WORKING PAPER

Digitisation of processes
Literature review

Automation, digitisation and platforms: implications for work and employment - Concept Paper

Contents

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Introduction

Digitalisation, the increase in the use of digital technology, is changing the world of work thanks to recent technological developments and the discovery of useful synergies obtained by combining different technologies. The Internet allows machine to machine communication, Artificial Intelligence (AI) augments data processing both in terms of speed and volume, robotics enhances industrial production and could as well impact other sectors where physical strength is a determinant component to complete a task successfully (for example, patient movement in healthcare); sensors and 3d printing allow new ways of monitoring the production process and making products. As Zuboff (2010) points out, changes happening in digitalisation are not only the introduction of new technologies (innovations) but the deep impact they are having, so big that they are provoking a 'mutation' in the framework used by businesses to meet customers' needs and wants.

This literature review is going to focus specifically on changes brought about by the digitisation of processes, focusing on the transformation of previously analogue processes into digital ones: for example, monitoring a production process with sensors' data or the 3d printing of a spare part for a piece of equipment[1]. As mentioned above, some changes are due to the combined effect of technologies but in the words of Baldwin (2016), this paper will explore the effects on work and employment in circumstances where 'the goods become the data'.

First, a short description and definitions of the three technologies being used in the digitisation of production processes: 3d printing, Internet of Things and virtual reality will be presented. Then findings on the impact of these technologies on job quality and employment will be reported and discussed. For this purpose we are classifying the effects of digitisation described in the literature according to the EJM Job Quality Index (Eurofound, 2013) which divides job quality into intrinsic quality of work (skills, autonomy and social support, and workplace risks), employment quality (contractual relation and development opportunities) and working time and work life balance. Finally, a discussion on the findings (up to August 2017) and on research gaps will be presented.

For a wider overview of the implications of the digital age for work and employment, the reader can consult 'Automation, digitisation and platforms: implications for work and employment Concept Paper' (Fernández-Macías, 2017); also, a separate literature review on coordination by platforms and on automation of work are part of this set of working papers.

This literature review is based on desk research on academic papers, specialised journals on productivity management and engineering, and some references to newspaper articles given that the topic is very much contemporary and new articles are published on an ongoing basis. The geographic scope includes EU Members States with comparison to developments in the United States were applicable. The review includes documents up to August 2017.

Technology definitions

Industry 4.0 and work 4.0

Changes due to the introduction of new technologies in the industrial sector have been deemed 'Industry 4.0'. In the German speaking countries, the term Industry 4.0 is used since 2011 the government sponsored an initiative called 'Industry 4.0', but there are other terms listed in Hermann et al (2015) which are considered equivalent such as: Industrial Internet, Advanced Manufacturing, Integrated Industry, Smart Industry or Smart Manufacturing.

> *'At the opening of the Hanover Fair 2011, "Industrie 4.0" emerged as the most recent term for automation. "Industry 4.0" is the fourth industrial revolution driven by the*

[1] It is important to highlight that 'digitalisation' is the wider phenomenon and 'digitisation' is the specific process transforming an analogue input into a virtual one.

Internet. It describes the technological change of today's production technology to cyber-physical production systems (SmartFactory)'. (Jasperneite, 2012)

Industry 4.0 is the term used to define a 4th industrial revolution, the current period in the history of humanity when the production process is being digitised. There is no globally shared definition of Industry 4.0 and it is a term which can be used to describe different aspects of current technological change. Brettel and Friederichsen (2014) found in their literature review of over 5,000 papers three main research topics: individualisation of production through a change of production and planning to a more modular and rapid manufacturing model, horizontal integration in collaborative networks which can be enabled by data coming from sensors (RFID) and end-to-end digital integration through virtualisation of simulation.

A year later, Hermann et al (2015) literature review of Industry 4.0 aimed at giving a shared definition of Industry 4.0, warning that it was based mainly on English and German language sources: 'Industrie 4.0 is a collective term for technologies and concepts of value chain organization. Within the modular structured Smart Factories of Industrie 4.0, CPS (Cyber-Physical Systems) monitor physical processes, create a virtual copy of the physical world and make decentralized decisions. Over the IoT, CPS communicate and cooperate with each other and humans in real time. Via the IoS, both internal and cross-organizational services are offered and utilized by participants of the value chain.'

