Czechia	■																		■	■	■		
DK	National	Strategy for Denmark's Digital Growth	■																	■	■	■			■
DK	Central Denmark	Industry 4.0	■																	■				■	
EE	National	Green Paper on Industrial Policy	■																					■	
EE	National	ICT Development Programme	■																	■	■	■		■	
FI	National	Digital Finland Framework			■																■	■			■
FI	Helsinki-Uusimaa	Research and Innovation Strategy for Regional Development 2014-2020	■																	■		■			■
FR	National	Industrie du Futur	■																	■	■	■		■	
FR	National	Transformer notre Industrie par le numérique	■																	■	■	■		■	
FR	Nouvelle-	L'usine du Futur	■		■		■													■	■			■	

Country	Region	Policy	Sectors targeted by policies																	Support Available			Objectives/aims		
			All Sectors	Accommodation	Manufacturing	RDI	Agriculture / Food	Energy	Construction	Human health	Transport	Advanced manufacturing	Marine / Naval	ICT	Creative, arts and entertainment	Aeronautics	Manufacture of textiles	Virtual Engineering	Automotive	Funding	Consulting	Dissemination	Reduce Disadvantage	Maintain Advantage	Increase Advantage
	Aquitaine		■		■		■													■	■			■	
FR	Pays de le Loire	SRDEII	■	■			■													■				■	
FR	Pays de la Loire	Smart Specialisation Strategy 2014-2020										■	■	■	■					■	■	■			■
FR	Ile-de-France	Smart Industrie 2017-2021	■					■								■	■		■	■					■
DE	National	Industry 4.0 Strategy and Platform	■		■															■	■	■		■	
DE	Schleswig-Holstein	New 4.0						■												■				■	
DE	Lower Saxony	Digitalagentur Niedersachsen	■																			■		■	
DE	Saxony-Anhalt	Regional Innovation Strategy 2014-2020						■																■	
DE	Brandenburg	Brandenburg Innovation Centre for Modern Industry	■																		■	■		■	

Country	Region	Policy	Sectors targeted by policies																	Support Available			Objectives/aims		
			All Sectors	Accommodation	Manufacturing	RDI	Agriculture / Food	Energy	Construction	Human health	Transport	Advanced manufacturing	Marine / Naval	ICT	Creative, arts and entertainment	Aeronautics	Manufacture of textiles	Virtual Engineering	Automotive	Funding	Consulting	Dissemination	Reduce Disadvantage	Maintain Advantage	Increase Advantage
DE	Thuringia	Thüringer Kompetenzzentrum Wirtschaft 4.0	■																		■	■		■	
EL	National	National Digital Policy 2016-2021												■						■		■	■		
EL	Dytiki Ellada	Regional Smart Specialisation Strategy												■						■			■		
HU	National	Industry 4.0 Development Strategy	■		■	■														■	■	■	■		
IT	National	Piano Nazionale Industria 4.0	■		■															■		■		■	
IT	Lombardy	Manifattura Diffusa Creativa e Technologia 4.0			■				■					■						■			■		
IT	Abruzzo	Tecnico Industria 4.0																	■		■		■		
IT	Campania	Manifattura Campania: Industria 4.0	■																	■		■		■	
LV	National	Data Driven Nation Action Plan	■																		■	■			■
LT	National	Pramone 4.0	■																		■	■		■	