The term 'Industry 4.0' defines an industrial space where machines' and sensors' role has changed. These changes paved the way to the definition of 'work 4.0' which includes the new skills and challenges that people working in industry 4.0 will face (Buhr et al, 2016; BDA, 2016).

Internet of things (IoT)

The term internet of things (IoT) was used for the first time in 1999 by Ashton at a conference about sensors and supply chain (Ashton, 2009) to convey the idea of using the internet in the supply chain through Radio-Frequency Identification (RFID). In his own interpretation, the Internet of Things is a way to enable computers to gather data, not only about ideas, but also about things without the need of input by humans. By 'things' the author and the practitioner community nowadays describe all types of objects or products, including vehicles, smart urban fittings and entire plants and ecosystems. The communication between the things, the computers and eventually the humans who want to analyse the data is to be enabled by the so-called 'fog'. This new infrastructure needs a platform to support the data collection and exchange to convey the fact that it is a cloud service closer to the ground and to the various wireless devices (Bonomi et al, 2012). Essential to the development of the internet of things is the development of the telecommunication infrastructure, 5G (5th generation) connectivity, which, compared to 3G and 4G networks, has the capacity to support a high number of devices using ipv6 addresses and an improved security and geographical coverage. There is a vast literature on IoT across various disciplines, from computer science to organisational management. Gubbi's (2013) definition leaves open the type of protocol that can be used:

'*Interconnection of sensing and actuating devices providing the ability to share information across platforms through a unified framework, developing a common operating picture for enabling innovative applications. This is achieved by seamless ubiquitous sensing, data analytics and information representation with Cloud computing as the unifying framework.*' (Gubbi, 2013).

There are various application domains where the Internet of Things have already been deployed and those which might happen in the near future. Gubbi (2013) correctly identified 2015 as the year when enterprises start to use sensors in retail and in industrial ecosytems. The next steps envisaged in his study are applications in the utility domain by 2020 (smart grids and critical infrastructure monitoring) while around 2025 transport could be the application domain most impacted with the use of autonomous vehicles and smart traffic management.

Virtual reality, augmented reality and telepresence

Virtual reality was invented in the 1960s and started to be applied in the 1980s for flight simulation, robotics and space-related research, reaching the wider public with cinemas built to make spectators believe they were immersed in the movie (Schroeder, 1993). Virtual reality provides a duplicate or alternate digital space of real world spaces or fictional worlds, in case of videogames or virtual spaces like Second Life. Augmented reality is meant to enhance the experience of the world by superimposing a digital information layer onto real surroundings or visualise tasks to be carried out in a particular location (Elia et al, 2016). Augmented reality could give a worker sensors' readings about their workspace directly on a head mounted screen (Oculus Rift, Google glasses) or virtual reality can be used to train a pilot with a flight simulator. Nowadays, there are augmented reality applications in manufacturing and other sectors, for example, it is possible to co-design a product in a 3-dimensional space accessible to workers based in different locations. As concerns the services sector, if the sudden interest in augmented reality which happened with the Pokemon-go game is excluded, applications of virtual reality have at least a 5-10 years horizon. According to Facebook CEO, 'there is no "killer app" at the moment which will make the average consumer want to spend money on it' (Fortune, 2017). However, if not with augmented reality, the services sector is likely to see an increase in telepresence (video calls, virtual meeting spaces) and in telerobotics, with robots controlled remotely (Baldwin, 2016).

3d printing

The development of 3d printing was enabled by the capacity of creating a virtual model of a product. 3d printing or additive manufacturing produces an object by adding layers according to a specific design file instead of cutting the excessive material as is the norm in traditional (subtractive) manufacturing. The European Commission uses the following definition: 'Additive Manufacturing refers to a group of technologies that build physical objects directly from 3D Computer-Aided Design (CAD) data. AM adds liquid, sheet, wire or other powdered materials to form component parts or products, usually in a layer-by-layer process (e.g. 3D-Printing) as opposed to subtractive manufacturing methodologies' (European Commission, 2014).

3d printing has been in existence for almost 35 years. It was invented by Charles Hull in 1983 and was then called stereolithography (CNN, 2014). The technology did not raise much interest until it was mentioned in the 2013 Gartner Hype Cycle[2] (European Commission, 2014). In 2014, advanced manufacturing technologies were almost exclusively used for prototyping and for small batches (Brettel and Friederichsen, 2014) but three years after, the technology is now being used for actual production by big manufacturers such as Adidas for shoes (The Economist, 2017) and GE Avio Aero, manufacturer of aircraft components (GE Avio Aero, 2013); as well as by SMEs to achieve fast prototyping. Furthermore, in recent years it has become clear that it has potential to become a home accessory for those individuals wishing to print or customise their own objects. The technology is not widely spread yet, but recent data on 3d printing contained in the 2017 Wholers report estimate a global market of products and services worth up to € 5.52 billion (Financial Times, 2017) and a potential growth of 3d printed products especially in sectors were reducing the weight of certain parts can be achieved through 3d printing techniques and materials. And, as described by the Gartner Hype Cycle, another sector where the use of 3d printing is becoming mainstream is the production of dental and hearing aids (Eurofound, 2017a).

Berger et al (2017) have simulated scenarios to check how the international supply chain would be modified by the introduction of 3d printing. Their model, using simplified data of existing normal cases, takes into consideration the location of: raw material, assembly centre, production centre and consumers' market. It also takes into account the freight volumes

[2] The Gartner Hype Cycle is a yearly classification made by Gartner. Available at http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

which need to be moved. The authors argue that 3d printing will not change the manufacturing sector to the point where consumers can print most of their own products in the foreseeable future for two reasons: first, currently different printers are needed depending on the material being used (even though some home 3d printers can use different materials, but with limited possibilities); second, the printing of big objects requires big amounts of material, involving storage and other costs, so most objects will still need to be produced in a factory. The model simulation, as explained by the authors, lacks the back-up of mature 3d printing manufacturers' data and further studies should include more than logistics aspects: HR, countries' technological level and capital. Nevertheless, the model shows that 3d printing would be advantageous for those companies which can shrink the supply chain and bring production closer to the market, thus having also an impact on logistics for the countries producing or acquiring raw materials. Changes in the supply chain will impact the workforce involved in each of the stages, hence policy makers should find ways, through incentives or customs taxes, to stir processes in a direction favourable for employment in their countries.

Implications for job quality

Skills

The data produced by each product's sensor can be collected and analysed eliminating the sample methodology for quality control which was previously used in the production process (Compagnucci and da Empoli, 2016). In digitised productive systems, managers will need to be able to interpret data and have ideas on how to improve processes both at micro and macro level (Barbato, 2015). According to (Schildt, 2017), the embedment of planning and real-time adjustment in ICT, the shift to sensors' information and data driven processes, is going to move the production control from managers to skilled technicians (programmers, data scientists) in a reverse situation of what happened in 1950-1960, when processes were taken out of the control of skilled machinists (Noble, 1984). Furthermore, these skills are rarely encountered in one worker only, so these tasks will be distributed in a team; this set up could prove an obstacle for small and medium-sized enterprises looking to digitise their processes due to the size of their workforce (Compagnucci and da Empoli, 2016).

Manufacturing would not be the only sector where an increase in digitisation would require workers to improve their IT skills, IOT could change agriculture, too, and perhaps enable farmers to monitor crops and control harvesting machines remotely, thus allowing for a lifestyle more similar to that of urban workers and with more opportunities to spend time away from the farm. CPS (robots and IOT) in agriculture might also help in alleviating demanding physical tasks (STOA, 2016). Not only the manufacturing side of food could be impacted but also the logistics and distribution function would be affected since the capability of following a product/item from the moment it is produced to the moment it is sold could change the way monitoring and conservation are carried out (STOA, 2016). The food distribution sector and the hospitality sector could also change significantly with the introduction of IOT and 3d printing. It has been proven that food can be 3d printed and there are studies on producing input material for 3d printing with aliments or with nutritional items which are not traditionally considered food, at least not by all cultures, for example insects, algae (Lupton et al, 2016). In a hypothetical scenario, perhaps crossing over the classification attempted in these reviews between automation and digitisation, 3d printed food could diminish the importance of chefs. And if robots were employed to serve 3d printed food this hypothesis would imply that the composition of the workforce in the hospitality sector could change dramatically (Financial Times, 2017b).