Country	Region	Policy	Sectors targeted by policies																	Support Available			Objectives/aims		
			All Sectors	Accommodation	Manufacturing	RDI	Agriculture / Food	Energy	Construction	Human health	Transport	Advanced manufacturing	Marine / Naval	ICT	Creative, arts and entertainment	Aeronautics	Manufacture of textiles	Virtual Engineering	Automotive	Funding	Consulting	Dissemination	Reduce Disadvantage	Maintain Advantage	Increase Advantage
LT	National	Lithuanian Industry Digitalisation Roadmap 2019-2030					■	■		■	■	■								■	■	■		■	
LU	National	The third industrial revolution strategy	■																	■		■			■
NL	National	Smart Industry	■		■															■	■	■			■
PL	National	Future Industry Platform	■			■						■									■	■		■	
PL	National	Industry 4.0 Programme	■																	■	■	■		■	
PT	Norte	NORTE RIS3	■									■		■										■	
PT	Centro Region of Portugal	RIS3 Strategy Centro	■																	■				■	
RO	North-East Region	Smart Specialisation Strategy															■						■		
SK	National	Smart Industry for Slovakia	■																		■	■		■	
ES	National	Connected Industry 4.0	■																		■	■		■	
ES	Aragon	PAIP	■																	■				■	

Country	Region	Policy	Sectors targeted by policies																	Support Available			Objectives/aims		
			All Sectors	**Accommodation**	**Manufacturing**	**RDI**	**Agriculture / Food**	**Energy**	**Construction**	**Human health**	**Transport**	**Advanced manufacturing**	**Marine / Naval**	**ICT**	**Creative, arts and entertainment**	**Aeronautics**	**Manufacture of textiles**	**Virtual Engineering**	**Automotive**	**Funding**	**Consulting**	**Dissemination**	**Reduce Disadvantage**	**Maintain Advantage**	**Increase Advantage**
ES	Basque Country	Basque Industry 4.0																							
ES	Navarra	Industrial Plan 2020																							
ES	Comunidad de Madrid	Plan Industrial de la Comunidad de Madrid 2019-2025																							
ES	Andalusia	Estrategia Industrial de Andalucía 2020																							
ES	Valencia	La Agenda Industria 4.0 Comunitat Valenciana																							
ES	Galicia	Agenda de Competitividad Galicia Industria 4.0 2015-2020																							
ES	Castile and León	Plan Industria 4.0 Castilla y León																							
ES	Murcia	Estrategia Murcia Industria 4.0																							
ES	Asturia	Programme Industria 4.0																							

Country	Region	Policy	Sectors targeted by policies																	Support Available			Objectives/aims		
			All Sectors	**Accommodation**	**Manufacturing**	**RDI**	**Agriculture / Food**	**Energy**	**Construction**	**Human health**	**Transport**	**Advanced manufacturing**	**Marine / Naval**	**ICT**	**Creative, arts and entertainment**	**Aeronautics**	**Manufacture of textiles**	**Virtual Engineering**	**Automotive**	**Funding**	**Consulting**	**Dissemination**	**Reduce Disadvantage**	**Maintain Advantage**	**Increase Advantage**
		Asturias	■																	■	■			■	
SE	National	Smart Industry	■																	■		■			■
SE	National	Produktion 2030	■																	■		■		■	
SE	National	Digitalisation and Industry 4.0	■																		■			■	
SE	West Sweden	Assar Industrial Innovation Arena																■				■			■
UK	National	Industrial Strategy	■																		■	■		■	

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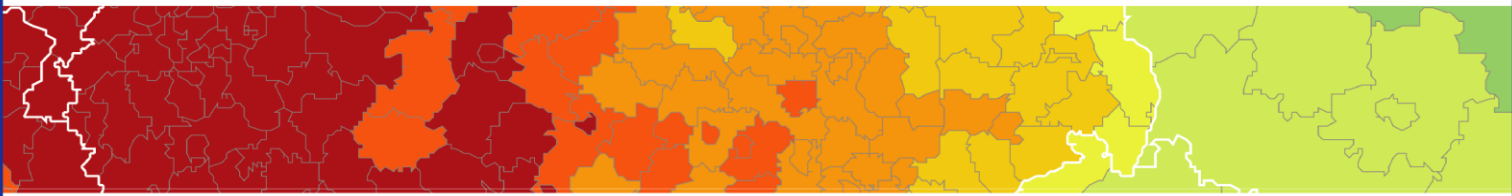

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