IT and data analysis skills become very important, not only where IoT is used but also in sectors where 3d printing is used. Janssen et al (2014) describe how supply chains could change in terms of materials' acquisition, production process and localisation, and customisation. 3d printing and 3d scanning allow the modification of a product design quickly to adapt it to customers' requirements. In order to perform these modifications, there will be a need to train workers on how to design and test these new products (European Commission, 2014). In cases similar to the one described, CAD software competencies would be a core skill in the jewellery industry (Rayna and Striukova, 2016).

If the nature of jobs is changing and workers need to acquire new digital skills in a fast-changing environment, continuous lifelong learning becomes very important (BCG, 2016; Compagnucci and da Empoli, 2016; Gosse and Dancette, 2016). Those best placed to succeed in the world of tomorrow are those who have a good education and can learn new skills fast. The idea is that '*workers should be protected and not jobs'* (Baldwin, 2016; Buhr et al, 2016), so policy makers should think about ways to provide a package of benefit, in monetary and training terms, to help those who lost their job due to digitalisation to re-enter in the job market. Companies will need highly adaptable skilled workers who can interact with machines. In McKinsey (2016) there is a more detailed breakdown of data analysis tasks listed as important ones for industry 4.0: the capacity to model the entire supply chain to reduce the need for trials, the ability to monitor processes and interpret data in order to carry out predictive maintenance, and being able to interact with technology and take autonomous decisions.

A survey run by the German Trade Union Confederation (Gewerkschaftsbund, 2016) found that 46% of employees who responded overall believed that the digitisation of production processes[3] raises the level of monitoring for both employees and work processes with the sectors most affected being finance (60%), recycling (59%) and logistics/transport (58%).

IoTs is not only used in industrial manufacturing to track processes or objects, sensors can be used to track workers as well. While this development is going to be beneficial to the management of factories to increase efficiency and prevent workers' injuries, it also implies that all the movements of workers are being recorded by sensors in their smart work equipment. Recently, a Swedish employer asked to place a chip under the skin of employees to allow seamless access to reserved areas or to machinery (BBC, 2015): the move was favourably accepted by some employees while for others the minor advantages of an implanted sensor did not overcome the disadvantage of being constantly tracked. Degryse (2016a) explains that tracking could also be perceived as a lack of trust on the part of the company:

> *'Delivery workers or maintenance technicians, whose managements previously allowed them some considerable degree of organisational autonomy, are now trackable via their satnavs and other composite mobile devices, so that a continuous check can be kept on their routes, their stops, their detours.* (Degryse, 2016a)

Not only lack of trust, but also the dignity of the worker could be affected since the request to obey orders by a machine could lead to workers being treated as objects. Moreover, if tasks are automated and digitised, how will errors made by the machine, or rather the software, reflect on workers' autonomy? Some outputs will be positioned outside their current decisional space and in cases of work accidents due to faulty software, compensation could be denied or the different stakeholders in the digital production process could accuse each other in an infinite vicious circle (CCOO Industria, 2015).

Digitisation can be deemed to be having an impact on the logistic sector too, the fact that a drone can go from point A to point B is facilitated by the digitisation of the space in which they move (Autor, 2015). In 2017, delivery trials by the company Starship are taking place in Estonia, UK and USto deliver take-away food from restaurant premises to customers' dwellings. One of the companies running trials is testing the option of getting humans working together with drones: drones would only move inside a restricted area close to the restaurant, leaving long-distance deliveries to workers: workers would pick up long-distance delivery from the drone once it has reached the limit of its area (Tang, 2017). This type of

[3] The terms digitalisation and digitisation are not clearly defined yet. In this case the survey was investigating work characteristics that might fit better into the digitisation realm.

work organisation could reduce workers' autonomy because the type of itinerary that they decide to follow will be pre-determined by drones' location and routes.

Social interaction and teamwork

On the one hand, as already pointed out by Watanuki (2011), digitisation can eliminate most of the face-to-face contact among workers since machines and sensors can take care of those interactions. On the other hand, some authors (Compagnucci and da Empoli, 2016; McKinsey&Company, 2016) identify teamwork and interdisciplinary cooperation as core competences of Cyber-Physical Systems (CPS), so more social interaction would be needed at the planning and control level rather than on the shopfloor.

Physical risk and psychosocial risk

There are very few studies on the effect of the digitisation of production on physical and psychosocial risks. As Stephens et al and Azimi, et al (Azimi et al, 2016; Stephens et al, 2013) argue, and as recently confirmed by Ryan and Hubbard (2016), there could be health risks connected to the emission of gas and ultrafine particles during the 3d printing process (Stephens et al, 2013). The health concern could be an obstacle to mass implementation (what happens to workers who are regularly exposed to an environment where there is not enough air circulation and which is filled of ultrafine particles?). The authors say that the type and quantity of particles can vary and it depends on the type of material (filament) used.

In their 2015 report, the Spanish Union CCOO remarks that spending more and more time in front of a screen could negatively affect workers' posture and musco-skeletal well-being. Moreover, digitisation facilitates remote working, hence morphing the definition of 'work location' which could have consequences on insurance costs. Also, from the point of view of mental well-being, social interactions in a (healthy) workplace are beneficial to workers and they could disappear in a telepresence or telerobotics environment (CCOO Industria, 2015).

Working time and work-life balance

A recent Eurofound (2016a) study warns about the possible erosion of working time standards, and about an alteration of work-life balance due to digital technologies pressuring workers to be always on call which can lead to an increase in stress levels.

For those already in employment, the need to be also constantly up-to-date with the latest IT developments would also put pressure on workers to get further training. In this context Lott (2015) argues that there is a need to debate the impact of digitalisation on gender since in the future, the 'ideal worker' (a worker who is always available when the employer needs them, for example staying late at work) might encompass a worker who has time to engage in training outside working hours to keep up with new technological developments. This shift in the concept of 'ideal worker' would impact more on women, demanding their time which, in general, is dedicated to care duties in a bigger share than men's. For young people entering the labour market, the digitisation of the industry could be an attractive feature by assimilating the factory to the office with super connected machines and computers and virtual spaces to operate in. On the one hand, the possibility of teleworking can be seen by many workers as a way to increase their autonomy and their efficiency (Eurofound and ILO, 2017); on the other hand, as highlighted by other authors, the blurring of boundaries between work and free time could negatively impact work-life balance (CCOO, 2016).

Implications for the labour market

The digitisation of the production process is a recent phenomenon and there are still not many quantitative or qualitative studies about its implications for work and employment. Predictions on the effects of these technologies on the labour market range from mild changes where jobs will just incorporate more technology and humans will continue performing tasks which cannot be digitised to scenarios where robots and algorithms will take up most of the jobs in manufacturing and in services. It is interesting to note that Baldwin (2016) predicts a change in the labour market where competition between workers of western countries and developing world countries will increase as a result of the 'platformisation' of digitised tasks. Impacts on job quality and employment are speculated upon but there is an interest in trying to understand as soon as possible the implications: policy makers, social partners and academics are posing questions about the challenges that digitised work processes could have for workers' wellbeing. A recent Eurofound-ILO report using data from the Sixth European Working Conditions Survey (EWCS)

> *'shows that 26% of ICT-mobile workers (in Europe) report having a poor work–life balance, as against only 18% of the rest of the workforce. This could be partially explained by the fact that a larger proportion of ICT-mobile workers work more than 48 hours per week (28% as against 14%). Overall, according to the job quality indices, ICT-mobile workers and teleworkers experiencing greater work intensity but more autonomy at work and better career prospects.'* (Eurofound, 2016a).

This report also found positive effects of ICT-mobile work such as: a shortening of commuting time, greater working time autonomy, better overall work–life balance, and higher productivity (Eurofound and ILO, 2017). Baldwin argues that work-life balance could be enhanced by telepresence or telerobotics, but these new uses of technology could also put high demands on the workforce to upskill in their own time to face fierce worldwide competition (Baldwin, 2016).

For the World Economic Forum (2016), the disappearance of some jobs or tasks in manufacturing could be counterbalanced by the demand for new materials (for 3d printing) and in particular in the architecture and engineering occupations which can be called upon to design the new sensor systems and 3d printing facilities or Cyber-Physical Systems (CPS) as they are referred to in the computer engineering literature. According to DG CONNECT's data market monitoring tool, in 2015 EU data analysis workers are distributed in all sectors but the top three sectors are professional services, mining and manufacturing, and retail (DataLandscape, 2016)[4]. In a study on the effects of industry 4.0 in Germany, (BCG, 2016) estimates a 6% growth in manufacturing in the period 2015-2025 due to the needs of the industry for data experts, mechatronics engineers and IT software development workers with a decrease in the demand of workers who run routine operations on the production line. At the same time, the changes the way production processes are monitored could bring about an expansion of workers in all the servitisation activities related to predictive maintenance (Eurofound, 2017b).

Hopes for an increase in the number of manufacturing jobs comes also from reshoring practices: for big manufacturers, 3d printing could provide a cheaper way of manufacturing mass products closer to the market, thus enabling reshoring from countries were it was previously convenient producing due to low labour costs (Autor, 2015; De Backer, K., 2016; Eurofound, 2016b). One recent example is the case of Adidas in Germany. The new factory in Ansbach will employ 160 workers, while the company is closing down a 1,000 workers factory in China (Eurofound, 2016b). However, in early 2017, the Adidas CEO said in an interview to the Financial Times (2017) that fully automated factories will not happen in the next 10 years since semi-automated factories in Asia are still faster at producing in bulk for big quantities. There are also limits to robots dexterity, as of 2017 the shoes industry is still looking for a robot capable of putting shoelaces in place, which for the moment is a manual task. However, not all the literature agrees on potential increases in employment in manufacturing. The digitisation of the production process exposes it to modularisation, and its tasks can be assigned to crowd employment (Rayna and Striukova, 2016).

[4] Collection method based on estimates of data workers according to ISCO and IDC survey (2014) on data workers: '*Collection of additional primary original data to compensate for the lack of sources with particular reference to the identification and assessment of data companies (that is companies supplying data products and services) and data users (that is companies and organisations using data products and services). This primary research effort was conducted through an extensive quantitative field survey during January and March 2015 and covering more than 1,400 respondents in eight EU Member States'*. Available at: http://www.datalandscape.eu/

> *For instance, online 3D printing services such as Additer, Kraftwürz and MakeXYZ enable businesses to crowdsource the manufacturing of their products using various materials and finish qualities (printers available through these services range from the basic plastic home printer to industrial grade alloy printer).*(Rayna and Striukova, 2016)

In this case, there could be a shift from long term contracts to short term contracts due to the 'platformisation' of certain jobs. In this way some contractual benefits attached to long-term employment would be lost for workers (Baldwin, 2016).

Teleworking and telerobotics

Baldwin (2016) pushes the concept of division into tasks further and states that digitalisation will change the services sector by allowing an increasing amount of tasks to be performed in digital form, diminishing more and more the importance of location; for example, apart from the platform phenomenon, online consultations with doctors, lawyers and other professionals could happen at long distance. He describes how improvements in information and communication networks and better virtual reality and teleconferencing technology could change the labour market not only at national or regional level but at global level. Two new ways of communicating, telepresence and telerobotics, technologies enabling face-to-face likeness of communication, could change both the production process and the services sector. Telerobotics refers to the capacity of a human being to control a robot remotely: a factory based in the EU could be run by robots controlled by workers based in a low-wage country or an engineer based in the EU could fix machinery in a factory based in a low wage-country. This scenario, according to Baldwin, could deeply disrupt the labour markets since workers, no matter their skills level, would be competing at global level, performance of their tasks not bound by location anymore (provided that they have access to the internet). This situation could resemble an expansion of the model used by Amazon Mechanical Turk to a much wider list of tasks and occupations. Baldwin also points out that these changes could happen soon, but that some assumptions are necessary: improvement of networks, so that there are no delays, since timing is fundamental in many production processes and in services, and the progressive decrease in robots' prices. Another important assumption is that cybersecurity is reinforced and that information flows are protected ('data are the new goods').

As described in an Economist article (The Economist, 2016) about IOT, there is a race among manufacturers to be able to integrate IOT and big data information into their offer to customers. Both Siemens (Germany) and GE (US) are developing 'virtual twins', copies of production processes and factories where, thanks to all the information captured by sensors on already existing products, it will be possible to simulate the behaviour of a product in a virtual setting. This process will also transform the way product testing and maintenance is performed. There are many varied applications for this simulation, for example one of the algorithms developed by Siemens can be used in bicycle repair shops to simulate the optimal truing of a wheel or in industrial baking facilities to map the frying process with one interface for all the baking products (Siemens). Siemens already simulated the full industrial cycle of a product:

> '*Using MindSphere – Siemens Cloud for Industry, customers are also able to create digital models of their plants with real data from the production process. This allows them to synchronize the model and the plant, enabling them to carry out simulations and optimize business processes*.' (Siemens, 2016).

This way, the internal processes of a factory could change in such a way that human input would only be required at the beginning and at the end of the production process:

> *Only at the start of the manufacturing process is anything touched by human hands. A Siemens employee places the initial component (a bare circuit board) on a production line. From this point, everything runs automatically, with machines and computers handling 75% of the value chain on their own. Products even control their*

> *own manufacturing processes, using a unique barcode to communicate and share requirements with other production robots. Astonishingly, an individual PLC*[5] *can take corrective action to avoid damage in the production process, and automatically replenishes individual parts in order to meet delivery deadlines* (Barbato, 2015).

Compagnucci and da Empoli observe that if these trends take hold, some other manufacturing tasks such as heavy lifting, precision positioning, and visual quality control could be performed by machines[6] while the ability to handle different digital devices and software would become more and more important for workers (Compagnucci and da Empoli, 2016). New jobs identified in the I-COM report and in the BCG study on industry 4.0 are robot coordinator and industrial data scientists. Robot coordinators would monitor robots on the shopfloor while data scientists would analyse data and manage production processes algorithms. Guy Ryder, ILO director, at Davos (The Guardian, 2017), painted a scenario where it could be envisaged that not only the managers' jobs will be taken by AI, but that one day a smart factory in Europe could be controlled by an outsourced data scientists team based in a low–wage country in South Asia (Degryse, 2016b; Ford, 2015). A pointer for policy makers would then be to rethink tax policies on goods produced with work based outside the EU, the phenomenon called 'virtual' immigration by Baldwin (2016), but physically outputted within its borders; an occurrence which already manifested itself in the services sector with negative consequences for employment in the EU, for example with call centres and back office activities being offshored (Eurofound, 2017c). Other sectors could be affected, for example the software industry where companies are progressively spreading their workload among geographically dispersed teams to diminish the amount of workers on open ended contracts and increase the number of people on short contracts characterised by less benefits and social protection rights (IndustriAll, 2016). Perhaps more linked to automation than digitisation as intended here, the increasing interest of customer service companies to use chatbots instead of human agents, possible thanks to the advancement in Artificial Intelligence (AI) developments, is also to be considered in terms of employment shifts and virtual space change (Premji and Raibagi, 2013).

According to the European restructuring Monitor (ERM)[7], the Eurofound database collecting information on large restructuring cases in EU Member States and Norway, one of the reasons indicated by European banks (nine cases in 2016-2017 for an announced job loss of 12,101 jobs) as a cause of their restructuring plans, is investment in digitisation of services and big data. However, the IT sector seems to have benefitted from the rush in digitisation since 11 cases of announced job gain were recorded for a total of 2,950 new positions created in 2016-2017 to cater for digitisation services.

Privacy and data protection

The increasing importance of data in productive processes raises issues about data protection and privacy. All the hype around the importance of data and ability to analyse them frames a question for researchers: If data are becoming the new goldmine - will companies share as freely as before how long it takes to make a product or how the machinery behaves? Will they want to share the task division and the number of workers involved in the industry 4.0 processes? Since part of these data will refer to workers' movements and even body functions, it can be used to gather information on their physical performance and even health. How will those data be used? Will workers be discriminated if their body function data are not normal over time? Will insurance companies have access to these data? (Buhr et al, 2016). These questions bring up the wider issue of big data and data protection which spans not only the world of work but the entire life of an individual. According to Zwitter (2014), big data

5 Programmable logic control: an industrial computer.

6 In this case it is difficult to separate automation from digitisation since CPS would handle both tasks with robots handling strength tasks and quality control and machine-to-machine communication would be ensured by sensors.

7 https://www.eurofound.europa.eu/observatories/emcc/erm/factsheets

allow a much higher chance of discovering patterns and correlations, making a priority to agree stricter rules on dataset anonymisation. The data compiled on workers could also have commercial value, which some employers may try to exploit if this issue is not properly regulated. Similarly to the blurring of the concept of workplace, where does the data monitoring stops to be a tool of the employer and becomes a way to exploit for commercial purpose a virtual profile of a person by including work data, social networks data, medical data, and optometric data? Who are the entities and people authorised to view these data? In this respect, two big changes of opposite nature are being implemented during 2017, one in the US where the government (S.J.Res.34) gave permission to private businesses to trade on personal data, and the other in the EU where the protection and control of personal data are a priority for governments and businesses alike (Regulation 2016/679 and Directive 2016/680).

Implications for social dialogue

Very few studies deal with the implications for industrial relations and social dialogue in relation to digitisation processes, probably due to the fact that applying one or a combination of these technologies (IOT, 3d printing or virtual/augmented reality) is a new phenomenon still to be further deployed and analysed, whilst automation and platforms are the two main topics on which researchers are currently focusing.

Digitisation of the production processes alters the traditional work places and work organisation. A recent TUAC paper calls for trade unions and employers to keep social dialogue alive and discuss changes in working conditions and in work organisation brought about by digitalisation in general.[8] ‘New technologies offer the prospect of improving productivity and transforming the economy in ways that support and protect decent working conditions. For example, technology could be used to ensure ethical supply chains through real-time monitoring of working conditions. If managed effectively, it has the potential to improve working conditions and the quality of life of workers in all sectors. Trade unions acknowledge this potential. At the same time, we are concerned that at the moment it seems that digitalisation moves ahead with little priority given to workers’ rights or social protection’ (TUAC, 2017).

BDA, the German Confederation of Employers' Associations, stresses that the changes to production processes and communication channels triggered by digitisation may render changes to existing workplace structures necessary. In these cases, it would be appropriate to widen the structural options open to works council and employer when adaptations are being made to necessary changes so that decisions can be taken directly in business units. This can enhance the attractiveness and flexibility of workplace rules. With regard health and safety issues, it is considered that the existing set of rules in force today is sufficiently flexible and also adequate for new forms of work and working conditions in the age of digitisation. However, it is not yet completely foreseeable how physical strains will evolve as the economy becomes digital and consequently, occupational safety and health must be able to react promptly (BDA, 2015).

An example of social partners’ involvement in the digitisation at the company level is provided by the Dutch case of Metalektro. In 2016, after difficult negotiations on traditional topics (payment, working times, flexibility), an agreement was reached including the need for workplace innovation to involve workers and their unions in automation, digitisation and organisational change[9]. The agreement links to the recently developed ‘workplace innovation’ dimension in the national Smart Industry programme, a national initiative on technology and digitalisation to fit the Dutch industry for the future. It was agreed that a ‘field lab workplace innovation’ should develop practices of skills development, work organisation and employee involvement’ (Pot et al, 2016).

[8] The paper does not refer specifically to any technology.

[9] Implications for automation are explored more in depth in the automation literature review on automation of work Peruffo et al (2017) which is part of this set of Eurofound working papers.

At company level, there are examples of how collective bargaining is starting to deal with implementation of digital change. In 2016, Orange signed an agreement framing the digital transformation process with its employees covering 96,000 employees in France. In this agreement, an intangible right to disconnect from their work smartphones, internet, emails, etc., while they are on leave or rest periods is granted and recognised to all employees (Eurofound, 2017d). This right to disconnect comes from the France's labour law reform adopted in July 2016 and came into force at the very start of 2017. The law establishes that if there is no agreement, the employer must draw up a charter defining how this right to disconnect is exercised. In this case, the employer must consider the opinion of the works council. The agreement also entitles employees to request a personal assessment of their digital tools as well as to receive digital training and voluntary digital auto-diagnosis on his/her competences.

Conclusions

This literature review looked at specific technologies, other than the usual automation and platforms, to cover potential impacts on workers and labour market: some of the effects described are the same as the ones found for the other two technologies, and in some cases almost impossible to distinguish since technologies can be used together, but in some cases specific effects, for example the health related risk in 3dprinting can be reported. One of the urgent points emerging is a call for a clear vision on how to educate and upskill a workforce who is going to be required to work more and more with ICT devices and possibly, in a scenario were collaboration and communication across disciplines are gaining importance. Another point mentioned by a few authors is that if jobs (or tasks) can be performed online, location could lose its importance and transfer the competition for a job to a global scale. It can be observed that, similar to what is happening with some crowd employment platforms, if this was going to happen on a bigger scale, serious thought should be paid on future systems of social welfare, taxation and, not least, conditions of work. A focus on implications on social dialogue and the digitisation process would also enrich the knowledge on industry and work 4.0.

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